DIVISION OF MINERAL RESOURCES
LIBRARY
VIRGINIA

Comment by Herbert P. Woodward
December 19, 1960

1. Geology and mineral resources of the Natural Bridge region (Eagle Rock and Natural Bridge topographic quadrangles), Virginia. Manuscript prepared for and filed with the Virginia Geological Survey in 1936. 350 mss. pp., maps and figures.

2. (with A. S. Furcron) Geology and mineral resources of the Stony Man quadrangle, Virginia. Manuscript prepared for and filed with the Virginia Geological Survey in 1936, revised in 1940. 230 mss. pp., maps and figures.

3. Geology and mineral resources of Scott County, Virginia. Manuscript prepared for and filed with the Virginia Geological Survey in 1937. 135 mss. pp., maps and figures.

The above manuscripts were prepared by me (in the instance of No. 2, with the collaboration of Dr. A. S. Furcron) during a sort of interim period in Appalachian geology, before the newer stratigraphic work of Dr. Butts had been completed which was the turning point of the modern school of interpretation. Thus as an outcome of Butts' work, together with my own studies and the subsequent excellent work of Prouty, the Coopers, Craig, Neuman and others, the ideas of Appalachian Paleozoic stratigraphy became modernized and revalued.

The history of these manuscripts is something as follows: While I was completing my published report on the Roanoke area in 1927, Dr. Harry S. Ladd started work on the Eagle Rock quadrangle, but was diverted from this project to assume other duties. It was then suggested that I pick up his work and continue the geologic study of the Eagle Rock quadrangle which I did during the 1928-1930 field seasons. Following this it was suggested that I next undertake the geology of the Natural Bridge Special quadrangle, field work for which was completed with the summer of 1934.

Individual reports were prepared and filed with the Virginia Geological Survey for both of these quadrangles, but in 1935 Dr. Bevan requested that they be combined into a single manuscript. This was done and the above-noted report was filed with the Survey in 1936.

A small section of the Natural Bridge Special quadrangle included Pre-Cambrian crystalline rocks, and Dr. A. S. Furcron was brought in as a contributing colleague for this portion of the report. During the summers of 1935 and 1936, Drs. Furcron and Woodward were assigned to work out the geology of the Stony Man quadrangle and a manuscript was submitted by the two authors in 1938 and later revised by Woodward in 1940.

Dr. Bevan suggested next a series of informal county reports designed for public school use. The first of these, on Russell County, was published in 1938; and the above-noted manuscript for an accompanying report on Scott County was submitted for publication. A third report on Craig County was prepared to be submitted after publication of the other manuscripts.

Viewed in the light of modern stratigraphy all of the above manuscripts are outdated and obsolete, yet they were considered to be useful and adequate at the time they were prepared. As above indicated, the fundamentals of Appalachian stratigraphy and structure were changing rapidly during this period and these manuscripts seem now quite old-fashioned. I believe the mapping is reasonably accurate in terms of the units used, but the texts are obsolete and it would involve too much effort to update them now. I do not recommend their publication.

I suggest instead that they be made available in the Survey's open files to anyone who wishes to use them and that a covering statement such as this be included as a foreword.

Author's comments to Survey Editor,
re
Natural Bridge manuscript

1. This manuscript and illustrations are in good editorial form; they should need little revision except insofar as the editor wishes to rearrange the author's sentence construction.

2. A uniform system of headings has been used in this manuscript to indicate the rank of various titles. This system is as follows:

VIRGINIA DIVISION OF MINERAL RESOURCES LIBRARY

INTRODUCTION	(Rank 1)
LOCATION AND AREA	Rank 2
The Upland Peneplane	Rank 3
Description	Rank 4
Mines	Rank 5
Character.-	Rank 6

In the section on Stratigraphy, in order to make all paragraph divisions of equal rank, headings of Rank 5 have been occasionally omitted. Elsewhere, the above system has been rigidly used. All headings of a given rank should be printed uniformly in accordance with whatever style of printing the Survey chooses. The system used in this typewritten manuscript should not be considered as of any significance except as it indicates the rank of the heading.

3. Miscellaneous comments to the Editor, written in green ink, occur within the manuscript.

4. The following spellings have been used throughout:

peneplane (author's preference)
Rocky Point)
Indianrock) (local, but not map, usage)

5. The section on Natural Bridge National Forest may be omitted if necessary; the author prefers it to remain. A short section on the "Salem fault block" may similarly be omitted.

6. The minor heading "Definition.-" customarily used by the Survey in each stratigraphic description has been purposely omitted except in the few instances where there is an actual definition of a formational name. Elsewhere, a short introductory statement without title opens the stratigraphic descriptions. This, it is thought, is proper practice.

7. Inasmuch as there is no indication of the Survey's present practice of including measured stratigraphic sections and fossil localities, the author has used a system commonly employed.

8. Thru error Plate 4 was not assigned.

9. The author has followed the Survey's practice of using "Plate 1, and Figure 10" rather than plate 1 and figure 10.

10. It is assumed that all line drawings and figures will be redrafted by a Survey artist. Hence, no attempt has been made to submit copy for any illustration in final form, nor to provide copy for all illustrations in a uniform stage of artistic merit. All copy, however, is legible and clean.

11. Outcrops of Quaternary deposits have not been delineated on the geologic map. If such data are needed, they can be furnished.

12. In the case of a few photographic illustrations, alternate views, so marked, have been included. The author has chosen the illustrations used from a large number of photographs available. It is thought that each one chosen is pertinent to the discussion.

13. I should like to see this manuscript printed without substantial condensation. In its present form it should be somewhat longer than other recent Survey publications, but the report covers in some detail two topographic quadrangles, and represents two separate reports that have been combined.

14. In considering the number of copies to be printed, it would be well to get in touch with Natural Bridge Inc., who intimated to me their hope that copies of the report could be sold, distributed, or in some manner made available to the public at the bridge.

15. The geologic maps of both quadrangles have been reviewed by Dr. Butts both in the field, and in the office. He had copies of both maps at hand during the preparation of his Valley map.

16. The present manuscript, maps, and illustrations supercede all other maps and manuscripts which the Survey may have received from the author in connection with either quadrangle. I think, however, that both of the two earlier reports have been returned to me.

17. In the case of a few specific names of fossils, I am unable to give the author's name, as the literature available to me is somewhat limited. The number of instances, however, is so limited that I should feel no discomfort if they were omitted in the printed copy as well as in this manuscript.

18. It has been suggested that I follow closely to the style of Bulletin 34, and I have done so. Whatever variation occurs represents a change for the better, in the author's opinion.

Geology and Mineral Resources of the Natural Bridge Region, Virginia

by

Herbert P. Woodward
Virginia Geological Survey

1936

Newark, New Jersey

C

CONTENTS

	Manuscript Page
Abstract	1
Introduction	4
Location and area	4
Nature of the report	6
Acknowledgments	8
Previous geologic work	13
Bibliography	14
General geography	19
Relief and drainage	19
Climate	22
Soils and vegetation	23
Cultural features	27
Natural Bridge National Forest	30
Physical geography	33
General statement	33
Physiographic provinces	34
Erosion levels	38
Upland peneplane	39
Valley-floor peneplanes	41
Intermediate levels	44
Trenches below the Valley-floor peneplanes	46
Special physiographic features	48
Natural Bridge	48
Description	48
History	49
Cedar Creek	51
Geology	52
Previous theories of origin	53
Present theory of origin	58
James River	67
Minor physiographic features	70
Stream diversion or capture	70
Floodplains	77
Miscellaneous features	78
Rocks of the Natural Bridge region	80
General statement	80
Pre-Cambrian rocks IGNEOUS ROCKS by A.S. ADDICION	81 81-A 81-O
Paleozoic sediments	82
General statement	82
Cambrian system	83
Arenaceous division; Chilhowie group	84
Unicoi formation	85
Character	85
Distribution	86
Basal contact	86
Thickness and relations	93
Economic products	93
Correlation	93
Hampton shale	94
Character	94
Distribution	94
Thickness and relations	95
Correlation	95

	Page
Erwin quartzite	96
Character	96
Distribution	97
Relations and economic products	97
Fossils	98
Thickness	98
Calcareous division	99
Shady dolomite	99
Character	99
Distribution	100
Thickness and relations	100
Economic products and correlation	100
Rome ("Watauga") formation	101
Definition	101
Character	101
Topography and soil	102
Thickness	103
Relations	103
Fossils	103
Elbrook formation	104
Character	104
Distribution	105
Topography and relations	105
Thickness and age	106
Ozarkian and Canadian systems	107
Ozarkian system	107
Conococheague formation	108
Character	109
Distribution	109
Thickness and soil	110
Fossils and age	110
Economic use	111
Chepultepec limestone	111
Character and thickness	111
Distribution	112
Age and correlation	112
Canadian system	113
Stonehenge limestone	113
Character	113
Local representation	113
Nittany dolomite	114
Character	114
Distribution	115
Topography and relations	117
Thickness	117
Fossils and age	117
Bellefonte dolomite	118
Character	118
Distribution	119
Age and correlation	119
Ordovician system	120
Stones River group	121
Lower Stones River limestone	121
Character	121
Distribution	122
Thickness and relations	122
Fossils and age	122

Page

Mosheim limestone ---------- 123
Character ---------- 123
Distribution and thickness ---------- 124
Surface features ---------- 124
Age ---------- 124
Lenoir limestone ---------- 124
Character ---------- 125
Distribution ---------- 125
Bluff City member ---------- 126a
Relations ---------- 126b
Thickness ---------- 126b
Economic use ---------- 127
Fossils and age ---------- 127
Blount group ---------- 128
Holston limestone ---------- 128
Character ---------- 128
Distribution ---------- 129
Thickness ---------- 129
Economic use ---------- 129
Fossils ---------- 130
Age ---------- 130
Whitesburg limestone ---------- 131
Character and distribution ---------- 132
Fossils and age ---------- 132
Athens shale ---------- 133
Character ---------- 133
Pebble-conglomerate member ---------- 135
Distribution ---------- 137
Thickness and relations ---------- 137
Fossils and age ---------- 138
Black River group ---------- 139
Moccasin-Lowville formation ---------- 139
Lowville limestone ---------- 140
Moccasin sandstone ---------- 140
Chambersburg limestone ---------- 141
Character ---------- 141
Distribution ---------- 142
Soil and relations ---------- 142
Fossils ---------- 143
Economic use ---------- 143
Thickness ---------- 143
Martinsburg shale ---------- 144
Character ---------- 144
Distribution ---------- 144
Subdivisions ---------- 145
Metabentonite ---------- 146
Topographic expression ---------- 147
Relations ---------- 147
Thickness ---------- 148
Fossils ---------- 148
Age ---------- 149
Juniata shale ---------- 149
Character ---------- 149
Distribution ---------- 150
Thickness and correlation ---------- 150

Page

Silurian system ---------- 152
Clinch sandstone ---------- 153
Character ---------- 153
Distribution ---------- 154
Thickness ---------- 154
Economic use ---------- 154
Fossils and correlation ---------- 154
Clinton group ---------- 155
Cacapon Sandstone ---------- 155
Character ---------- 155
Topography and soil ---------- 155
Distribution ---------- 156
Iron ore ---------- 156
Thickness and relations ---------- 156
Fossils and correlation ---------- 157
Keefer sandstone ---------- 158
Character ---------- 158
Distribution ---------- 158
Thickness ---------- 159
Economic products ---------- 159
Fossils and age ---------- 159
Tonoloway limestone ---------- 160
Character ---------- 160
Distribution and thickness ---------- 160
Fossils and correlation ---------- 161
Devonian system ---------- 162
Helderberg group ---------- 163
Keyser formation ---------- 163
Definition ---------- 163
Lower Keyser member ---------- 163
Clifton Forge sandstone ---------- 164
Upper Keyser limestone member ------ 165
Age and correlation ---------- 166
Coeymans limestone ---------- 167
Character and thickness ---------- 167
Fossils ---------- 168
Relations and correlation ---------- 168
Healing Springs sandstone ---------- 169
Character ---------- 169
Thickness ---------- 169
Age ---------- 169
Becraft limestone ---------- 170
Character ---------- 170
Distribution and fossils ---------- 171
Thickness and age ---------- 171
Oriskany sandstone ---------- 172
Character ---------- 172
Iron Ore ---------- 173
Thickness ---------- 173
Fossils ---------- 173
Relations and age ---------- 174
Onondaga shale ---------- 174
Character ---------- 174
Thickness ---------- 174
Distribution and fossils ---------- 174
Age ---------- 175

Page

"Romney" black shale ---------- 176
Definition ---------- 176
Character ---------- 176
Structure and soil ---------- 177
Distribution ---------- 177
Thickness ---------- 178
Fossils ---------- 178
Age and correlation ---------- 179
Brallier shale ---------- 179
Character ---------- 179
Relations ---------- 180
Distribution ---------- 180
Thickness ---------- 181
Correlation and fossils ---------- 181
Chemung formation ---------- 181
Character ---------- 181
Distribution ---------- 182
Thickness ---------- 183
Fossils ---------- 183
Correlation ---------- 183
Catskill formation ---------- 184
Character ---------- 184
Distribution and thickness ---------- 184
Age ---------- 184
Mississippian system ---------- 184
Osage group ---------- 185
Price formation ---------- 185
Character ---------- 185
Coal ---------- 185
Distribution ---------- 185
Thickness and relations ---------- 186
Quaternary deposits ---------- 186
Character ---------- 186
Organic remains ---------- 188
Igneous rocks of uncertain age ---------- 189
Geologic sections ---------- 192
Laurel Run section (No. 1) ---------- 192
Jennings Creek section (No. 2) ---------- 193
North Creek section (No. 3) ---------- 194
Snowden section (No. 4) ---------- 195
Balcony Falls section (No. 5) ---------- 196
Natural Bridge Station section (No. 6) ---------- 197
Cedar Ridge section (No. 7) ---------- 198
Indianrock section (No. 8) ---------- 199
Rocky Point Road section (No. 9) ---------- 200
Slate Branch section (No. 10) ---------- 201
Blue Spring Creek section (No. 11) ---------- 202
Catawba Creek section (No. 12) ---------- 203
Rocky Point Quarry section (No. 13) ---------- 204
Murat Post Office section (No. 14) ---------- 205

Page

Section at Lexington (No. 15) ---------- 206
Dunkard Church section (No. 16) ---------- 207
North Mountain section (No. 17) ---------- 208
Hooks Mill section (No. 18) ---------- 209
Cartmell Gap section (No. 19) ---------- 210
Iron Gate section (No. 20) ---------- 211
Eagle Rock section (No. 21) ---------- 212
Back Creek (Rich Hill) section (No. 22) ---------- 213
Prices Bluff section (No. 23) ---------- 214
Jackson River section (No. 24) ---------- 215
Island Ford section (No. 25) ---------- 216
Lyle Tunnel section (No. 26) ---------- 217
Big Hill section (No. 27) ---------- 217
Price Mountain section (No. 28) ---------- 218
Fossil localities ---------- 219
Collections made by Dr. Harry S. Ladd, 1927 ---------- 219
Collections made by Herbert P. Woodward, 1929-34 ----- 220

Page

Geologic structure ---------- 226
General features ---------- 226
Major folds ---------- 230
Rich Patch anticline ---------- 230
Geographic description ---------- 230
Geologic structure ---------- 231
Iron Gate watergap ---------- 234
Mapps Mill anticline ---------- 235
Big Mill anticline ---------- 236
Spreading Spring anticline ---------- 237
Flatwoods syncline ---------- 238
Craig Creek syncline ---------- 239
Short Hills syncline ---------- 240
Natural Bridge syncline ---------- 240
Minor folds ---------- 241
Faults ---------- 242
Pulaski overthrust ---------- 242
General description ---------- 242
Fault-line phenomena ---------- 244
Salem fault-block ---------- 248
Amount and date of displacement ---------- 252
Blue Ridge overthrust ---------- 254
Kerrs Creek fault ---------- 256
Minor faults ---------- 257
Structure of the Eagle Rock-James River ranges ---------- 259
General features ---------- 259
Eagle Rock Gap ---------- 263
Minor geologic structures ---------- 268
Joints ---------- 268
Cleavage ---------- 269
Geologic history ---------- 270
General features ---------- 270
Early geographic conditions ---------- 271
Pre-Cambrian time ---------- 273
Paleozoic era ---------- 275
Cambrian period ---------- 275
Ozarkian and Canadian time ---------- 276
Ordovician period ---------- 277
Silurian period ---------- 278
Devonian period ---------- 280
Mississippian period ---------- 280
Post-Mississippian time ---------- 281
Mesozoic era ---------- 285
Cenozoic era ---------- 288
Mineral resources ---------- 291
General statement ---------- 291
Metallic ores ---------- 292
Iron and manganese ---------- 292
General statement ---------- 292
Blue Ridge Hematite ---------- 294
Description---------- 294
Mines and prospects ---------- 296
Bearwallow Hollow prospects ---------- 296
Jennings Creek prospect ---------- 297
Glenwood prospects ---------- 298
Pico mine ---------- 299

Page

Clinton hematite ---------- 300
General statement ---------- 300
Mines and prospects ---------- 301
Roaring Run hematite prospect ---------- 301
Horse Mountain mine ---------- 301
Other prospects ---------- 302
Blue Ridge brown iron and manganese ---------- 303
General statement ---------- 303
Mines and prospects ---------- 304
James River iron prospects ---------- 304
Bearwallow manganese prospects ---------- 305
Oriskany brown iron and manganese ---------- 306
General statement ---------- 306
Mines and prospects ---------- 308
Lowmoor mines ---------- 308
Rich Patch mine ---------- 309
Big Hill mines ---------- 310
Roaring Run Oriskany mines ---------- 311
Oriskany and adjacent mines ---------- 312
Callie and adjacent mines ---------- 315
Retreat and adjacent mines ---------- 317
Sand Bank iron mine ---------- 319
Cook or Ruhl manganese mine ---------- 320
Burman manganese prospect ---------- 321
Sheets mine ---------- 321
Iron furnaces ---------- 322
Future development of iron and manganese ---------- 324
Non-metallic materials ---------- 325
Limes and cements ---------- 325
General statement ---------- 325
Lime ---------- 326
General features ---------- 326
Local developments ---------- 327
Cement materials ---------- 332
Summary of limes and cements ---------- 333
Clays and shales ---------- 334
True sedimentary clays or shales ---------- 334
Residual clays from decomposition of bedrock ---------- 335
Summary of clays and shales ---------- 337
Coal and oil ---------- 338
Miscellaneous non-metallic materials ---------- 339
Ocher ---------- 339
Travertine ---------- 340
Construction materials ---------- 340
Minor economic products ---------- 342
Summary of mineral resources ---------- 343
Water resources ---------- 344
Surface water ---------- 344
Ground water ---------- 348

ILLUSTRATIONS See binder 2

PLATE		Near manuscript Page
1.	Geologic map of the Natural Bridge region	In pocket
2.	Geologic structure sections of the Natural Bridge region	In pocket
3.	Natural Bridge, viewed from the south	Frontispiece
4.		
5.	A, Village of Buchanan, viewed from the flank of Purgatory Mountain; B, Village of Eagle Rock, viewed from the eastern pinnacle of Crawford Mountain	19
6.	A, The blunt southwestern end of Short Hills; B, Short Hills, viewed southward from the crest of North Mountain	20
7.	Fincastle and the Fincastle Valley. View looking north	20
8.	A, Apple Orchard Mountain; B, The crest and summit of Rich Patch Mountain	21
9.	A, Subsoil pinnacles of Nittany dolomite produced by unequal decomposition and exposed by removal of residual soil; B, Gullied outcrop of Conococheague limestone near Midway School	25
10.	A, Irregular foothills of Rich Patch Mountain; B, Headwaters of Sloan Branch in the heart of the James River range east of Eagle Rock	28
11.	A, Floodplain of James River, south of Purgatory Mountain; B, Floodplain of James River, north of Eagle Rock	29
12.	A, Mining camp of Lignite; B, View of Bathole Mountain looking northeast along new concrete bridge over James River	29
13.	A, Symmetrical cone-like end of Purgatory Mountain; B, Montgomery Knob	33
14.	A, Gorge of James River through the Blue Ridge above Balcony Falls; B, Entrance of James River into its gorge above Balcony Falls	35
15.	Panoramic view looking northeastward up James River valley	38
16.	A, Upland peneplane on Rich Patch Mountain; B, Level crest of Pine Mountain southeast of Indianrock	39
17.	A, Rolling valley-floor peneplane west of Buchanan; B, Level surface of the valley-floor peneplane near Bessemer	42
18.	A, The Knob, north of Buchanan; B, Northern end of Short Hills	45
19.	A, Lace Falls of Cedar Creek, above Natural Bridge; B, Cedar Creek, viewed southward from the arch of Natural Bridge	51
20.	Arch of Natural Bridge, viewed from the north	52
21.	A, Entrance to "Lost River", in the gorge of Cedar Creek, above Natural Bridge; B, Cascade Creek, near its discordant junction with Cedar Creek, immediately below Natural Bridge	59
22.	August view of Natural Bridge, looking northward from Pine Laden	62
23.	April view of Natural Bridge, looking northward from Pine Laden	62
24.	A, Watergap of James River at Eagle Rock; B, Rocky face of Bathole Mountain and the Eagle Rock Gap of James River	68
25.	A, "The Gorge"; B, View of the Gorge looking northwestward	73
26.	A, Confluence of James River and Craig Creek floodplains; B, Fertile James River floodplain above Eagle Rock	77
27.	A, Coarse conglomerate at the base of the Unicoi formation; B, Contact of the Hampton shale and the Unicoi sandstone	85

28. A, Contact of Erwin quartzite and Hampton shale; B, Prominent jointing in the Erwin quartzite ---------- 96
29. A, Folded members of the Erwin quartzite; B, Massive Shady dolomite near the Pico camp ---------- 99
30. A, Sharp-crested Blue Ridge foothills of Erwin quartzite east of Glascow; B, Rounded hills on the Rome ("Watauga") outcrop southwest of Buchanan ---------- 102
31. A, Sharp hogback ledges of Rome ("Watauga") shale east of Buchanan; B, Rockly Elbrook limestone along Lee Highway -- 104
32. A, Contact of dolomite and limestone in the Conococheague formation; B, Irregular calcite veins in the Conococheague formation ---------- 109
33. A, Cryptozoa in the Conococheague formation northeast of Buchanan; B, Sandstone lense in the Conococheague formation ---------- 111
34. A, Canadian (Nittany) dolomite along Lee Highway; B, Lower Stones River limestone in Rich Patch valley ---------- 114
35. A, Chert on exposure of the Lower Stones River limestone, Rich Patch valley; B, Residual chert in weathered soil of the Nittany dolomite, Rich Patch valley ---------- 121
36. A, Horizontal surface of Lenoir limestone showing laminated character and structural unconformity; B, Gently folded shaly limestone at base of Athens shale near Dunkard Church-125
37. A, Jointed black Athens limestone; B, Pebbly conglomerate in Athens shale ---------- 135
38. A, Knoboy phase of Chambersburg limestone south of Collierstown; B, Reticulated surface of Chambersburg limestone north of Oakdale ---------- 141
39. A, Green Hill; B, House Mountains, west of Lexington ------- 142
40. A, Shaly phase of the Martinsburg formation in Rich Patch valley; B, Towers of lichen-covered Clinch sandstone on Bethole Mountain ---------- 144
41. A, Heartsblood, between Panther and Camp mountains; B, Gorge of Back Creek through Rich Hill ---------- 154
42. A, Purplish shale and shaly sandstone of the Juniata formation in Keys Gap; B, Massive red Cacapon sandstone near Hooks Mill ---------- 155
43. A, Ledges of Keefer sandstone along Roaring Run; B, Massive beds of Keefer sandstone in the Eagle Rock Gap ---------- 158
44. A, High quarry face of Tonoloway limestone at Prices Bluff; B, Contact of Healing Springs sandstone and Cocymaus limestone at Prices Bluff ---------- 160
45. A, Oriskany sandstone at Prices Bluff; B, Mural cliff of Brallier shale along Potts Creek ---------- 172
46. A, Stratified high-level gravels of James River above Buchanan; B, Contact between peridiotite stock and Ordovician limestone southwest of Oakdale ---------- 187
47. A, Quaternary deposits of travertine along Lapsley Run; B, Solution channels and cave deposits along Cedar Creek below Red Mills ---------- 188

(Page)

48. A, Gentle folds in Unicoi sandstones near Snowden; B, Closely contorted Honaker limestone, Eagle Rock Gap -- 227
49. A, Gentle folds in Chambersburg limestones, west of Collierstown; B, Anticlinal fold in the Shady dolomite below Buchanan ---------- 228
50. A, Symmetrical anticline of Brallier shale along Craig Creek valley; B, The "Rainbow Arch" at Iron Gate ------- 231
51. Panoramic view of Rich Patch Mountain and its eastern line of foothills ---------- 231
52. A, Sharp northern elbow of the Rainbow Arch at Iron Gate; B, Small folds in Brallier shale along Little Patterson Creek ---------- 234
53. A, Remarkable folds within the Unicoi formation on Cove Mountain; B, Small vertical fault in the Conococheague formation northeast of Buchanan ---------- 241
54. A, Quarry face along Lee Highway near Highbridge Church showing Elbrook limestone overthrust upon crumpled Athens shale; B, Small block of Elbrook limestone overthrust upon "Romney" shales ---------- 244
55. A, Underground limestone mine at Eagle Rock, formerly operated by the Moore Lime Company; B, Knife-edge contact of Nittany dolomite above, and Holston limestone below, the plane of the Pulaski overthrust in the quarry shown above ---------- 245
56. A, Face of cliff along James River opposite Eagle Rock showing the entrance to the underground limestone mine, or quarry; B, View within quarry figured above --------- 246
57. Panoramic view of the northeastern face of the Eagle Rock Gap; Natnole Mountain in foreground ---------- 263
58. Panoramic view of the southwestern face of the Eagle Rock Gap; Crawford Mountain in foreground ---------- 264
59. A, Abandoned stack of Glenwood furnace; B, Ruins of Retreat furnace ---------- 304
60. A, Abandoned stack of the Roaring Run charcoal furnace; B, Ruins of the Catawba charcoal furnace ---------- 305
61. A, Narrow Bank of the Alleghany Ore and Iron Company; B, "Big cut" at the Oriskany iron mine ---------- 313
62. A, Virginia Iron, Coal, and Coke Company's quarry in Shady dolomite near Buchanan; B, Shady dolomite in above quarry ---------- 331
63. A, Limestone quarry operations at Eagle Rock; B, Quarry operations southwest of Buchanan ---------- 329
64. A, Inactive underground mine in the Becraft limestone west of Lowmoor; B, Inactive limestone mine in Holston limestone near Eagle Rock ---------- 341
65. A, Small power dam on Cedar Creek below Natural Bridge; B, Large sink in Chambersburg limestone northeast of Collierstown ---------- 348

FIGURE		Near manuscript page
1.	Index map showing the location of the Natural Bridge region, Virginia	5
2.	Generalized block diagram of the Natural Bridge region	19
3.	Ideal profile section across the Natural Bridge region showing erosion levels	38
4.	Sketch map of the Eagle Rock and Natural Bridge topographic quadrangles showing the distribution of various erosional surfaces	38
5.	Topographic map of the vicinity of Natural Bridge	48
6.	Sketch map of Cedar Creek	51
7.	Outcrop map of the vicinity of Natural Bridge	52
8.	Map showing present drainage near Natural Bridge	59
9.	Sketch map suggesting the course of drainage before the development of Natural Bridge	60
10.	Map showing topography near Natural Bridge and present relations of Cedar Creek, Cascade Creek, Bread Run, and Poague Run	62
11.	Progressive diagrams showing the development of a natural bridge or tunnel	64
12.	Progressive diagrams to suggest the production of a watergap by stream erosion upon a rising land	70
13.	Sketch illustrating the imminent capture by Rocky Run of the headwaters of Purgatory Creek	72
14.	Sketch showing the drainage changes at the southeastenn end of North Mountain	73
15.	Sketch illustrating the diversion of North Fork of Buffalo Creek southeast of Oakdale	73
16.	Sketch indicating the imminent capture of Back Creek by tributaries of Elk Creek in Arnold Valley	73
17.	Diagrams to indicate the possible erosion of Sallings Mountain windgap by James River	74
18.	Sketch map showing Slash School marsh, 2½ miles southeast of Horton	77
19.	Generalized outcrop map of the Natural Bridge region	80
20.	Outcrop map of pre-Cambrian rocks	81
21.	Outcrop map of Cambrian rocks	83
22.	Outcrop map of Ozarkian and Canadian rocks	108
23.	Outcrop map of Ordovician rocks	120
24.	Outcrop map of Silurian rocks	152
25.	Outcrop map of Devonian rocks	162
26.	Outcrop map of Mississippian rocks	185
27.	Areal geologic map of the northern portion of the Rich Patch anticline and the region between Covington and Clifton Forge	231
28.	Cross section along James River at Iron Gate	234
29.	Cross section through Big Hill	236
30.	Cross section along railway cut at Prices Bluff	236
31.	Cross section through the Spreading Spring anticline	237
32.	Areal geologic map of the region near Fincastle	238
33.	West-east section through the abandoned Moore Lime Company quarry at Eagle Rock	244
34.	North-south section through the abandoned Moore Lime Company quarry at Eagle Rock	246
35.	Areal geologic map of the region between Collierstown, Lexington, and Buffalo Mills, Virginia	256

FIGURE		Near manuscript page
36.	Cross section of the southwestern wall of the Eagle Rock Gap	264
37.	Cross section of the northeastern wall of the Eagle Rock Gap	264
38.	Map showing location of the most important mines, quarries, prospects, and furnaces in the Natural Bridge area	291
39.	Generalized cross section showing the location of Oriskany brown iron-ore deposits	306
40.	Sketch map of the Big Hill iron mines	310
41.	Sketch map of the Oriskany and other mines adjacent to Lignite, Virginia	312

P

TABLES

Near manuscript page

1. Sedimentary bedrock formations of the Natural Bridge region ---------- 82
2. Thickness and distribution of Paleozoic formations in the Natural Bridge region ---------- 82
3. Analyses of Blue Ridge hematite, Bearwallow Creek, Botetourt County, Virginia ---------- 297 *
4. Analyses of ore, Horse Mountain mine, Alleghany County, Virginia ---------- 302 *
5. Analyses of Oriskany ore, Lowmoor mines, Alleghany County, Virginia ---------- 308 *
6. Analyses of ore, Big Hill mines, Botetourt County, Virginia ---------- 310 *
7. Analyses of ore, Oriskany mines, Botetourt and Craig counties, Virginia ---------- 315 *
8. Analyses of Oriskany ore, Callie and Wilton mines, Botetourt County, Virginia ---------- 316 *
9. Analyses of Oriskany ore, Retreat mines, Botetourt County, Virginia ---------- 317 *
10. Analyses of Oriskany ore near Retreat Furnace, Botetourt County, Virginia ---------- 317 *
11. Analyses of Oriskany ore, Purgatory Mountain, Botetourt County, Virginia ---------- 318 *
12. Analyses of Ordovician limestones, Natural Bridge region, Virginia ---------- 328 *
13. Analyses of Holston limestone, Eagle Rock, Virginia ----- 330 *
14. Analyses of Shady dolomite, Buchanan, Virginia ---------- 331 *
15. Discharge, temperature, and analysis of spring water, Natural Bridge region ---------- 349

(* already typed in manuscript)

ABSTRACT

This report is a description of the areas mapped as the Eagle Rock and Natural Bridge quadrangles of the ~~United States quadrangles of the~~ region United States Geological Survey topographic maps. The ~~area~~ is situated entirely in west-central Virginia and lies mainly in Alleghany, Botetourt, and Rockbridge counties; small portions of Craig and Bedford counties are also included. With a maximum relief of about 3,500 feet, the region drains into James River and its tributaries.

The scenery of the Natural Bridge area is typical of the central Appalachians, exhibiting a broad fertile valley bounded by rugged forest-covered mountains. The area is served by the Chesapeake and Ohio Railway and by the Shenandoah Division of the Norfolk and Western Railway. United States Highway 11, and several hard-surfaced State highways furnish other lines of communication. The climate is pleasant, and fish and small game abound in the mountains.

The Natural Bridge region includes portions of the Blue Ridge, the Valley of Virginia, and the Appalachian Valley and Ridges; the country is sparsely settled and, except in the Valley lowland, is not well adapted for farming. The mining industry belongs to the last century when a number of iron mines were in active operation. The chief mineral wealth of the area consists of non-metallic materials, ~~chiefly~~ mainly limestones and clays. Lime quarrying is the only active mineral industry.

A portion of the Blue Ridge crosses the southeastern corner of the area where pre-Cambrian and Early Cambrian rocks produce the rugged upland of the Natural Bridge National Forest. The east-central part of the region is occupied by the Valley of Virginia, along which James River meanders in a deeply entrenched course. The surface of the Valley, which stands about 1,250 feet above tide, is a physiographic level known as the Valley-floor peneplane, and was developed by long stages of the erosion and weathering of relatively weak bedrock. The Valley is enlarged into a broad rolling lowland in the southern part of the western half of the region, where it is locally known as Fincastle valley. The latter is a shallow syncline in which Ordovician shale has been infolded within a triangular area of Early Paleozoic limestones and dolomites. The level floor of Fincastle Valley is broken by minor ridges that mar the evenness of the Valley-floor peneplane.

The central and northwestern portions of the area are occupied by long, narrow, parallel mountains of the Valley and Ridge physiographic province. Resistant rocks--chiefly Silurian sandstones--uphold the crests of ridges, and softer rocks--chiefly Devonian shales--underlie narrow, intermontane valleys. The rocks of the Valley and Ridge province include Ordovician, Silurian, Devonian, and lowermost Mississippian sediments, reaching a total thickness of at least 12,000 feet. They have been compressed into a series of symmetrical folds that attain geographic importance in the Rich Patch anticlinorium, which occupies the northwestern part of the area. The level crests of mountain ridges reveal the Upland peneplane, or erosion level, most of which has been destroyed by subsequent erosion. Quaternary deposits of sand, gravel, and residual soil are widely scattered over the entire area.

The geologic structure of the Natural Bridge region involves a complex series of folds, faults, and other attendant diastrophic phenomena. The most important structural feature is Rich Patch anticline, which has been unroofed by erosion to produce the fertile Rich Patch valley. Excellent structure sections of various rock formations are exposed where the rim of this valley has been breached by streams. Other folds produce Big Hill, Spreading Creek valley, Patterson Mountain, and Short Hills. The Pulaski overthrust crosses the area and exhibits many phases of major rock displacement along its trace.

Of special interest to geologists are (1) the fault-line phenomena near Eagle Rock, (2) the complex structure exposed in Eagle Rock gap, (3) a thick and nearly complete pre-Pennsylvanian section, (4) the volcanic material at the pre-Cambrian--Paleozoic contact, and (5) the physiographic relations of Natural Bridge.

The region is abundantly supplied with both surface and underground water. As subsurface circulation has developed numerous channels in soluble limestones, sinks and depressions are common. Almost the entire region drains into James River, of which Craig, Catawba, Cedar, Purgatory, Jennings, and Buffalo creeks are large tributaries; an abundance of smaller branches furnish surface water to nearly all parts of the district. Little use has been made of local water power, and the water of James River in the recent past has been rendered unfit for domestic use through pollution by mill-waste.

Natural Bridge, the best-known feature of the area, is a popular attraction for tourists from near and far. It is the last remaining portion of the roof of an underground water-way through which drainage from the Valley-floor peneplane was captured by an active tributary of James River.

THE GEOLOGY AND MINERAL RESOURCES OF THE NATURAL BRIDGE REGION, VIRGINIA

by

Herbert P. Woodward

INTRODUCTION

LOCATION AND AREA

The Natural Bridge region of this report is the area covered by the Eagle Rock and Natural Bridge quadrangles of the United States Geological Survey topographic maps.[1]

1. A topographic map bearing the name "Natural Bridge quadrangle" was surveyed by the United States Geological Survey between 1886 and 1888, and was published in 1894. It included an area approximately 28 miles wide by 35 miles long representing a 30-minute square (900 square minutes) of latitude and longitude. In 1906, the southeastern quarter of this quadrangle was resurveyed, and was issued in 1907 as a 15-minute quadrangle (225 square minutes) under the title "Natural Bridge Special quadrangle." In 1915, the southwestern quarter of the old Natural Bridge sheet was issued as a 15-minute quadrangle under the title "Eagle Rock quadrangle." The United States Geological Survey reissued the original Natural Bridge sheet in 1931 under the new title "Rockbridge quadrangle," and the former Natural Bridge Special quadrangle has been reissued under the title "Natural Bridge quadrangle." The present report, therefore, describes the southern half of the old "Natural Bridge" or Rockbridge quadrangle.

It is entirely within the State of Virginia, and lies mainly in Alleghany, Botetourt, and Rockbridge counties; a very small portion of Bedford County is included at the extreme southeastern corner of the area, and the eastern portion of Craig County enters the region at the southwest.

The territory is quadrangular in shape, and is bounded on the east and west by meridians of 79° 30' and 80° 0' West Longitude respectively, and on the north and south by parallels of 37° 45' and 37° 30' North Latitude respectively. (See Fig. 1.) It is approximately 28 miles long in an east-west direction and 17½ miles wide in a north-south direction. It includes nearly 500 square miles of mountain and valley country.

NATURE OF THE REPORT

Early in 1927, the Virginia Geological Survey assigned a geologic survey of the Eagle Rock topographic quadrangle to Dr. Harry S. Ladd, then assistant professor of geology at the University of Virginia. Doctor Ladd spent six weeks in the field during 1927 in preliminary reconnaissance, devoting his attention largely to the southern part of the quadrangle. Nearly ten days of this time were spent in collaboration with the present author who was engaged at the time in geologic work for the Virginia Geological Survey in the Roanoke area immediately south of the Eagle Rock quadrangle. In 1929, Doctor Ladd withdrew from the project to assume other duties, and the area was assigned to the present writer, who spent four months in the field during the summers of 1929 and 1930.

In 1931, a geologic survey of the adjoining Natural Bridge quadrangle was assigned to the author who had already studied portions of the area between 1927 and 1930 during the progress of geological reconnaissance in the nearby Roanoke and Eagle Rock regions. An intensive field program was begun in the summer of 1931 when three months were spent in the field. The latter part of March and the first week of April, 1932, as well as the months of June, 1932 and July, 1934, were also spent in the area.

In 1932, an invitation was extended to Dr. A. S. Furcron, then engaged in mapping the crystalline rocks of the Blue Ridge in Shenandoah National Park, to study the pre-Cambrian rocks of the Natural Bridge quadrangle. His field studies, made in 1932 and 1933, supplied data that have been incorporated into the section of this report dealing with pre-Cambrian rocks.

Except for the section prepared by Doctor Furcron, the accompanying report is the work of the present writer. It is intended to serve as a guide to the natural resources and geologic features of the Natural Bridge region.

An attempt has been made to describe the natural features of this area in a manner which will enable the lay reader to appreciate their structure and origin; the present development and future possibilities of the mineral resources are also described. The detailed outcrop map, Plate I, which accompanies this report indicates the extent of the surface area that is underlain by each of the various rock formations. Structure sections (Plate 2) show the actual and projected relations of these formations below ground, and discussions of the various surface features, rock units, geologic structures, and other points of geographic interest are also given. The report is designed to present these facts not only to the scientist but also to the non-technical reader, and all discussions mainly of scientific interest have been condensed or localized within the report.

As it was originally planned to publish ~~the accompanying material in two~~ a separate bulletin for each of the ~~single~~ two topographic quadrangles, ~~A~~ a report on the Eagle Rock quadrangle was prepared by the writer in 1932, and another on the Natural Bridge quadrangle in 1933. ~~In view~~, however, in view of a number of considerations, including the costs of publication and the ~~necessary~~ partial duplication of analogous material, it was decided in 1935 to combine the previous reports into a single manuscript from which the present report has been printed.

ACKNOWLEDGMENTS

The writer is under considerable obligation to many sources for material presented herein. He is grateful to those residents of the region who willingly cooperated by allowing him free access to their property, as well as to those who have given him various types of information which would otherwise have been difficult to obtain. He also acknowledges his indebtedness to those authors whose reports and other descriptions ~~have been published~~ form the geological literature dealing with this region.

Preliminary work in this area was begun in 1927 by Dr. Harry S. Ladd, who spent six weeks in the field and drafted a short abstract of the geology of part of the Eagle Rock quadrangle. Doctor Ladd graciously turned over to the present writer his field notes and map in 1929, and the Virginia Geological Survey has allowed the writer to make use of Doctor Ladd's specimens and abstract. Careful acknowledgement of all material derived from Doctor Ladd's work has been made, and all geologic sections, illustrations, collections of fossils, and specific mention of localities have been accredited to him. For this material the writer acknowledges his indebtedness to Doctor Ladd.

Dr. Charles Butts, of the United States Geological Survey, spent several days with the writer during the various field seasons, and has helped in the solution of many problems of stratigraphic interpretation, as well as in the unravelling of the geologic structure of the region. His kindly interest in this work has given the author much assistance and encouragement.

Professor Roy J. Holden, of Virginia Polytechnic Institute, has furnished valuable information about ~~data relative to~~ the mineral resources of the Blue Ridge ~~Region~~. Doctor Holden contributed specific data concerning the Blue Ridge hematite, and accompanied the author to several of the iron prospects of the region; for both of ~~which~~ these services the author expresses his appreciation.

Professor Wilbur A. Nelson, of the University of Virginia, has discussed the geologic structure of the Eagle Rock region with the writer and furnished him with several measured sections and other data. Dr. Paul H. Price, State Geologist of West Virginia, kindly escorted the writer over parts of Greenbrier and other counties in West Virginia which are adjacent to the Eagle Rock region.

With Dr. A. S. Furcron, formerly of Western Reserve University, who has contributed a section in this report on the crystalline rocks of the Blue Ridge, the author has discussed many of the problems relating to the nature and mapping of the basal Cambrian contact, and he is appreciative of the material assistance which Doctor Furcron has rendered to this study.

In 1931, Mr. F. F. Musgrove, treasurer of the Alleghany Ore and Iron Company, conducted the writer through the company's mines at Oriskany and graciously gave much valuable information about the former mining industry of the region. Mr. Jack Seay, then general manager of the Moore Lime Company at Eagle Rock, similarly furnished important data about the lime industry at Eagle Rock.

During the field season of 1930, Mr. Walter L. Smith of Charleston, West Virginia, was a willing and capable assistant and the writer especially acknowledges this assistance.

Mr. Robert A. Laurence, of Cincinnati, Ohio, acted throughout the field seasons of 1931 and 1932 as field assistant and junior associate in the securing of the data for this report. Mr. Laurence materially contributed to the progress of the field work, and his able assistance is sincerely acknowledged.

Mr. Robert L. Bates, of Iowa City, Iowa, who accompanied the author in 1934 in the capacity of a field assistant, has also made contributions of value to the survey, and assisted in the collection of field data.

Preliminary identifications of fossils were made independently by Dr. Harry S. Ladd and the present writer. Subsequently, the joint collections, together with prepared faunal lists, were restudied by Mr. D. M. Secor at Columbia University, under the direction of Dr. Horace N. Coryell. Many of the accompanying lists of fossils were compiled by Mr. Secor, to whom the writer extends his appreciation for their preparation.

Messrs. Jack Pechin of Buchanan, and Frank Dillon of Indianrock have furnished valuable data about the lime industry near Buchanan. For information regarding the Buchanan quarry of the Virginia Iron, Coal, and Coke Company, the writer is indebted to Mr. W. D. Skidmore of Buchanan. Messrs. J. W. Stull, O. D. Stull, and J. L. Teaford were kind enough to furnish information regarding the quarrying operations of the Liberty Limestone Corporation of Rocky Point. Natural Bridge Incorporated, present owners of the "Natural Bridge Estate", kindly furnished the writer free access to all parts of its property.

Mr. and Mrs. W. W. Lugar, of Eagle Rock, hospitably furnished the writer and other transient members of the Virginia Geological survey with a pleasant residence during several seasons in the progress of this study.

The final editing of this bulletin has been made by the staff of the Virginia Geological Survey, and the writer is especially indebted to Dr. Arthur Bevan, State Geologist of Virginia, and to Mr. Linwood H. Warwick, Chief Clerk of the Survey, for full coöperation throughout the field work and preparation of the final report.

PREVIOUS GEOLOGIC WORK

The earliest geologic work in the Natural Bridge region consisted of the general investigations made by William B. Rogers, at first under the direction of the Virginia Board of Public Works, and later for the Geological Survey of the State of Virginia. Although these investigations began about ~~one hundred~~ 100 years ago, their data were not available in print until 1884, when, under the editorship of Major Jed. Hotchkiss of Staunton, a volume entitled "Geology of the Virginias" was published, collecting together the manuscript reports of Rogers.

In the last decades of the nineteenth century many portions of the region were visited by geologists, most of whom were engaged in examining the mineral wealth of the district. Since 1900, other localities have also been described, but no previous attempt has been made to survey the geology of the entire district.

Note: Throughout this bibliography, which is typed with the page numbers, I omit the terminal items. Date, etc.

BIBLIOGRAPHY

Ashburner, C. A., Notes on the Natural Bridge of Virginia: Amer. Phil. Soc. Proc., no. 21, 1884, pp. 690, 699-700, et seq.

_____, The Natural Bridge of Virginia: Science, vol. 5, 1885, pp. 13-14.

Bassler, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, 1909.

Beckwith, L. C., The Arcadia iron property: The Virginias, vol. 1, 1880, pp. 110-12.

Butts, Charles, Geologic map of the Appalachian valley of Virginia, with explanatory text: Virginia Geol. Survey Bull. 42, 1933.

Butts, Charles, and others, The Southern Appalachian region: XVI Intern. Geol. Congr. Guidebook 3, Washington, D. C., 1932.

Campbell, M. D., The Cambro-Ordovician limestones of the middle portion of the valley of Virginia: Amer. Jour. Sci. 4th ser., vol. 20, 1905, pp. 445-47.

Campbell, J. L., The geology of Virginia: Amer. Jour. Sci., 3d ser., vol. 18, 1879, pp. 16-30, 119-28, 435-446.

_____, The geology of the Rich Patch, Virginia, iron region: The Virginias, vol. 1, 1880, pp. 185, 188-9, 192-3.

_____, The geological features of the Arcadia iron property, Botetourt County, Virginia: The Virginias, vol. 1, 1880, pp. 104-5.

_____, The mineral resources and advantages of the country adjacent to the James River and Kanawa canal and the Buchanan and Clifton Forge RR: The Virginias, vol. 1, 1880, pp. 2-8.

(sic.) _____, The Purgatory iron property, Botetourt County, Virginia: The Virginias, vol. 1, 1880, pp. 156-58.

_____, Geology and mineral resources of the James River valley, Virginia: New York City, 1882.

_____, The Clinton and Oriskany iron ores near the Richmond and Alleghany Railway: The Virginias, vol. 3, 1882, pp. 126-28.

_____, Geology of the Blue Ridge in James River gap, Virginia: The Virginias, vol. 5, 1884, pp. 145.

_____, Geology of the Blue Ridge near Balcony Falls, Virginia: Amer. Jour. Sci., 3d ser., vol. 28, 1884, pp. 221-23.

_____, and Campbell, M. D., The Snowden slate quarries: The Virginias, vol. 5, 1884, pp. 162-63.

Catlett, Charles, Iron ores of the Potsdam formation in the valley of Virginia: Amer. Inst. Min. Eng., Trans., vol. 29, 1900, p. 308.

de Chastellux, Marquis, Travels in North America in 1780-82: vol. 2, 1787, pp. 90 et seq., and p. 418.

Collins, W. D. and others, Chemical character of surface waters of Virginia, preliminary report: Virginia State Division of Water Resources and Power, Bull. 2, 1930, pp. 1-41.

_____, Springs of Virginia: Virginia State Division of Water Resources and Power, Bull. 1, 1930, pp. 1-55.

Darton, N. H., Fossils in the "Archean" rocks of central piedmont Virginia: Amer. Jour. Sci. 3d ser., vol. 44, 1892, pp. 50-52.

_____, Notes on the stratigraphy of a portion of central Appalachian Virginia: Amer. Geologist, vol. 10, 1892, pp. 10-18.

Dirzulaitis, J. J. and Stevens, G. C., Water resources of Virginia: Virginia Geol. Survey Bull. no. 31, 1927.

Eckel, E. C., The Oriskany and Clinton iron ores of Virginia: U. S. Geol. Survey Bull. 285, 1906.

Ellett and Askridge, Virginia marls: Virginia Agr. Exper. Sta. Bull. 6, new ser., 1897, pp. 65-70.

Featherstonehaugh, G. W., Natural Bridge in Rockbridge County, Virginia: Monthly Amer. Jour. Geol., vol. 1, 1832, pp. 481-90.

Fontaine, W. M., On some points in the geology of the Blue Ridge in Virginia: Amer. Jour. Sci., 3d ser., vol. 9, 1875, pp. 14-22, 93-101.

_____, On the Primordial strata of Virginia: Amer. Jour. Sci., 3d ser., vol. 9, 1875, pp. 361-69, 416-28.

Froehling and Robertson, A handbook of the minerals and mineral resources of Virginia: Richmond, Virginia, (Prepared for the Virginia Commission to the St. Louis Exposition), 1904.

Geologic map of Virginia: Virginia Geological Survey, 1929.

Gilmer, F. W., On the geological formation of the Natural Bridge of Virginia: Amer. Phil. Soc. Trans., new ser., vol. 1, 1818, pp. 187-92.

Harder, E. C., The iron ores of the Appalachian region in Virginia: U. S. Geol. Survey Bull. 380, 1909, pp. 215-54.

Holden, J. R., The iron ores of Virginia: in Mineral resources of Virginia, by J. L. Watson, Virginia-Jamestown Exposition Commission, Lynchburg, Virginia, 1907, pp. 402-491.

Holden, R. J., The Oriskany clay: Engineering Extension Division, Virginia Polytechnic Inst. Bull., no. 14, 1928, pp. 1-12.

Hotchkiss, Jed, Sundry articles, editorials, and other items: The Virginias, vol. 1-6, 1880-1886.

Hubbard, G. D. and Croneis, C. G., Notes on the geology of Giles County, Virginia: Denison Univ. Bull., vol. 20, 1924, pp. 307-77.

Jefferson, Thomas, Notes on the State of Virginia: Philadelphia, 1794.

Kain, John R., Mineralogy and geology of the northwestern part of the State of Virginia and eastern part of the State of Tennessee: Amer. Jour. Sci., 1st. ser., vol. 1, 1818, pp. 60-67.

Kindle, E. M., The Onondaga fauna of the Alleghany region: U. S. Geol. Survey Bull. 508, 1912.

Lyman, Benj. S., Geology of the Low Moor, Virginia, iron ores: Trans. Amer. Inst. Min. Eng., vol. 14, 1885, pp. 801-809.

McCreath, A. S., The mineral wealth of Virginia: Harrisburg, Pennsylvania, 1883.

Malott, C. A. and Shrock, R. R., Origin and development of Natural Bridge, Virginia: Amer. Jour. Sci. 5th ser., vol. 19, 1930, pp. 257-273.

Mooney, C. N., Martin, F. O., and Caine, T. A., Soil survey of the Bedford area, Virginia: U. S. Department of Agriculture, Bureau of Soils, Ann. Report 1901, 1901, pp. 239-57.

Nelson, Wilbur A., Volcanic ash deposit in the Ordovician of Virginia: Geol. Soc. Amer. Bull., vol. 37, 1926, pp. 149-50.

Pechin, E. C., The iron development and ore resources of Virginia: Trans. Amer. Inst. Min. Eng., vol. 19, 1891, pp. 1016-35.

Raymond, Percy E., Some trilobites of the lower middle Ordovician of eastern North America: Bull. Mus. Comp. Zool., vol. 67, 1925, pp. 1-180.

_____, The brachiopods of the Lenoir and Athens formations of Tennessee and Virginia: Harvard Coll., Mus. Comp. Zool. Bull., vol. 68, 1928, pp. 255-309.

_____, The correlation of the Ordovician strata of the Baltic basin with those of eastern North America: Bull. Mus. Comp. Zool., no. 56, 1916, pp. 179-286.

Reeds, Chester A., The Natural Bridge of Virginia and its environs: Richmond, Virginia, 1930.

Ries, Heinrich and Somers, R. E., The clays and shales of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 20, 1920,

Rogers, W. B., Geology of the Virginias: New York, D. Appleton and Co., (Edited by Jed Hotchkiss), 1884.

Ross, C. S., Altered Paleozoic volcanic materials and their recognition: Am. Assoc. Pet. Geol. Bull., vol. 12, 1928, pp. 143-64.

Sears, R. M., Natural Bridge National Forest, Virginia: U. S. Department of Agriculture, Forest Service pamphlet, 1930.

Steidtmann, Edward, Faceted sandstone pebbles of the North River, Virginia: Jour. Geol., vol. 34, 1926, pp. 836-39.

Stose, G. W. and Miser, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, 1922.

Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, 1919.

Stow, M. H., A preliminary investigation of some sediments from James River, Virginia: Amer. Min., vol. 15, 1930, pp. 528-33.

Swartz, Frank M., The Helderberg group of parts of West Virginia and Virginia: U. S. Geol. Survey Prof. Pap., 158-C, 1929, pp. 27-75.

Walcott, C. D., Correlation papers: Cambrian: U. S. Geol. Survey Bull. 81, 1891, pp. 133-38, 290-98.

_____, Notes on the Cambrian rocks of Virginia and the southern Appalachians: Amer. Jour. Sci., 3d ser., vol. 44, 1892, pp. 52-57.

_____, The natural bridge of Virginia: Nat. Geog. Mag., vol. 5, 1893, pp. 59-62.

_____, Cambrian brachiopoda: U. S. Geol. Survey Mon. 51, 1912, pp. 200, 218.

Watson, T. L., Bibliography of the geological, mineralogical, and paleontological literature of the State of Virginia: Bull. Amer. Paleontologist, vol. 2, 1897.

_____, Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, Lynchburg, Virginia, 1907.

Watson, T. L., and Cline, J. H., Petrology of a series of igneous dikes in Central western Virginia: Geol. Soc. America Bull., vol. 24, 1913, pp. 301-34.

Watson, T. L. and Laber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3A, 1913.

Weld, C. M., The Oriskany iron ores of Virginia: Econ. Geol., vol. 10, 1915, pp. 399-422.

Willard, Bradford, The brachiopods of the Ottosee and Holston formations of Tennessee and Virginia: Harvard Coll., Mus. Comp. Zool. Bull., vol. 68, 1928, pp. 255-309.

Woodward, Herbert P., The age and nomenclature of the Rome ("Watauga") formation of the Appalachian valley: Jour. Geol. vol. 37, 1929, pp. 592-602.

_____, Paleozoic oberts of west-central Virginia: Jour. of Geol., vol. 39, 1931, pp. 277-87.

_____, The geology of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, 1932.

Woodward, Herbert P., The Salem block of the Pulaski overthrust: Pan-Am. Geol., vol. 58, 1935, pp. 321-333.

_____, Fault-line phenomena near Eagle Rock, Virginia: Amer. Jour. Sci. 5th ser., vol. 31, 1936, pp. 135-143.

_____, Natural Bridge and Natural Tunnel, Virginia: Jour. Geol., vol. 44, 1936, pp. 604-614.

Wright, J. J., The physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 21, 1925.

_____, The newer Appalachians of the south: Denison Univ. Bull., Jour. vol. 2a, 1934, pp. 1-105.

GENERAL GEOGRAPHY

RELIEF AND DRAINAGE

The Natural Bridge district extends into three geographic areas, or provinces, which are, from southeast to northwest, the Blue Ridge, the Great Valley, and the Appalachian Valley and Ridges.

The southeastern portion of the region, which is a part of the true Blue Ridge, is a rugged area having an average elevation of about 2,000 feet above sealevel. It is thickly wooded and is included in the area of the Natural Bridge National Forest. The steep northwestern face of the Blue Ridge descends abruptly to James River which follows its base. (See Pl. 5A.)

A block diagram, figure 2, shows the generalized topography of the Natural Bridge region.

The Great Valley extends southwestward across the district and expands into a wide triangular area between Buchanan, Eagle Rock, and Fincastle. Although the valley is relatively a lowland, its surface is undulating, and many small streams have developed deep valleys that mar the evenness of its surface; James River flows nearly 500 feet below its general level. The northeastern portion of the local valley is broken by a long ridge that extends along the middle of the lowland area. This ridge, called Short Hills, stands nearly 1,500 feet above the floor of the valley which it divides into two distinct portions. (See Pl. 6.)

A mountainous tract of complicated geologic structure occupies a large area in the central portion of the Natural Bridge region (See Fig. 2.) where it has the shape of an inverted "Y". It enters the area from the north in the broad mass of North and Brushy mountains, and, east of Eagle Rock, diverges into two narrow, broken ranges that end (1) in Purgatory mountain near Buchanan and (2) in Switzer Mountain northwest of Fincastle. The term "Eagle Rock Range" is applied to the northwestern range which includes Sheets, Bathole, Crawford, Switzer mountains, and Poplar Hill. The term "James River Range" is applied to the eastern unit which includes the two Camp Mountains, Grassy, Garden, Mays, Back Creek, and Purgatory mountains. The broad limestone lowland which lies between the Eagle Rock and James River ranges widens toward the southwest, extending to Tinker Mountain which constricts it, near Daleville, to a width of scarcely 2 miles. This enlarged portion of the valley lowland, in which the town of Fincastle occupies a central position, is locally known as the Fincastle valley. (See Pl. 7.)

The western and northern portions of the area lie within the true Appalachian Valley and Ridge region, and are rugged,

well-forested, and sparsely settled. The tongue of mountains which extends southward to Buchanan, contains short irregular ridges that follow a southward trend. West of Eagle Rock, the ridges and valleys exhibit the normal northeastward strike of the Appalachian Mountains, and form a rugged hinterland that is accessible only along the valley lowlands. The highest local summit is Apple Orchard Mountain which is located along the Botetourt-Bedford county-line. (See Pl. 8,A.) This peak reaches an elevation of 4,224 feet above sealevel and is the most conspicuous elevation in this part of the Blue Ridge. The highest summits of the Appalachian ridges include Rich Patch Mountain, elevation 3,728 feet (Pl. 8,B), and Sugar Loaf Mountain, elevation 3,533 feet. James River leaves the local area at an elevation of about 710 feet above sealevel; hence, the maximum relief is about 3,500 feet.

The entire territory drains into James River and its tributaries, chief of which are Potts, Craig, Catawba, Looney (Mill), Purgatory, and Cedar creeks. James River flows southeastward from Eagle Rock to a point near Buchanan whence it turns sharply to the northeast to follow the escarpment of the Blue Ridge. The northeastern section of the area is drained by Buffalo Creek which enters North River, a large tributary of James River, several miles east of this area. Most of the local streams are permanent, although some of the smaller branches flow only in the rainy season. In the limestone area of the valley lowlands there is evidence of considerable underground drainage which is responsible for many sinks (Pl. 6,B) and small caves.

CLIMATE

The region is favored with a pleasant climate that is well adapted to agriculture. The average annual precipitation, which is about 39 inches, is evenly distributed throughout the year, although it is slightly less in winter than in other seasons. The mean annual temperature is about 56°F. The winters are normally open and mild and the summers are warm and pleasant. The last killing frost in the spring occurs about April 10 and the first killing frost in the fall seldom occurs earlier than October 23; hence, a long growing season favors the cultivation of wheat, corn, and other cereal crops. There is a slight difference in climatic conditions between the valley and adjacent mountain areas. This is especially marked in the approach of spring which arrives considerably later along the higher slopes of the mountains than in the Great Valley. Although they occupy different geographic regions, farming and fruit growing are the principal agricultural industries of this area.

SOILS AND VEGETATION

The Great Valley is the most prosperous section of the district, for it contains the areas of most fertile soil. (See Pl. 7.) In the valley lowlands, the houses are more pretentious, farm buildings are larger and better kept, and the roads are more abundant and in better condition, than in other parts of the region. In the mountainous sections, little farming is possible, and cleared fields along the mountainsides are devoted chiefly to pasture. Considerable fruit-farming is attempted along the Blue Ridge, especially in the area immediately south of Buchanan. Little or no livestock is grazed in the mountains except for

local use. Considerable tobacco is grown in the valley of Goose Creek, a short distance south of this area, but there is very little tobacco production in the area of this report.

The local soils may be roughly separated into three types which correspond closely to the three major physiographic provinces.[1] The soils of the Blue Ridge include three varieties. The most important (Muskingom) group occurs along the tops and slopes of the mountains; it is a grey, or yellowish-gray, sandy loam containing much fragmentary rock debris. Because of a poor location, it is seldom cultivated. Where cleared, however, it gives good pasturage but is easily subject to drought and steadily receives loose rock float from higher ledges along the crests of the mountains. It supports the sturdy Appalachian forest. In addition to this soil type, there is a yellow to gray sandy loam (Ashe stony loam) which occurs on the lower and gentler slopes of the Blue Ridge, where, in favored localities it is suitable for orchards. This soil, which commonly contains much quartzite and other coarse rock debris, is underlain by a yellow or red clay-loam. In some places, the crystalline pre-Cambrian rocks produce a red clay-loam (Porters loam) which contains much fresh and partly weathered residual debris produced by disintegration of the underlying granites and gneisses. This soil is apparently derived from a sandy loam by the removal of the sand which leaves a stiff thin red clay. It is found in isolated areas in the higher mountainous tracts of the Blue Ridge.

---

1. For a more detailed description of local soils, the reader is referred to a "Soil Survey of Rockbridge County, Virginia", by M. C. Jurney and others, published as No. 4, Series 1931, by the Bureau of Chemistry and Soils, U. S. Department of Agriculture, 1931.

The soils of the Great Valley are by far the most fertile soil types of the area. The most conspicuous variety of these is the widely distributed group which includes the Frederick silt loam and the various Hagerstown loams. This group is represented by a heavy, reddish-brown, unctuous soil about 1 foot thick and overlying several feet of soft, red, sticky clay. (See Pl. 9A.) It is residual from the disintegration of limestone and dolomite and is both fertile and favorably located for agriculture. In some of its outcrops, however, it produces sufficient chert and sandy debris to impede or prevent its successful cultivation. The normal crop of this soil belt is bluegrass, but the soil is good for wheat, clover, and tobacco. Corn also thrives on the limestone soil, and grasses and pasturage are common in those areas where the underlying rock is somewhat shaly. Apparently much of this soil outcrop has never been forested, having always supported grasses. Soils of adjacent shale outcrops are somewhat less productive than limestone soils, and contain tiny shale splinters that impair their fertility. Most of the shale soil is a light clay-loam that is rather shallow but is well adapted for wheat and pasturage.

The soils of the Appalachian ridges are loose and sandy; they are poorly located and drain easily. Soil removal, through rain wash and stream gullying (Pl. 9B), is a continuous process along the steeper slopes. Little has been done as yet to halt this unfortunate waste or to reclaim lands already deeply gullied. Cultivation of the mountainous soils has progressed slowly, and their areas, even where cleared, make only temporary pasture lands. Where uncleared, they support a sturdy growth of hardwood and conifers. (See Pl. 10.) In the shale valleys between the Appalachian ridges, the soils are deeper

but scarcely more fertile, and the outcrops of certain black shales are so unproductive as to justify the common name "poor valleys." Where soils are developed upon shaly limestones or upon calcareous shales, they are productive and approach the fertility of true limestone soil.

Most of the woods of central Virginia flourish in this area. Throughout much of the Natural Bridge National Forest the timber is gradually returning to its original state and a good stand of the primitive American forest may be seen. In other parts of the area, however, the timber is open and shabby as the result of repeated forest fires. Both the Blue Ridge and Appalachian ridges have been repeatedly cut over during Colonial and later settlement when lumbering was an important local industry. The most common types of wood are white oak, locust, pine, hickory, cedar, and birch. Many of the mountain slopes have a thick undergrowth of laurel, grape, and berry which make travel difficult; rhododendron is also common in the Appalachian ridges.

CULTURAL FEATURES

The Natural Bridge district is sparsely populated. Buchanan, (Pl.5,A), the largest village within the area, is located on James River immediately southeast of Purgatory Mountain. (See Pl.13,A.) It has a population of about 800, and was once the western terminus of navigation on James River; modern railroads and highways, however, have completely obliterated all river trade. Buchanan is located near the former site of Looney's ferry, which was established in 1742 as the first local crossing over the James. It was named to honor Colonel John Buchanan whose colonial home formerly stood near Looney's ferry. Fort Fauquier (1758-1763) was then situated at the mouth of Looney Creek near the present site of the town.[1]

---

1. It should be noted that this creek was originally called Looney's Mill Creek. On the Natural Bridge quadrangle the name is represented as Looney Creek, but the stream is equally well known as Mill Creek.

Fincastle, the seat of Botetourt County, is located along the west-central portion of the southern boundary of the region, 11 miles southwest of Buchanan. (See Pl.7.) It is one of the oldest and best-known settlements in the Appalachian Mountains, and was formerly seat of the vast Fincastle County which extended from the Blue Ridge to Mississippi River. Its relative importance, however, has been relinquished to newer and larger centers, and its present population, about 500 inhabitants, is scarcely larger than its population 100 years ago.

Eagle Rock, known as Eagle Mountain Station of the Chesapeake and Ohio Railway, is situated on James River immediately southeast of the water-gap through Crawford-Rathole mountains. (See Pls.5,B, and 63,A.) Its population is about 500, and the town owes its local importance to the railroad and to nearby lime quarries.

Several other small settlements occur within the limits of this area, but none contains more than 200 or 300 inhabitants; most of them are located along or near James River, including Glen Wilton, Gala, Saltpeter Cave, Springwood, Indianrock, Arcadia, Rocky Point, and Natural Bridge Station. Oriskany, Norton, and Lignite (Pl. 12A) are similar settlements on Craig Creek; Murat, Oakdale, and Mapps Mill are other community centers. The valley lowland of the Natural Bridge and Eagle Rock-Fincastle districts (Pl. 7), the intermontane valleys of South Buffalo and Craig creeks, the fertile Rich Patch valley, and the floodplain of James River (Pl. 11) all contain numerous prosperous farms. The timber ridges of the Fincastle valley, the rugged Blue Ridge, and the linear Appalachian ridges have been but little cleared, and represent the typical wilderness of the central Appalachian type. (See Pl. 10.)

The area is served by two railroads. The James River Division of the Chesapeake and Ohio Railway follows the north bank of James River across the district. A branch line, the Craig Valley Division, follows the valley of Craig Creek from Eagle Rock to Newcastle, Craig County. The Shenandoah Division of the Norfolk and Western Railway follows the southern bank of James River from Buchanan to Natural Bridge Station where it crosses the river and the Chesapeake and Ohio Railway.

United States Highway 11 (Lee Highway) crosses the eastern portion of the region and connects with Virginia State Highway 249 at Natural Bridge. State Highway 12 serves the western portion of the area passing through Gala, Eagle Rock (Pl.12,B), and Pincastle. State Highway 43 (Pl.53,A) extends from Bedford east of the Blue Ridge, through Buchanan and Eagle Rock into Rich Patch valley, and connects, near Strom, with State Highway 42 which follows Craig valley to Newcastle.

A foot-trail, known as the "Appalachian Trail", follows the crest of the Blue Ridge from Maine to Georgia, but is used only by hardy hikers. A ~~proposed~~ main highway, to be called "The Blue Grass Trail," is planned to cross this area from east to west. It will ultimately connect Murat, Oakdale, Eagle Rock, Oriskany and Newcastle with points south. Several roads in the Blue Ridge area have been recently improved under supervision of various federal authorities, but the majority of other roads are unimproved sand and dirt roads over which travel is difficult or impossible after rains.

The Virginia Gas Transmission Corporation, a subsidiary of the Columbia Gas and Electric Corporation of New York, has constructed a pipe-line which crosses this area from Rich Patch valley to Lexington. Near Great Falls on the Potomac, this line connects with another pipe-line from Coatesville, Pennsylvania. It is designed to transport natural gas from Kentucky and West Virginia, and is a twenty-inch pipe laid in a cut-and-cover trench.

Note: If necessary to condense space, this section may be omitted. The writer prefers it to remain.

NATURAL BRIDGE NATIONAL FOREST

The area south of James River and east of Looney (Mill) Creek lies within the Natural Bridge National Forest.

In 1911, the Congress of the United States passed a law providing for the purchase of mountain lands to protect the watersheds of navigable streams. Later in that year purchases of land in Botetourt and Bedford counties initiated the Natural Bridge National Forest which is now more than 70 miles long and includes 280,000 acres of land, two-thirds of which is government-owned. The forest extends northward from the Peaks of Otter, 15 miles southwest of Buchanan, nearly to Waynesboro and includes some of the best timber-producing land of the country.

In the early settlement of this part of Virginia, a great depletion of the primitive forest followed the introduction of agriculture, and shortly after the Civil War, many tanneries and paper mills were established within the limits of what is now the National Forest. During the last decades of the nineteenth century, discovery of iron and manganese along the Blue Ridge increased the need for timber, and large saw mills, one of which was located at Arcadia, began to make inroads upon the forests of the Blue Ridge. With the removal of timber, great areas of mountain land were exposed to the heat of the sun; forest fires were common, and game, once plentiful, sought refuge elsewhere or was wantonly killed off in absence of any protective laws. After the creation of Natural Bridge National Forest, this land came under government supervision, and is now protected

for the future by the laws governing such forests. The large areas previously subject to repeated fire damage and excessive timber extraction received careful protection, evidence of which may be found in many parts of the forest, where the planting of young trees has changed the color of the mountains from the brown of barren slopes to the green of new forests.

This forest is one of ~~sixteen~~ 16 National forests comprising the eastern region and is under the general jurisdiction of a Regional forester at Washington, D. C. The local forest supervisor, who has direct charge of all activities within this forest, has headquarters at Lynchburg, and a number of rangers are responsible for the care of the ~~two~~ 2 districts into which the forest is divided. Lookout towers, which are located for the prompt detection of forest fires, are in telephone connection with the rangers' headquarters. One of these towers is located on Apple Orchard Mountain.

The forest ~~theater~~ is a magnificent area of wild, unbroken, mountain land belonging to the people of the United States. It furnishes pure water to many of the adjacent towns and supplies timber and forest products for local use. The growth of young trees is fostered, and the area is protected not only for today but for all future time. The forest is available as a playground for thousands otherwise denied the pleasure of rugged scenery and mountain air. It furnishes an ideal summer home for the city man and a safe retreat for wild life. Roads within the forest are maintained by the rangers and many of these are in fine condition. Well-marked trails and other roads are clearly shown on maps furnished by the United States Department of Agriculture (Interior now?) and most of these have markers by means of which one may follow them. The well-known Appalachian Trail, which follows the crest of

the Blue Ridge, is clearly blazed and crosses the district in the area of the forest.

Natural Bridge National Forest is open to the public, and visitors are welcome so long as they obey the few simple rules as to the care of fire and as to sanitation. The forest is readily accessible by foot, horse, automobile, or railroad. It may be entered from Arcadia, which is reached from the Lee Highway by ~~means of~~ a good road to Indianrock and a ferry across James River. Another route into the forest is along State Highway 43 which leads from Buchanan up Bearwallow Creek to the Peaks of Otter which are famous for the grandeur of the view from their summits. A fine camp accomodating ~~fifty~~ 50 guests is located near the summit of Apple Orchard Mountain, 10 miles north of the Peaks of Otter. Permission to occupy summer homes within the forest area may be obtained for a small fee by applying to forest Rangers at Buena Vista or at Natural Bridge.

PHYSICAL GEOGRAPHY

GENERAL STATEMENT

All local land features are the result of three geologic processes working simultaneously--(1) The action of the weather, or weathering, (2) erosion by streams and rivers, and (3) differential uplift or warping of the land surface. The interactions of these three processes, together with the results produced, fall in the field of physical geography, or physiography, which may be defined as the study of the surface of the earth and the interpretation of its topographic forms. The many striking scenic features of the region, such as Natural Bridge (Pls. 3 and 20), Purgatory Mountain (Pl. 13,A) and Montgomery Knob (Pl. 13,B), Apple Orchard Falls, and the Blue Ridge all owe their present forms to the interplay of the various geologic processes.

The following pages are devoted to a discussion of the physiographic features of this region. They describe the phenomena with which the average person is most keenly interested--the elements of the scenery and the nature of the landscape.

PHYSIOGRAPHIC PROVINCES

The Natural Bridge region lies within ~~three~~ 3 distinct geographic provinces. The Blue Ridge Province is restricted to the eastern portion south of James River. The Appalachian ~~Ridge and~~ Valley and Ridge Province occupies the remainder of the area and includes two units, the Great Valley, and the Appalachian Ridges, ~~region~~. These ~~regions~~ areas may be described as physiographic provinces because they are characterized throughout by similar surface features which have been produced as a result of similar, or closely related, stages of physiographic history. Neither the Appalachian Plateau Province, which is northwest of the local area, nor the Piedmont Plateau Province, which lies to the southeast extends into the ~~area~~ region covered by this report.

The term "Blue Ridge" is applied to a narrow belt of rugged mountains developed upon resistant rock of complicated structure immediately southeast of the Great Valley. An area of igneous and metamorphic pre-Cambrian ~~crystalline~~ rocks makes up the eastern and more rugged portion of the Blue Ridge; ~~lower~~ early Cambrian sediments produce a line of foot-hills that form ~~the~~ its northwestern face, ~~of the Blue Ridge~~. (See Pl. 30, A.) ~~As a matter of actual fact,~~ Actually, there is ~~very~~ little difference in the ruggedness of the two areas, the Cambrian sandstone ridges ~~of the Cambrian~~ being scarcely inferior in height to the pre-Cambrian granite ridges. (See Pl. 25, A.) The two portions of the local Blue Ridge ~~here~~ are indistinctly separated and it is not possible to trace any sharp topographic line of demarcation between them. It should be noted, however, that the quartzite foothills of the Blue Ridge are commonly divided into ~~two~~ 2 tiers by the outcrop of ~~the~~ a weak formation (the Hampton shale, see pg. 94-95) which lies between ~~two~~ 2 resistant

sandstones(Unicoi and Erwin, see pages 85 and 96).

The Blue Ridge province contains maturely dissected mountains of complex structure and coarse topography. The drainage of this province is dendritic except in the narrow valley between the ~~two~~ 2 quartzite foot-hills, where subsequent streams follow the outcrop of the intervening shale. No stream crosses this part of the Blue Ridge save James River which has cut a deep gorge at Balcony Falls a few miles to the east of this area. (See Pl. 14.) The divide, or crest, of the Blue Ridge crosses the extreme southeastern corner of the area; all northward-flowing drainage reaches James River through North, Jennings, and nearby creeks. The drainage of the southern slope makes its way along Otter Creek into Roanoke River. The highest peaks of this part of the Blue Ridge, including Apple Orchard Mountain (Pl. 8A), are located along this divide. The average elevation of the Blue Ridge is between 2,000 and 3,000 feet above sealevel, and, with the exception of the foothills, there is little evidence of any intimate structural control of the topography. The northwestern descent from the Blue Ridge to the Great Valley is sharp and straight. This face and its line of foothills are well shown south of James River near Gilmore Mills and are even better displayed between Glascow and Buena Vista. (See Pl. 30A.) The Blue Ridge is traversed by few roads and for the most part is well covered with forested areas. It is entirely within the limits of Natural Bridge National Forest.

The Great Valley portion of the Appalachian Valley and Ridge Province extends across the area from northeast to southwest, and is developed upon a thick series of limestones and shales of Cambrian and Ordovician age. These rocks have been strongly disturbed, by folding and faulting, and their general structure is so complex that it is rare to find them in their original horizontal position. They are now deeply weathered and their erosion is responsible for a narrow lowland that extends from New York State into Alabama, as a continuous topographic unit between the Blue Ridge on the southeast and the Appalachian ridges on the west. The lowland, however, was never the valley of a single stream, nor was it drained at any time by one river.

The floor of the Great Valley is rolling and its level surface is interrupted by many elevations--such as Timber, Little Timber, and Cedar ridges--which rise above the valley floor, as well as by stream valleys that sink below the general level. (See Fig. 2.) In fact, the evenness of its floor is best appreciated as one travels along the strike of the rocks, and is scarcely evident in crossing the valley from southeast to northwest. Most of the streams are subsequent in origin, having become adjusted to positions upon the weaker zones within the folded calcareous rocks. For the most part the valley is well cleared, and prosperous farms line the highways that traverse it. (See Fig. 7.)

The Appalachian Ridge sub-province is the area of the Alleghany, or "Newer Appalachian",[1] Mountains and lies immediately north

---

1. The Appalachian Mountains are sometimes classified as the "Older Appalachians" or Blue Ridge area, and the "Newer Appalachians"or Alleghany Ridges. The terms "older" and "newer" refer to the relative ages of the underlying rocks.

and west of the Great Valley. It is a rugged region developed upon a folded series of rocks, with ridges that are developed upon hard-rock layers and valleys that follow belts of weak materials. The area is maturely dissected and the mountains are in at least a second cycle of development, having been produced by the long-continued erosion of an original peneplaned surface. Early Silurian sandstones produce most of the rugged mountain crests; the intervening valleys are developed chiefly upon late Ordovician and middle Devonian shales.

Throughout the Appalachian region almost all ridges and valleys are aligned in a northeastward direction. Because of the involved geological history of the Natural Bridge region, some of the local ridges diverge considerably from the usual northeastward trend, the James River range, which includes Wildcat, Garden, Mays, Back Creek, and Purgatory mountains, (Pl. 13A), being a conspicuous example.

The mountains of the western half of the area are typical Appalachian ridges. Long parallel mountains, such as Rich Patch, Patterson, Price, Switzer, North, Panther, and Brushy mountains, maintain the northeastward trend that characterizes the Appalachian Mountains from Pennsylvania to Alabama. The linear shale valleys between them, including the valleys of Craig, Patterson, and Little Patterson creeks, are likewise typical of the Valley and Ridge belt. Rich Patch valley and the valley of South Fork of Buffalo Creek are developed upon soluble limestones, and contain more fertile soils than the shale valleys mentioned above.

The drainage of the Appalachian Valley and Ridge province is largely of the trellis type with long, parallel tributaries that enter the master streams at right angles. The ridges reach elevations of 3,000 feet above tide and stand more than 1,000 feet above the intervening valleys. (See Pl. 15.) The topography of this province is rugged, and mountains and valleys alike are but little cleared. The soil is not especially fertile, the farms are small, and the farm buildings are less pretentious than those in the Great Valley.

EROSION LEVELS

The surface features of this region reveal several erosion levels at different elevations representing definite stages in the physiographic history of the area. These levels are remnants of former wide-spread terraces, or peneplanes, that were developed by streams at a time when the entire country stood much lower than at present. Two of these levels are very conspicuous and may be traced throughout the entire Appalachian region. (See Fig. 3.) The uppermost surface, which is developed along the crest of the higher ridges, is called the upland peneplane. The lower surface, present on the floor of the Great Valley, is called the Valley-floor peneplane. Two other erosion levels or surfaces are also associated with the peneplanes. These are (1) monadnocks above the upland peneplane, and (2) trenches below the Valley-floor peneplane. All of these forms have been described by Stose.[1] Their areas of local distribution are shown in Figure 4.

---

1. Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 34-40, 1919.

Upland Peneplane

This erosion surface is preserved on the even crests of Rich Patch (Pl. 16A), Bearwallow, Carpenter, and North mountains. Some of the higher summits in the Blue Ridge section also reach this level.

The elevation of the Upland peneplane in the Natural Bridge region ranges from 3,200 to 3,400 feet above sealevel. Whatever its original extent, it has been so strongly dissected that its remnants are now preserved only on the summits of the mountains, and until one imagines the intervening valleys to be filled up to this level, it is difficult to picture the nature or extent of the old surface. The uneroded remnants of the Upland peneplane now exhibit a rolling surface about 3,200 feet above sealevel. At the time this surface was formed, the entire area must have been much lower in elevation--probably close to sealevel--and the Upland peneplane was then a lowland surface across which the larger streams meandered as they approached baselevel. As the surface was probably developed during, or at the close of, the Cretaceous Period, it is often called the "Cretaceous" peneplane. No clue to its exact age, however, can be obtained in this region. It is thought to be the southern equivalent of the "Schooley" and "Kittatiny" peneplanes of the northern Appalachians.

After the initial formation of this old land surface, uplift of the entire region took place, and erosion was set actively to work. In this part of Virginia the uplift must have amounted to nearly 3,000 feet. Large streams, such as Roanoke and James rivers, had already established meandering courses across the old surface.

As the uplift was very gradual, these streams were able to cut their channels downward without much lateral change of position, so that they retained their original courses even though the surface upon which they formerly meandered was largely destroyed. Their tributaries developed rapidly along belts of weak rock while the upturned edges of resistant strata were soon etched out as growing elevations that were ancestral to the Appalachian ridges of today. As a result of this uplift and subsequent erosion, nearly all trace of the original surface was removed. In those areas where it was underlain by soft rock, the land surface was lowered by weathering and erosion as much as 3,000 feet below its original level, and only in favored localities--upon belts of very resistant strata, or in isolated interstream areas--is there any visible evidence of the former existence of the Upland peneplane. Its chief present effect upon the scenery of the Appalachian Mountains is to produce a remarkably level skyline. Rich Patch (Pl. 16A) and North mountains, for example, whose crests exhibit the 3,200 foot level, present flat, smooth profiles along the horizon. The remnants of the peneplane in the Blue Ridge area are less continuous and more isolated.

Valley-floor Peneplanes

A striking physiographic level is developed along the Great Valley of Virginia whose floor is an undulating surface rising gently to the bounding ridges on either side. No single river drains this valley which is the result of long-continued erosion upon a continuous belt of soft and soluble rocks. Near Natural Bridge, it is drained solely by James River and its many tributaries.

This erosional surface extends northward from Virginia into Maryland, Pennsylvania and New Jersey, where its outcrop has been widely studied. In the northern regions, the name "Harrisburg" peneplane has been applied to levels developed upon Paleozoic (chiefly Ordovician) shales, while the name "Somerville" peneplane has been used for levels developed upon Cambrian and Ordovician limestones and Triassic shales. The exact equivalence of the local levels with those of the northern region is not wholly clear, and it does not seem advisable to transfer either of the names "Harrisburg" or "Somerville" to the Natural Bridge region, where, in this report, the erosional surfaces are called the Valley-floor peneplanes, in recognition of their lowland position.

In the present area, the Valley-floor peneplane is best developed in the region between Buchanan and Eagle Rock, and in the area north and east of Natural Bridge. (See Fig. 3.) There is a wide triangular region between Buchanan, Eagle Rock, and Troutville in which the valley shows its typical peneplane topography, although a few low monadnocks rise above its general surface. (See Pl. 7.) The peneplane has not been strongly dissected and its surface is gently undulating. (See Pl. 17,A.) Catawba and Spreading Spring creeks have developed small local erosion levels below the peneplane, while Cedar and both of the Timber ridges rise slightly

above its general surface.

The Valley-floor peneplane was produced by continued erosion of the weak-rock belts that had been truncated during the formation of the Upland level. The areal development of the Valley-floor peneplane is now much greater than that of the remnants of the earlier level, although its original extent was by no means as wide. (See Fig. 4.) The later period of Valley-floor erosion was sufficient only for the removal of that part of the earlier surface which was underlain by soft rocks, although this removal has now progressed well toward the heads of the larger streams. Only the belts of limestones and weaker shales were lowered during Valley-floor peneplanation as compared with the almost complete surface reduction of the Upland cycle.

In the western Appalachian Ridge province, the Valley-floor peneplane is less well developed than upon the broad outcrop of Cambrian and Ordovician limestones where a greater single area of soft rock is exposed than occurs elsewhere. Extending in all directions from Gala is a region of low relief in which the hilltops reach an average elevation of about 1,250 feet. (See Pl. 17, B.) This area, underlain by Devonian (Brallier and "Romney") shales, was reduced to the Valley-floor level and later dissected; it is one of the most striking Valley-floor surfaces within the Appalachian Ridge province.[1] The same level is represented along Craig Creek by flat-topped meander spurs that are rock-capped and are covered with floodplain gravels and sands. Probably the creek acquired its meandering course in a broad valley on the surface of the Valley peneplane, and, because of recent uplift, has been able both to entrench its meanders and dissect

---

1. Wright, Frank J., Physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, p. 32, 1925.

(See Pl. 26.)

the surface of The peneplane. The local valley-floor levels stand at elevations between 1,200 and 1,400 feet above sealevel; they are dissected by present drainage to depths ranging from 200 to 400 feet below the general valley floor. James River, for example, has a surface elevation of about 800 feet which is 300 to 400 feet below the valley through which it flows. (See Pl. 62,A and 63,A.)

The time of the formation of this peneplane is not definitely known, but it must have been subsequent to the Upland cycle. If, as is commonly supposed, the Upland peneplane was the result of Cretaceous erosion, it may be concluded that the Valley-floor peneplane was produced in, or immediately following, the Tertiary period. Formerly it was called the "Tertiary" peneplane.

It is possible, as recently stated by Wright[1], that two stages,

---

1. Wright, Frank J., The newer Appalachians of the South: Denison Univ. Bull., Jour. Sci. Lab., vol. 29, pp. 79-87, 1934.

---

of levels, of the Valley-floor peneplane are present between Buchanan and Natural Bridge Station. According to Wright, the two levels come together near Buchanan at an elevation of approximately 1,050 feet above tide, but diverge toward the northeast, the upper, western level rising in the direction of Plank Road, the lower, eastern, surface sloping down the valley of James River. Wright believes that the higher level was maintained and produced by tributaries of James River while the lower surface was being developed by the master stream. An escarpment of several hundred feet, now considerably dissected by recent erosion, separates the two levels and, according to Wright, is

responsible for some of the minor aspects of the local drainage.

An equally cogent interpretation of this escarpment is that it is a normal unsymmetrical divide between adjacent, but separate, portions of the same drainage basin, rather than a cliff between peneplanes.[2]

Intermediate Levels

Many of the local mountain summits stand conspicuously above the valley-floor levels but fail to reach the elevation of the upland surface. The crests of Price, Patterson, Switzer, Crawford, Mays, Back Creek, Panther, Brushy, and Pine mountains (Pl. 16B) are beveled at elevations ranging from 2,250 to 2,700 feet. There is a strong possibility that these summits represent a definite stage of erosion between the epochs of valley-floor peneplanation. Indeed, such a stage, called the "Intermediate" peneplane by Stose[1], and the "Buckeye" peneplane by Hubbard and Croneis[2], has been invoked in explaining the physiography of adjacent regions.

---

1. Stose, G. W., and Miser, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, p. 21, 1922.

2. Hubbard, G. G., and Croneis, C. G., Notes on the geology of Giles County, Virginia: Denison Univ. Bull., Jour. Sci. Lab., vol. 20, p. 313, 1924.

It is also possible that equal erosion on opposite sides of a ridge of inclined resistant rock would symmetrically lower its summit and produce an even profile that would simulate an erosion level. The occurrence, however, of many mountain summits at the same intermediate elevation tends to suggest that a partially complete peneplane was produced after the upland peneplane had been well dissected but before the final uplift which produced the valley-floor surfaces.

Short Hills, which rises conspicuously above the valley-floor level does not reach the upland surface. (See Pls. 6, B and 18, B.) It is a symmetrical synclinal structure whose southern portion is rimmed by almost horizontal Silurian sandstones. It is thought that the sandstones of this ridge failed to reach the original upland peneplane and were exposed in the early stages of subsequent erosion when they were sufficiently resistant to retain an elevation in the Great Valley not attained by areas of softer rock. (See also p. 240.)

Several other monadnocks rise from the floor of the valley lowland to elevations intermediate between the two major peneplanes. Big Hill stands prominently above the peneplaned region near Gala; Cedar, Timber, and Little Timber ridges are similar monadnocks between Eagle Rock and Pincastle. (See Fig. 2.) Each represents an area underlain by more resistant rock than in the adjoining territory.

A striking series of level surfaces is developed on the southeastern flank of Rich Patch Mountain, where Iron Knob, Deisher Mountain, and their southwestward continuations are truncated at an elevation of about 2,250 feet above sealevel. Although this series of levels strongly resembles an erosional plane, it is actually produced by the sloping arch of a long symmetrical anticline which plunges southwestward. (See Pl. 51.) The anticline is

one of the minor structures of the Rich Patch anticlinorium, and its crest is upheld by Keefer sandstones. Surfaces of this type are easily mistaken for true erosional levels.

Trenches below the Valley-floor Peneplanes

The local floor of the Great Valley stands between 1,200 and 1,400 feet above sealevel. Into its rolling surface, the present streams have etched their valleys and are well entrenched into the widespread erosion level. The formation of the Valley-floor peneplane was closed by an epoch of slight uplift which increased the gradients of all streams and caused them to renew downcutting. This incision is well displayed by Craig Creek and James River, the latter exhibiting a series of incised meanders nearly 400 feet below the valley level. (See Pl. 26.) Most of the entrenched streams flow in narrow valleys with small floodplains that are irregularly distributed along their course. Larger streams, such as James River, Craig, Catawba, and Buffalo creeks, possess terraces along their courses. Some of the terraces are the result of lateral planation by widening meanders of the stream. Many are cut in alluvial material or developed in former floodplain deposits. Others are benches resulting from slight land uplift and are developed directly in the bedrock. Terraces of the latter type have been described by Wright[1] as "rock-defended terraces." Most

1. Wright, Frank J., Physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, 1925. p. 40,

of the benches are covered with gravels (Pl. 46, A) and other floodplain deposits and cannot readily be correlated with ~~each other~~ one another.

SPECIAL PHYSIOGRAPHIC FEATURES

Natural Bridge

The most famous geologic and scenic feature within the limits of this area is Natural Bridge, one of the best-known and most commonly visited natural wonders in the eastern United States. Natural Bridge is located on Lee Highway, 14 miles southwest of Lexington and 39 miles northwest of Lynchburg. It is 39 miles northeast of Roanoke and 12 miles northeast of Buchanan. Virginia State Highway 249 intersects Lee Highway at Natural Bridge, which is 2 miles west of the Natural Bridge station of the Norfork and Western Railway and the Chesapeake and Ohio Railway.

Description

The bridge is a massive arch of limestone which spans the deep gorge of Cedar Creek. (See Pl.3, Frontispiece) Its upper surface is approximately 1,160 feet above sealevel; its under surface is about 145 feet above the level of the creek. The thickness of the arch is about 45 feet, and the bridge varies in width from 50 to 150 feet; it is approximately 90 feet long. It is estimated that the arch contains 450,000 cubic foot of solid rock, weighing approximately 36,000 tons. The bridge is situated on the slope of Mars Hill which rises 100 feet above the top of the bridge; the upper surface of the latter slopes toward the northeast. (See Pls. 22-23.) Lee Highway crosses Natural Bridge about one-third of the way to the top of a short steep hill. The road-bed has been cut down 10 feet into the solid rock of the arch; hence the bridge and adjacent gorge cannot be seen from the highway. The topography of the area adjacent to the bridge is shown on Figure 5.

History

Natural Bridge has been known for at least 200 years, for written mention of it was made as early as 1759. A survey of the bridge was made in 1750, and it is a common legend that this survey was made by George Washington. In 1774, a grant of 156 acres along Cedar Creek including Natural Bridge was made to Thomas Jefferson by King George III of England. Jefferson visited the property many times, and made a personal survey of the land and bridge in 1802.

An early visit to the bridge was made by the Marquis de Chastellux, a member of the French Academy, who traveled widely throughout the United States between 1780 and 1782. The Marquis, accompanied by other French officers, visited the bridge shortly after the surrender of Cornwallis at Yorktown, and at his suggestion, a survey and description of the bridge were made by Baron de Turpin and assistant engineers.[1] Jefferson[2] also wrote a brief description of the bridge.

1. de Chastellux, Marquis, Travels in North America in 1780 to 1782: Vol. 2, p. 418, 1787.

After Jefferson's death, the property passed into other hands, and

2. Jefferson, Thomas, Notes on the State of Virginia: Philadelphia, 1794.

the "Natural Bridge Estate," a tract of 1,500 acres, is now privately owned by Natural Bridge of Virginia Inc.

The name of Washington is commonly associated with Natural Bridge, but without adequate confirmation. He is reputed to have made the original survey of 1750 on the basis of which the Royal grant of land was made to Jefferson. At several places in the vicinity of the bridge, early surveyors' monuments have been discovered, one of which now carries the initials "G. W." A block of limestone with the same initials lies on the floor of the creek beneath the bridge. This block is described as having fallen from a high position on one of the abutments of the bridge, and it is a current report that Washington climbed the bridge to this point where he carved his initials. There is also the somewhat incredible legend that he once threw a stone over the bridge.

Although the present owners have materially added to the repair and upkeep of Natural Bridge, it is regretable that such a famous and accessible scenic feature is in private hands and is not the property of the Commonwealth. The bridge and surrounding territory would make an ideal State park, which if created, would allow the natural beauty of the locality to be more accessible than is possible under existing conditions.

Cedar Creek

Natural Bridge is located about 2 miles above the mouth of Cedar Creek which enters James River at Gilmore Mills. The length of the creek is about 11 miles and it drains 16 square miles of southern Rockbridge County. Cedar Creek rises in the synclinal valley at the top of Short Hills and flows northward east from its source for about 4 miles to a point where it breaks through the rim of Silurian sandstones to descend in a narrow and beautiful gorge to the level of the Great Valley. The middle portion of the creek crosses the main valley at right angles to the strike of the bed rock, and occupies a broad, open valley which is about 200 feet below the surface of the lowland. Near Red Mills, Cedar Creek enters a narrow, steep-sided valley which continues nearly to its mouth at Gilmore Mills. The canyon is vertically walled and for more than 3 miles, its floor is from 200 to 300 feet below the rim of the gorge. (See Pl. 19B.) There are many rapids and falls (Pl. 19A) as well as several caves and springs along the gorge. A small power dam has been erected a short distance below Natural Bridge. (See Pl. 65A.) The total fall of the creek is nearly 2,000 feet in an airline distance of 5½ miles from source to mouth. (See Fig. 6.) The creek falls 200 feet from Natural Bridge to James River, a drop of nearly 100 feet per mile.

In the vicinity of Natural Bridge the gorge contains many fine specimens of unusual trees, including witch hazels and arbor vitae. Usually, the latter occur as small bushes, but in the gorges of Cascade and Cedar creeks, there

are trees that attain heights of nearly 100 feet. The boles of two giant arbor vitae exceed 15 feet in circumference. Their age must approach, if not exceed, 1,000 years.

Geology

The arch of the bridge is composed of Chepultepec limestone and dolomite near the center of the broad, shallow Natural Bridge syncline. (See also pp. 240-241.) Outcrops of Ozarkian formations extend northward from Natural Bridge to Red Mills and southeastward for ~~one~~ mile downstream from the bridge. (See Fig. 7.) The rocks are substantially horizontal at the bridge where their regular stratification is visible in the walls of the gorge. (See Pl. 20.) A few small faults exist and many vertical joint-planes intersect the bedding. As a result of structural weaknesses, large blocks of limestone and dolomite have become detached from the walls of the canyon by frost action and other agents of weathering. Even the bridge itself suffers from such attack, but it will be many centuries before the results of this action will destroy the beauty of the bridge or impair the strength of its arch.

The bridge is located on the lower reaches of Cedar Creek at a point where the creek is deeply entrenched into the Valley-floor peneplane. The general level of the peneplane is from 1,250 to 1,350 feet above sealevel, and the floor of Cedar Creek at the bridge is some 400 feet below this general level.

Previous Theories of Origin

The origin of Natural Bridge has long been a problem of considerable interest. The first published explanation was made by Thomas Jefferson[1] in 1782, who suggested that the hill

1. Jefferson, Thomas, op. cit.

upon which Natural Bridge occurs was "cloven through its length by some great convulsions."

Gilmer[2], in 1818, determined the horizontal structure and calcareous nature of the nearby rocks[3], and wrote:

2. Gilmer, F. W., On the geological formation of the Natural Bridge of Virginia: Amer. Phil. Soc. Trans., vol. 1, pp. 187-92, 1818.

3. Both of these facts had been previously observed by Baron de Turpin in 1782, who wrote:

> "We see that these rocks being of a calcareous nature, excludes every idea (of a volcanic origin), which besides cannot be reconciled with the from of the bridge and its adjacent parts."

de Chastellux, op. cit., p. 418.

"The rock is soluble in water (sic.) * * * and is so soft as to yield not only to its chemical agency, but also to its mechanical attrition. Here, as in calcarious countries generally, there are frequent and large fissures in the earth, which are sometimes conduits for subterranean streams called 'sinking rivers' ***It is probable, then, that the water of Cedar Creek originally found a subterranean passage beneath the arch of the present bridge, then only the continuation of the transverse bridge of hills. The stream has gradually widened and developed this river to its present situation."

It was Gilmer's theory that a subsurface passageway ~~through the rock~~ was developed by a portion of Cedar Creek, which, for this section of its course, was a "sinking", or underground, stream. In time, the underground passage became enlarged both by solution and by corrasion, so that upon the collapse and removal of a large part of the roof of the channel, there was left only a small section which now bridges the original conduit or opening. Gilmer made no attempt to explain the former course of Cedar Creek across or around the ridge through which the underground channel was developed. He remarked upon the similar character of Natural Bridge and Natural Tunnel, Scott County, Virginia, and summarized his ~~remarks~~ conclusions with the general comment that the partial collapse of an underground cavern will produce a natural bridge.

In 1884, Ashburner,[1] noted the synclinal structure of the local rocks, ~~near the bridge,~~ and suggested a possible relation between this structure and the position of the arch. His explanation of the ~~origin of the~~ bridge is as follows:

---

1. Ashburner, C. A., Notes on the Natural Bridge of Virginia; Amer. Phil. Soc. Proc., No. 21, 1884, p. 699.

"The bridge is undoubtedly the remnant of the top of a cave which was probably formed long before the Luray Cavern, which is excavated out of the same limestone formation. The bridge seems to be located in the center of a gentle basin or syncline in the strata, which may account for the roof of the ancient cavern being left at this special point. The height of the bridge has evidently been much augmented by a lowering of the bed of Cedar Creek through the agency of chemical and mechanical erosion after the destruction of the original cavern. The height of the cavity at the point where the bridge now exists being, in consequence, very much less than the present height of ~~[illegible] of~~ the bridge arch."

In 1895, Charles D. Walcott[1] proposed ~~gave~~ another explanation

---

1. Walcott, Charles, D., ~~[illegible]~~. The Natural Bridge of Virginia: National Geog. Mag., Vol. 5, pp. 59-62, 1893.

~~for the origin~~ of Natural Bridge. He assumed a rejuvenation of the general region in which

"Cedar Creek was engaged for a considerable period in excavating the gorge from James River to a point not far below the present site of the bridge, where the fall appears to have existed, the summit of which was not far, if at all, below the present level of the top of the bridge. About this time the water found a subterranean passage in the limestone further up the stream than the present site of the bridge, and through this it flowed and discharged below the brink of the falls. The passage gradually enlarged until all the waters of the creek passed through it and the bridge began its existence. What the length of this subterranean passage was is a matter of conjecture; it may have been a hundred or several hundred feet. All of the roof has disappeared except the narrow span of the bridge, and the abutting walls have been worn back by erosion until the gorge or canyon is much wider than at the bridge."

According to Walcott's theory, the bridge is located at, or near, the site of a high waterfall on Cedar Creek, where the waters of the creek formerly passed over what is now the top of the bridge. Later, underground drainage seeped through the rocks below the crest of the falls, and was thus able to reach the lower portion of the stream without flowing over the waterfall. Continued use ~~which enlarged~~ of this lower channel ~~[illegible]~~ ultimately ~~[illegible]~~ prevented any water from passing over the original brink of the falls, which remained as ~~[illegible]~~ Natural Bridge. This theory readily explains many of the observed features at the bridge, and differs from Gilmer's theory, in

assuming the upper surface of the bridge to have been part of the original channel of Cedar Creek.

There are several objections to Walcott's hypothesis, one of which is the fact that the bridge is located along the side, and not upon the floor, of an earlier shallow valley. The surface of the bridge slopes strongly northeastward (Pl. 23) and the present gorge is unsymmetrically placed with respect to this former valley. There is no present evidence that any considerable body of water flowed on the surface of the bridge, for the arch is deeply weathered and its surface is overlain by a thick residual soil in which there is no trace of stream gravels.

Another ~~A third~~ hypothesis for the origin of Natural Bridge was proposed by Malott and Shrock[1], who assume the surface course of Cedar Creek to have been considerably altered in the vicinity of the bridge. There is a sharp bend in Cedar Creek about ~~one quarter~~ 1/4 mile above the bridge which is opposite a gap, or col, in the eastern wall of the canyon. Malott and Shrock suggest that Cedar Creek once flowed northeastward through this col into the valley now drained by Cascade Creek--a course which would take the stream completely around the deepest portion of the present gorge and also around the site of Natural Bridge. According to Malott and Shrock, underground water seeped along the nearly horizontal limestone strata from a point near the col to a point somewhat below the site of the bridge, a subterranean distance of possibly ~~one third of a~~ 1/3 mile. Continued use of this channel by a constantly increasing volume of water so enlarged the shorter route that it was ultimately adopted by the entire

1. Malott, C. A., and Shrock, R. R., Origin and development of Natural Bridge, Virginia: Amer. Jour. Sci., 5th ser., vol. 19, pp. 267-72, 1930.

volume of Cedar Creek, to form an underground cut-off across the bend of the stream. The collapse of most of the roof of this underground channel left only a short remnant, now the bridge.

This theory invokes a change in the position of Cedar Creek, and locates the early channel as a bank around the present site of the bridge. The underground drainage, by means of which the bridge was formed, is thought to be a direct cut-off across the bend beneath the hills around which the surface drainage formerly flowed. Thus, according to Malott and Wilson, at the time the Natural Bridge located in the floor of the valley of Cedar Creek, a waterfall occurred at this present site of the bridge. Although the authors of this theory compare it to Gilmer's much earlier hypothesis, it is probable that Gilmer had no such surface derangement of Cedar Creek in mind.

With several of the tenets of this hypothesis, it is necessary to disagree. The "soil," which is designated by Malott and Wilson as part of the ancient course of Cedar Creek around the meander spur, is found to be a relatively inconspicuous soil profile examined in the field. It is highly improbable that so shallow and small a deposit could ever have been part of the course of a stream possessing the volume of water which Cedar Creek must then have contained. Malott and Wilson have described "stream gravels and well-rounded cobbles of quartzitic sandstone which have very probably been derived from the Hasamatton sandstone" on the rim of the upland just north of the sharp "meander turn" of Cedar Creek. These gravels actually lie on the top of a slight spur which projects somewhat into the ancient valley now overdeepened by Cedar Creek.

they have exactly the position of high-level terrace debris. Similar material in analogous locations occurs on the opposite side of the present gorge. These gravels are not located in the supposed "col", nor do they demonstrate occupancy of the "col" by the stream which left them in their present position.

Malott and Shrock describe a gravelly soil in the floor of the so-called "col" at an elevation of approximately 1,190 feet above tide, and state that "in the road-cuts the soil is partly composed of gravels." When examined by the writer in 1932, the gravelly material was found to consist largely of residual chert derived from the underlying Ozarkian formations together with weathered masses of sandy material common to certain horizons of the Conococheague formation. Scarcely a single fragment of quartzite was observed, for the debris on the floor of the "col" is almost wholly of residual origin, a fact which cannot defend use of the "col" by Cedar Creek.

Present theory of Origin

Inasmuch as the course of Cedar Creek above Red Mills is entirely different in character from the portion of the creek below Red Mills, it is suggested that the stream is a hybrid, produced by the grafting of portions of two dissimilar and originally distinct drainage basins. The explanation is offered[1] that the

---

1. Woodward, H. P., Natural Bridge and Natural Tunnel, Virginia: Jour. Geology, vol. 44, pp. 604-616, 1936.

waters of present Cedar Creek above Red Mills were at one time tributary to Poague Run, a long eastward-flowing branch of North River. At that time, the lower valley of modern Cedar Creek below the bridge was occupied by a small active stream, the precursor of Cascade Creek. Then, Cascade Creek descended rapidly from the valley-floor peneplane to James River; now, it is a small tributary of present Cedar Creek which it joins immediately below the bridge. (See Pl. 21, B.) Before the formation of the bridge, however, the Poague Run basin and the drainage of Cascade Creek were separate and distinct. The present [illegible] near Natural Bridge is shown on Figure 8.

There are several points to support the interpretation that Poague Run once carried the upper drainage of present Cedar Creek. The col between the two basins now contains gravels of Silurian sandstone, a fact which indicates that it was once occupied by a stream which headed in Silurian rocks: Cedar Creek has such a source. The gradient of the modern branch of upper Cedar Creek valley, if projected across the col into the valley of Poague Run, shows no inconsistencies with the suggested interpretation that the two valleys were once a single basin. At present, the valleys are linear continuations of each other and are controlled by the same soft rock strata.

Prior to the development of Natural Bridge, Cascade Creek, kept active by its steep gradient, developed a youthful valley in which its headwaters, working northwestward, were considerably below the level of the elongated Poague Run. Although both streams had the same base-level (James River), Cascade Creek was scarcely 3 miles long, whereas the nearby waters of Poague Run were more

than 15 miles distant from James River. This difference in distance from base-level enabled the shorter stream to keep its incision more apace with that of the master stream than its longer rival. Inevitably, a situation arose in which, within a short lateral distance, two different portions of a river system were vying with each other for control of the same local drainage basin. It is suggested that there may have been a difference in elevation of as much as 200 feet between the upper tributary near the present location of Red Mills, and Cascade Creek near the site of Natural Bridge.

Given this sharp difference in elevation and a regional dip of the soluble limestones to the southeast, the headwaters of Roague Run had ample opportunity to seek and find a shorter descent to their local baselevel, James River. It is suggested that this descent took place underground, the water sinking into the limestones about 1/8 mile southeast of Red Mills and emerging into Cascade Creek a short distance below the present site of the bridge. Figure 9 shows the suggested drainage before the development of Natural Bridge.

Possibly this underground course had previously been utilized by drainage; probably it was a well developed line of weakness in the limestones, transversely crossing the Natural Bridge syncline. Evidences of underground drainage along this line occur in abundance. That a large opening was developed near the supposed entrance of the channel southeast of Red Mills is evinced by unmistakable cave deposits and fluted channels along the east bank of Cedar Creek. "Lost" River, (Pl. 21A), Saltpeter Cave[1], Isabella's

1. This cave is located near waterlevel of Cascade Creek, about 1 mile upstream from Natural Bridge. It should not be confused with a cave of the same name located on James River above Buchanan.

Staircase, and other cavernous openings exhibited to the visitor, lie along this line.

Diversion of the headwaters of Pogue Run into the drainage of Cascade Creek gave the latter a greatly increased volume which enabled it to incise its valley much faster than before. Probably this incision proceeded headward along the underground channel, while erosion and weathering began to uncover the roof of the tunnel. No doubt the latter process was already under way even before incision began. As the arch of the tunnel was thicker at its lower end, unroofing would proceed faster and with greater ease at the upper end. The combined effect of incision of the creek bed and weakening and collapse of the tunnel roof would tend to produce a canyon-like gorge, widest in those portions where the unroofing first occurred and narrowest in those portions where the roof remained intact. Disappearance of the remaining elements of the underground channel would leave the

span or Natural Bridge as the sole remaining portion of the original tunnel roof.

At the time when the waters of Pogue Run first began to escape through the underground passage into Cascade Creek, the latter was a comparatively small but active stream heading on the Valley-floor peneplane, and descending rapidly to James River. The additional volume from the captured stream enabled the lower portion of the creek to incise itself much faster than the portion above the point of capture. ~~Hence~~ Erosion of the floor of its former headwaters ~~would proceed~~ proceeded much slower than along the lower portion and the engrafted section. ~~In consequence~~ Gradually, the old headwaters ~~would gradually become~~ assumed a perched position with reference to the lower portion, and ~~would eventually become a~~ were reduced to the rôle of a small tributary discordant to the engrafted and invigorated master stream. Present Cascade Creek, formerly the main headwaters of original Cascade Creek, is now in such a ~~condition~~ condition, and enters Cedar Creek a short distance below Natural Bridge, descending by means of a waterfall from the old level of the original valley to the new level of the incised Cedar Creek. (See Fig. 10.)

For the reason that the underground channel from the upper drainage level entered Cascade Creek at an angle to its surface course, and as the tunnel was unroofed in a direction upstream from its original outlet, Natural Bridge now preserves on its upper surface a portion of the valley slope of the original Cascade Creek; this slope is readily seen from Pine Laden southeast of the bridge. (See Pls. 22 and 23) In view of the sloping surface and deeply weathered rocks of the bridge, it is improbable that any considerable

body of water ever flowed over the top of the bridge as postulated by Walcott.

The straight course of Cedar Creek from Red Mills to Saltpetre Cave is almost exactly at right angles to the strike of the underlying rocks and to the grain of the topography. It is assumed that this course is inherited from the underground conduit which, no doubt, transported the water from the upper level to Cascade Creek along the dip of the country rocks. Probably the sharp turn in Cedar Creek between Saltpetre Cave and Natural Bridge represents a shift from one underground channel to another, and is not a meander as postulated by Malott and Shrock. The position of Saltpetre Cave opposite the upstream course of the creek suggests that the cave may have been a continuation of the original conduit, abandoned when a more open, or lower, channel developed along what is now the present course of the creek. It is thought that the curves in Cedar Creek immediately downstream from Red Mills may represent the "angle of capture" enlarged and modified as a result of downstream recession of the entrance to the conduit, as well as by subsequent lateral erosion.

At the present time, Poague Run heads in a small branch about 3/4 ~~three quarters of a~~ mile north of Rural Valley School. The divide between Poague Run proper and its beheaded upper portion, southeast of the school, is now followed by the valley road, and there is evidence in the form of gravels and sand to show the former presence of a stream across the present divide.

It is possible before the headwaters of Poague Run became part of the drainage basin of Cascade Creek that the stream draining the synclinal valley at the top of Short Hills (now tributary to Cedar Creek) was then tributary to Broad Creek which flows into Buffalo Creek. It is logical to assume that after the capture which led to the formation of Natural Bridge, the invigorated and elongated pirate stream would work headward more rapidly than before, and that capture of the headwaters of an elongated Broad Creek could readily take place. That this diversion may have occurred is further suggested by the capture, already taking place, of the headwaters of the stream at the top of Short Hills by one of the active branches of Cedar Creek, the point of present capture being located in Spring Gap.

In accordance with the views herewith presented, Natural Bridge is the remnant of the roof of an underground channel which diverted the waters of the upper portion of Poague Run into Cascade Creek thereby forming present Cedar Creek. The addition of these waters to the volume of the creek enabled it more deeply to incise its course, while the roof of the former conduit largely disintegrated and collapsed through erosion and weathering. Little by little the obvious elements of the underground channel disappeared until, at the present time, only the span of Natural Bridge preserves a portion of the original roof.

Progressive diagrams in Figure 11 suggest the stages in the development of a natural bridge or tunnel in accordance with the theory outlined above.

The above interpretation of Natural Bridge was prepared in May 1932, after a careful study of the locality in the summer of 1931 and during March and early April, 1932. The manuscript was checked in the field during the summer of 1932, and in the following fall a report on the entire Natural Bridge quadrangle was prepared for publication. Publication of this report was delayed, and several years have elapsed between the ~~preparation~~ drafting of the original manuscript and its present publication.

In April 1934, Wright[1] published his excellent interpretation of the history of Natural Bridge, and the writer has subsequently discussed both theories with Doctor Wright. Although independently

---

1. Wright, F. J., The newer Appalachians of the South; Denison Univ. Bull., Jour. Sci. Lab., vol. 29, pp. 73-101, 1934.

---

arrived at, the two explanations of the origin of Natural Bridge are similar in almost all of their details.

Wright has postulated the local presence of two levels of the "Harrisburg" peneplane in the Natural Bridge region. It is his conclusion that "drainage--not any particular stream"[2] from the upper level was diverted into an active tributary of James River on the lower level, the tributary gnawing into the eastward-facing escarpment between the two erosion surfaces. He suggests that the point of diversion was in a belt of sinks just northwest of Natural Bridge, and that surface drainage on the upper "Harrisburg" level was gradually diverted underground, stream by stream, until the stem of Cedar Creek, leading from Short Hills, was eventually taken. In all other respects his interpretation is based upon the same hypotheses as those suggested above by the present writer, and the two theories of origin are but slightly varying statements of the same conclusion.

---

2. Personal communication, 1934.

The present writer and Doctor Wright are in complete agreement that the earlier theories for the origin of the bridge are untenable, and that the bridge has resulted from the subsurface capture of higher drainage by an active tributary of James River. In order to arrive at an interpretation of the actual mechanics of bridge origin, the two authors have invoked slightly variant stages of history, but even these difference become unessential in view of the general harmony of the main tenets. Both authors feel that the strong similarity of the two interpretations is a significant demonstration that the current theories of origin satisfy the available field evidence.

James River

James River (Pl.63,A), the master stream of this region, crosses the area in a general west-east direction. It rises in western Virginia and its two main branches merge at Covington to form Jackson River which is joined, near Lick Run, by Cowpasture River. From this point to its mouth the stream is called James River. The river cuts across the Appalachian ridges, the Great Valley, and the Blue Ridge almost at right angles to their strike, and in so doing has developed conspicuous water gaps at three points--Iron Gate, Eagle Rock, and Balcony Falls. The gorge of the river in each gap is narrow and steep-sided, and the river has succeeded in cutting through resistant rock of pre-Cambrian, Cambrian, and Silurian ages.

In its gap at Iron Gate, James (or Jackson) River cuts through the symmetrical Rich Patch anticline to display the spectacular "Rainbow Arch" of Silurian quartzite on either side of the gorge. (Pl.50,B and 52,B) (See p. 234.) At Eagle Rock, it cuts through a complexly folded anticline and syncline (Pl.57 and 58) which are separated by a fault that passes directly through the center of the gorge parallel to the strike of the mountain. (See pp. 263-268.) At Balcony Falls, James River bisects a broad ridge of steeply tilted Early Cambrian sandstones and resistant crystalline pre-Cambrian rocks.

After leaving its gap at Eagle Rock (Pl.24), James River flows southeastward in a meandering course across the strike of the Conococheague and Elbrook limestones to the end of Purgatory Mountain (Pl.13,A), whence it turns sharply northeastward and meanders along a belt of Shady and Rome ("Watauga") formations to a point near Glasgow, where it is joined by North River (See Pl.14.). Thence, it turns sharply to the southeast to pass through the Blue Ridge.

The course of James River is that of a maturely developed stream, and it shows wide, sweeping, regular meanders such as those normal to the floodplain of a mature stream (See Pl.26.). In the present area, however, the meanders are deeply incised from 200 to 500 feet below the general surface of the lowland. In each of the three water-gaps, the level of the water is more than 1,000 feet below the bisected ridges.

It is thought that the meandering course of James River was developed during the Cretaceous Period, when the surface of the entire region was a more or less level plane, sloping gently toward the ocean. This level plane was the "Cretaceous", or "Upland" peneplane whose production had been the result of long epochs of surface denudation (See pp.39-40.). The flat crests of many of the present ridges are now the only existing remnants of this original surface, for subsequent erosion has largely removed all trace of the Upland level.

Upon this comparatively level surface, James River flowed eastward in a broad, shallow valley across rocks of many different types. No doubt, the outcrops of harder rocks rose as low elevations above the level of this surface, but the general tenor of the peneplane was comparatively even. It is probable that James River crossed the site of its present water-gaps through low depressions in the few elevations that existed upon the surface of the peneplane.

It has been suggested[1] that part of this Cretaceous peneplane was then covered with coastal-plain deposits which sloped eastward below the surface of the ocean, and that the courses of the James and other large Appalachian streams may have been developed upon the soft, poorly consolidated floodplain materials. There are, however, too numerous objections to this hypothesis, to warrant its present consideration.

At, or near, the close of the Cretaceous period, the entire area underwent a gradual emergence or uplift. This change in elevation increased the slope and velocity of the streams so that they were able to entrench whatever valleys they had previously established. As the uplift progressed, the streams found themselves occupying successively lower positions with respect to the original peneplane surface. Their tributaries were rejuvenated, and a general surface-lowering of the entire area was initiated. As the softer rocks, which were most readily attacked, were reduced to lower levels than were the outcrops of the resistant rocks, the belts of harder rocks began to assume more and more elevation and the present Appalachian ridges began to appear in the topography.

---

1. Johnson, Douglas, Stream Sculpture on the Atlantic slope: Columbia University Press, New York, 1931.

James River, however, had already established a satisfactory course across the old peneplane surface. Although this original course crossed both soft and resistant rock belts, the river was able to cut down through the harder rocks as fast as the land was uplifted, a fact which enabled it to retain its original course. No doubt, in the course of its down-cutting, rapids or even falls developed on the resistant rock ledges; but, with abundant sand and boulders as tools and a constantly increasing angle of slope, the river was able to hold its own and cut downward apace with the uplift.

As the uplift of the land continued, the tributaries succeeded in lowering the outcrop of weaker rocks, while James River continued to saw through whatever barriers arose in its long-established channel. From a combination of these three processes, the three water-gaps developed. When the river first started its down-cutting, the mountains were insignificant hills, and the river stood at an elevation but slightly lower than their crests. As the land rose and the hills became etched into high relief, the river was able to maintain its former position, although its elevation was constantly becoming lower with respect to the summits of the ridges. The river did not find the gaps already made nor did it need to cut through mountainous ridges. It merely maintained an original position while the height of the mountains was being produced. Three stages in the formation of a watergap are shown on Figure 12.

Minor Physiographic Features

Stream Diversion or Capture

Many examples of diversion or capture of small streams occur in the region. Some of the diversions have already taken place, others are in progress, still others are imminent. A good example of stream capture now in progress has been noted by Wright[1] at Spring Gap

---

1. Wright, Frank J., Physiography of the upper James River basin in Virginia:

where an active tributary of Cedar Creek has reached and cut through the low rim of Short Hills. The headwaters of this stream now drain a swamp that is fed by a number of springs. Formerly the entire drainage of this swamp flowed northwestward into the upper portion of Cedar Creek. At present the waters of the swamp drain both into Cedar Creek and into the active tributary. Ultimately, the entire headwaters of Cedar Creek will probably find a more convenient route through Spring Gap and will flow into the tributary rather than along the more circuitous route of the main branch of the creek.

Stream capture on a small scale is also evident near Garsts Store, ~~four~~ 4 miles southwest of Buchanan, where Looney (Mill) Creek now flows northeastward to enter James River immediately south of Purgatory Mountain. At present it is joined by Back Creek; yet at no great time in the past, Looney Creek flowed northward into the valley now occupied by Long Run and met Back

Creek 2 miles farther downstream. An active tributary of Back Creek tapped the waters of Looney Creek and thus diverted it into its present course. The abandoned channel of Looney Creek leading from Garsts Store to Long Run is now occupied by a country road.

The headwaters of Rocky Run, which flows between Short Hills and The Knob (Pl. 18A), have reached a point within a few hundred yards of the headwaters of Purgatory Creek. Only a low divide near Dunkard Church separates the two drainage basins, and it is probable that this divide will soon be removed with continued erosion, in which event Purgatory Creek above Dunkard Church will become a part of the Rocky Run drainage. (See Fig. 13.)

A minor stream capture has occurred about 1 mile northeast of Springwood, where 2 small streams flowing westward from Purgatory Mountain converge near the road from Buchanan to Springwood. At the present time the waters of these creeks flow south and eastward to enter James River 1½ miles below Springwood. Formerly, however, they flowed northwestward to enter the stream which meets James River at Springwood, the abandoned course of this drainage now being occupied by a secondary road.

A similar small capture has occurred along the country road at a point where it crosses Lick Run, midway between Seceder Church and Murat. The road passes through a low narrow windgap, through which drainage formerly entered Broad Creek near the Plank Road. At the present time, however, this drainage has been diverted into Lick Run and now enters Broad Creek 1½ miles downstream. Big Hollow Branch flows northeastward behind a narrow ridge to enter James River two miles southwest of Gilmore Mills. The upper portion of this stream once followed a course which the country road now occupies, and reached James River at a point immediately opposite Gilmore Hollow.

At the southwestern end of North Mountain there are several small windgaps between Limestone Hollow and Mill Creek which reveal diversions of the drainage from Limestone Hollow. It is probable that each of these windgaps was once utilized by the creek which drains Limestone Hollow, and that the present course of the creek is of recent origin (See Fig. 14.) At the confluence of Moore Creek and North Fork of Buffalo Creek, there is evidence of a short diversion of the waters of Buffalo Creek. It is probable that Buffalo Creek formerly flowed along the valley now occupied by the county road, and was joined by Moore Creek at Oakdale. It is thought that its present course is that of an active tributary which tapped the main drainage of Buffalo Creek and diverted it away from the Oakdale channel as indicated in Figure 15.

The headwaters of Back Run are in imminent danger of being diverted into Arnold Valley. (See Pl. 8,A.) Tributaries of Elk Creek, both north and south of Cave Mountain, are working rapidly toward the drainage of Back Run. The elevation of the Elk Creek basin is about 200 feet lower than that of the adjacent portions of Back Run, and because of this local difference is elevation, capture will soon take place. Elevations only 50 feet high now separate the waters of Back Run from the drainage basin of Elk Creek. (See Fig. 16.)

A fine windgap, immediately south of Buchanan between Jones and Boyd Mountains[1] is locally known as "The Gorge"

---

1. Jones and Boyd Mountains lie southwest and northeast of this windgap respectively but are not named on the topographic map.

---

and is occupied at present by a small intermittent stream. (See Pl. 25.) It is evident that this gorge is the former course of a considerable body of water and probably represents the erosive work of Back Creek at a time when its elevation was considerably above the present level.

An excellent windgap in Sellings Mountain about 2½ miles east of Sherwood Post Office (Natural Bridge Station) is one of the best of its type in Virginia.[1] The floor of the gap, which is about 400 feet above the floodplain of James River, stands at the elevation of the valley-floor peneplane. Many large water-worn boulders are strewn over the floor of the gap; however, they are deeply weathered, a fact which indicates that the gap is not of recent formation.

1. Wright, Frank J., The Physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, pp. 53-4, 1925.

As the windgap is immediately opposite the course of James River through the Blue Ridge ex(See Pl. 14, A.), it is suggested that the gap was formed by James River at a time, early in the erosional history of the region, when the James flowed northeastward from the present site of Natural Bridge Station along the northwest foot of the southwestern half of Sellings Mountain. Then, the present valley of James River from Sherwood to Glascow was the linear continuation of Arnold Valley and was occupied only by ancestral Elk Creek. It is suggested that the southwestern end of Sellings Mountain separated the valleys of James and Elk rivers, and formed a continuous quartzite ridge with Mill Mountain.

The lateral erosion of James River against this narrow ridge would ultimately wear a channel through which the river could escape from its original course into the adjacent valley of Elk Creek which was developed upon weak Shady dolomite. The river, finding the new route shorter and more evenly graded than its former course, would adopt the more convenient channel and would become more and more entrenched as uplift continued. The original course of the James is suggested in Figure 17a. The present position and the abandoned windgap are shown in Figure 17b.

Such a hypothesis appears adequate to explain the Sallings Mountain windgap. Arnold Valley and that of the James from Sherwood to Glasgow are linear continuations of each other and appear to have been originally occupied by the same stream. Sallings and Mill mountains are formed by the same ledges of Erwin quartzite and appear once to have been a continuous ridge. The alignment of the Sallings and Balcony Falls gaps is explained by this theory and the size of the former gap--evincing the presence of a large stream--is more satisfactorily explained than by any other hypothesis.

Wright[1] has suggested an alternate theory in which he assumes

1. Wright, F. J., The Newer Appalachians of the South; Denison Univ. Bull., Jour. of Sci. Lab., vol. 29, 1934, pp. 96-107,

the Sallings Mountain gap to be the work of Cedar Creek at a time previous to the series of events leading to its capture and the formation of Natural Bridge. This is a plausible hypothesis, but one with which the present author does not agree. In the first place, he is unwilling to assign the wide and deep Sallings windgap to so small a stream as the ancestral Cedar Creek must have been. In the second place, he is unable to reconstruct the historical stages necessary to place Cedar Creek in the gap. Thirdly, he can not clearly see how all trace of the course assigned by Wright to Cedar Creek could have been so completely obliterated by subsequent erosion. In the fourth place, the mass of Sallings Mountain is definitely a part of the Blue Ridge, although now detatched from it by the valley of James River, and the windgap is, in his view, a continuation of the Balcony Falls gap. It seems to be more suggestive to assign the production of the two gaps to the

same river, than to call upon the James for one, and a small -- almost hypothetical--stream for the other. Finally, it is the author's impression that the hypothesis presented here agrees more fully with the observed data than does that of Wright. As in the case of the explanation of Natural Bridge, the throry presented by the writer was formed in 1931-2; that presented by Wright was published in 1934. The author has discussed both hypotheses with Doctor Wright through the medium of correspondence.

Evidence of several small stream captures can be found in the shale country between James River and Craig Creek north of Bessemer. From the observed topographic relations, it is thought that the headwaters of Black Lick have been partly captured by Skirkey Mill Branch, and that the head of Dutchman Branch has been cut off by Saville Branch. Just north of Gala, Mud Run and James River flow very close together and are separated by a low ridge scarcely 25 feet high through which the James may ultimately capture the smaller stream by intercision.

The valleys of Spreading and Blue Spring creeks are good examples of anticlines ~~which~~ That have been breached by erosion to form a lowland bounded by a ridge of harder rock ~~that~~ which formerly roofed the area. The wide triangular lowland between Pine Hills, Flatwoods School and Catawba Creek is a synclinal valley developed on a shallow mass of Athens shale infolded ~~on~~ upon Ordovician limestones. Big Hill is a symmetrical anticline in which ~~lower~~ early Devonian sandstones emerge through a cover of Middle and ~~Upper~~ late Devonian shales. Poplar Hill, southwest of Eagle Rock has a similar structure to that of Big Hill.

Craig Creek presents several ~~unusual~~ features of an entrenched meandering stream. (See Pl. 26, A.) It was a maturely developed stream occupying a shale valley between Patterson and Rich Patch Mountains when uplift terminated the Valley-floor cycle. Since then the stream has lowered its channel about 250 feet to form a fine series of entrenched meanders with well-developed undercut and slip-off slopes. Contrast between the two slopes has been emphasized, by vegetation, as most of the undercut slopes are wooded, whereas the slip-off slopes are largely cleared. Near Slash School, there is a crescent-shaped marsh which evidently represents the floor of an abandoned ~~entrenched~~ meander of Craig Creek. Craig Valley Branch of the Chesapeake and Ohio Railway and a country road occupy the notches at either end of the marsh. The marsh itself shows that the change in drainage has been recent.[1] (See Fig. 10.)

1. Wright, F. J., The physiography of the upper James River basin in Virginia: Virginia Geol. Survey Bull. 11, p.52, 1925.

Floodplains

James River has developed several fine floodplains along its course; ~~which~~ the largest and most conspicuous occurs at its confluence with the Looney-Back Creek drainage (Pl. 11), immediately west of Buchanan, where the floodplain of the two drainage systems occupies more than 2 square miles, and is ~~very~~ level, fertile, and well adapted ~~for~~ to agriculture. Other conspicuous flood plains occur along James River (1) from Glen Wilton to Bessemer (Pl. 26), (2) near Arcadia, and (3) for ~~two~~ 2 miles downstream from Rocky Point. Many small floodplains can be found along Craig Creek, especially near Oriskany and Cedar Grove School. Catawba Creek has a well-developed floodplain at Howell Mills, as well as at a point about ~~two~~ 2 miles below (north of) Fincastle.

It should be noted that most of these floodplains occur on the inside of meander curves of their streams, for a river erodes on the outside and deposits the removed material on the inner slopes

of the meanders. The floor of Arnold Valley (Pl. 8, A) holds a wide floodplain area developed by Elk Creek. A small floodplain occurs near the junction of North and South forks of Buffalo Creek.

Miscellaneous Features

There is abundant surface evidence of underground drainage in the form of sinks (Pl. 65B) and shallow depressions many of which are sufficiently extensive to be shown on the topographic map. The largest and most conspicuous belt of sinks lies between Eagle Rock and Saltpeter Cave, where several individual depressions, although comparatively shallow, are more than ½ mile in length. A nest of sinks occurs near Murat, and there is a large depression 1 miles south of Fancy Hill. The outcrop of Ordovician limestones in the Rapps Mill anticline is marked by a continuous line of small sinks or depressions which faithfully follows a belt of Holston and associated limestones.

Several good examples of subsequent streams occur in the region. A subsequent stream is one which has adjusted its course to the underlying rock structure, normally following an outcrop of weak rocks. In the lower portions of Rocky and Roaring runs, the creeks bend sharply from their general course to assume a strike parallel to that of the underlying rocks, having adjusted this portion of their channels to the outcrop of Ordovician limestones.

Mention should be made of the beautiful gorge of Bearwallow Creek southeast of Buchanan. The stream rises along the crest of the Blue Ridge and flows almost due north to enter James River near Buchanan. Its course is followed by the road leading from Buchanan to the Peaks of Otter (State Highway 43) along which a fine view of

the deep, steep-sided gorge may be obtained. In places the surface of the stream is more than 500 feet below the level of the road and 1,000 feet below the rim of its valley. (See Pl. 53, A.)

The most spectacular waterfall of the area is located on the headwaters of North Creek at a point where the creek plunges over a ledge of granodiorite with a direct fall of nearly 100 feet. The gorge of the creek is narrow and the falls have worn back a deep, circular recess along the foot-trail from Apple Orchard Camp to Jennings Creek. A trip to Apple Orchard Falls is well worth the hike from Jennings Creek, or from Hotel Mons; and it is unfortunate that the waterfall is inaccessible to the majority of visitors to the Natural Bridge region.

Short Hills (Pl. 6, B) and the two Camp mountains present unusually fine examples of synclinal mountains. Wide, level valleys, which nestle below the crests of both hills, surprise the visitor who ascends either of the mountains. Each ridge contains a perched lowland that stretches for some distance to the other rim of the mountain. Both synclinal valleys are now so densely overgrown with brush and small timber that travel through, or across, them is exceedingly difficult. Their drainage is so imperfect that large swampy areas exist on the summits of the mountains.

Rich Patch Valley, which is anticlinal in character, has been developed upon an arch, or up-fold, of limestone.

ROCKS OF THE NATURAL BRIDGE REGION

GENERAL STATEMENT

The bedrock formations of the Natural Bridge region may be grouped into four main classes: (1) Pre-Cambrian crystalline rocks, (2) Paleozoic consolidated sedimentary rocks, (3) Quaternary unconsolidated surficial deposits, and (4) igneous rocks of uncertain age. Figure 19 the geologic map, Plate 1, shows the areas of outcrop of each system of rocks, and, [illegible], shows the local distribution of many smaller units into which the larger groups may be divided.

Although the outcrop of crystalline rocks is restricted to the southeastern portion of the district, pre-Cambrian rocks underlie all other strata throughout the entire area and undoubtedly could be reached at any point by sufficiently deep wells. The greater portion of the surface of this region is occupied by the outcrop of Paleozoic sediments, over which Quaternary deposits are irregularly distributed. The igneous rocks of uncertain age form a small outcrop near Tory Hollow.

The section which immediately follows, dealing with crystalline rocks in the local Blue Ridge, was written by Dr. A. S. Eurcron. The remainder of the report is the work of the present writer.

PRE-CAMBRIAN ROCKS

(Note to Survey Editor:

Doctor Aurcron's description of the pre-Cambrian rocks should be introduced into the report at this point. I have not seen his manuscript, and am, therefore, unable to edit his headings, etc., to the form of this manuscript.

It is my understanding that his section is to constitute a separate unit, or chapter, carrying a by-line to indicate his authorship, as well as to differentiate it from the remainder of the report.

(Use Figure 20 here)

IGNEOUS ROCKS

GENERAL FEATURES

~~THE BLUE RIDGE REGION~~

The Blue Ridge Province:-

The Blue Ridge ~~trp~~ between northern and central Virginia is a distinct range of crystalline rocks. Although only about five miles wide in northern Virginia, the range is ten miles wide in this district, and 35 miles ~~wide~~ attains a width at the Carolina border. Secondary mountains occur in arkosic and quartzitic formations of Lower Cambrian age upon its western slopes which increase the width of ~~this~~ the province. The mountain range is also flanked on its eastern side by high peaks in granodiorite and granite which increase in number and height from northern to central virginia. In southwest Virginia the Blue Ridge province widens out into a high plateau ~~surface~~ with an elevation of 2500-3000 feet which ~~is~~ surface corresponds to the higher parts of the range ~~in~~ to the north.

Between northern and central Virginia, the rocks of this province consist for the most part of massive pre*Cambrian lava flows and intrusives of granodiorite and granite. These rocks lying between the softer and much metamorphosed older schists and gneisses of the central belt of the state, and the soft Paleozoic shales and limestones of the Newer Appalachian mountain province, have produced a distinct ridge-like highland.

North of the area of this quadrangle narrow belts of arkose and phyllite of probable Lower Cambrian age outcrop locally upon the flanks and crest of the range, but none have been found in such positions upon this quadrangle.

This great linear-shaped batholith of granodiorite, which is accompanied by a mica-free perthitic granite, is found over the total length of the area.

1. This great linear-shaped batholith of granodiorite, which is accompanied by a mica-free perthitic granite, is found over the total length of the area.

IGNEOUS ROCKS

GENERAL FEATURES

Location and accessibility.--Igneous rocks are exposed at the surface in Parts of the three ~~the~~ southeast ~~quarter~~ rectangles of the Natural Bridge Special quadrangle. The crest of the Blue Ridge strikes through the southeastern corner of the map so that ~~most of~~ most of the igneous rocks crop out upon the western slopes of the mountain. The region may be entered by car via Arnold Valley and Indian Rock. Very good soil and gravel roads run several miles up the valley of Middle River, and North Creek, and these roads are connected with Arnold Valley by a soil road over Big Hill Ridge. The western slopes of the mountain are accessible only by foot trails. The Appalachian Trail follows the crest of the Blue Ridge through the southeastern part of the quadrangle.

General character of the rocks.--The rocks of this portion of the Blue Ridge closely resemble these found to the northeast in this province. They are in general massive, and have been but little affected by dyhamometamorphism. All the intrusives are well jointed. These igneous rocks belong to ~~two~~ several different periods of pre-Cambrian vulcanism.

The oldest rock is a meta-basalt which is often an epidote-greenstone. It consists of flows with possibly some intrusive sills. Erosion had removed most of this rock by the close of pre-Cambrian times. It is believed that those volcanics belong to the Catoctin greenstone series which is so widespread in the Blue Ridge north of Central Virginia.

Into the Catoctin greenstone was intruded in later pre-Cambrian times a batholith of granodiorite. Immediately following the intrusion of the granodiorite came dikes and larger linear bodies of blue quartz granite.

Reactions of the granodiorite and granite with the basalt flows developed red and pink hybrid rocks here called unakite and pink epidote-bearing granite.

CATOCTIN GREENSTONE

Distribution.--Bodies of altered basaltic rock occur along the western edge of the area of crystalline rocks, where they separate the intrusive granodiorite and granite from basal Cambrian sediments. These areas of volcanic rock are non continuous, and are belt-like in form of outcrop. There are at least five separate occurrences of this rock upon the quadrangle. The volcanic rock was evidently widespread over the surface of the intrusives before the last great pre-Cambrian erosion period.

Megascopic character.--The volcanics vary in color from nearly black to dark green, the latter variety carrying considerable epidote. Near granite contacts the rock is sometimes reddish brown in color, but may be readily distinguished from chilled granite of the same color by use of the hand lens. The rock is dense, massive and very fine grained. It may be amygdaloidal. Columnar jointing sometimes occurs in the massive, nonamygdaloidal variety (fig. 1). Usually no original minerals may be distinguished in hand specimens. Specimens north of Cave mountain contain numerous rods of altered plagioclase in a fine, aphanitic matrix. Patches of red jasper are common in the basalt on North Creek. Several cracks in the basalt are often filled with white calcite. Epidote, calcite, jasper or chalcedony may serve as amygdiloidal fillings, although they are not prominent in the greenstones of this district. Near granite, the greenstone is sometimes traversed by thin dike-like bands of red iron oxide.

Geologic age.--A pre-Cambrian age must be ascribed to this rock north of Cave Mountain, since it is definately intruded by pre-Cambrian granite. In the peculiar occurrences at the crystalline boundary on North Creek and on Chestnut Ridge, basalt appears to have been intimately intruded and assimilated by granite, and a similar age should be ascribed to those occurrences. The narrow body of slaty, amygdaloidal meta-basalt which crosses the North Creek road about one and eight-tenths miles by road east of Arcadia might be interpreted as a lower Cambrian flow within the lower beds of the Unicoi. There is, however, a basal conglomerate which consists of granite and greenstone fragments directly against it on the east side. Moreover this volcanic may be traced into the pre-Cambrian greenstone of the crystalline border above North Creek. It seems more likely to the writer, that in spite of the narrowness of the outcrop, this greenstone belongs to the pre-Cambrian floor and is brought up here in a sharp anticline, or possibly by faulting.

The peculiar occurrences upon North Creek about a mile east of Arcadia[1] is associated with granite as well as with Unicoi sediments which show large scale cross-bedding. These sediments are sometimes fine grained and red. They are not to be confused with rhyolite which they superficially resemble. The red facies of the sediment is interlayered with typical arkose beds.

There is no reason why lower Cambrian flows may not have occurred in this district since they have been discovered in other sections of the Blue Ridge region. But on the whole, the burden of evidence favors a pre-Cambrian age for the volcanics so far to be discovered on this quadrangle. They do not resemble Cambrian volcanics which occur at and near the base of the Unicoi further north in the Shenandoah National Park area. A different interpretation of these rocks near Natural Bridge has been suggested by Holden[1]

---

[1] Holden, Roy J., Algonkian formation in the Blue Ridge, Virginia (abstract):

Geol.Soc.America Bull., Vol 43, 1932, pp. 141-42.

HYPERSTHENE GRANODIORITE

Distribution.--This rock composes the main mass of the Blue Ridge in this district. It is one of the most important rocks in the middle and northern Blue Ridge of Virginia where it has been described by several writers.[1]

---

[1] Watson, T.L. and Caine, J.H., Hypersthene Syenite and related rocks of the Blue Ridge region, Virginia: Geol. Soc. Amer. Bull., Vol. 27, 1916, pp. 193-234.

Furcron, A.S., Igneous rocks of the Shenandoah National park area; Jour. Geol., Vol. 42, 1934, pp. 400-410.

Jonas, Anna I., Hypersthene granodiorite in Virginia; Bull Geol. Soc. Amer., Vol. 46, 1935, pp. 47-60.

Furcron, A.S. and Woodward, H.P., Geology and mineral resources of the Stony Man quadrangle: manuscript in the files of the Virginia Geological Survey.

Granodiorite crops out over most of the crystalline area of the quadrangle. The region mapped as granodiorite contains many granite intrusives which can not be separated from it on the map.

Megascopic character.--The rock of this section is typical of that occurring elsewhere in the Blue Ridge. It is sometimes medium fine grained but usually coarse. It is a dark gray rock. Feldspars are dark gray or greenish gray in color, sometimes showing polysynthetic twinning. Quartz is a common constituent, sometimes abundant. It is blue, milky or smoky in color. Hornblende, pyroxene or biotite occur in most hand specimens, generally sparingly. On outcrops the rock frequently has a striped appearance due to layers of less basic and often typically granitic composition. This effect is much enhanced by weathering and is less distinct upon freshly broken surfaces. It is not due to ~~pressure metamorphism~~ regional metamorphism, but to the injection of granitic lava shortly after the granodiorite, probably before that rock

was consolidated. Boundaries between these two types are usually indistinct. Distinct, dike-like bodies of granite are common in the granodiorite.

Granodiorite weathers into large round boulders. The outer oxidized and hydrated crust of weathered rock is usually porus and full of irregular shaped cavities formed by the decomposition of feldspar. Black magnetite sands accumulate in road gulleys. The final product of weathering is a red, sandy clay soil.

Microscopic character.--

Geologic age.--Geologists who have worked in the Virginia Blue Ridge agree upon a pre-Cambrian age for this rock.[1] Lower Cambrian sediments which contain recognizable fragments of granodiorite rest unconformably upon its eroded surface. There is disagreement concerning its relation to the Catoctin flows. The writer believes that the granodiorite is younger than the Catoctin greenstone. The granite which is so closely associated with the granodiorite, definately intrudes the flows in this district. Granodiorite intrudes the Catoctin rocks further north in the Shenandoah National Park region.[2]

[1] Op. cit., Watson and Cline, Jonas, Furcron.

[2] Furcron, A.S., op. cit., pp. 404-5

OLD RAG GRANITE

Distribution.--This rock was named from the region of Old Rag Mountain upon the Stony Man quadrangle in the Shenandoah National Park area.[1]

[1] Furcron A.S., op. cit., pp. 406-7

This granite is abundant in the Blue Ridge province and there its distribution is coextensive with that of the hypersthene granodiorite. It is formed in large and small bodies where it intrudes the granodiorite. It is intimitely associated with granodiorite and often can not be separated from this rock upon the geologic map. Two bodies of granite crop out on the western flank of the Blue Ridge upon this quadrangle. A small occurrence is found in the Sugarland near the crest of the ridge. A large occurrence lies at the headwaters of north

Creek, striking northeast through the southeastern part of the quadrangle. Many narrow dike-like bodies of granite occur in granodiorite. These may be observed to good advantage on Middle Creek between Chestnut and Bryant ridges.

Megascopic character.--Where typically developed the rock is a light gray, mica-free granite. It is generally much finer grained than granodiorite, where it occurs in dikes and narrow bodies. It is composed almost entirely of light gray feldspar and quartz. The feldspar is sometimes pink, and the quartz may be blue, purple, milky or smoky in color. Small, red garnets are at times scattered sparingly throughout hand specimens. The quartz is often evenly distributed throughout the mass, but frequently it shows a tendency to occur in thin, discontinuous bands. Some facies of this rock [redacted] grade into granodiorite in texture and mineral composition.

Geologic age.--This rock is of pre-Cambrian age. It is the youngest intrusive in this region where it intrudes catoctin greenstone and granodiorite. The basal Unicoi beds contain recognizable pebbles of the granite. These beds are generally deposited over the eroded surface of the granite and granodiorite.

UNAKITE AND PINK GRANITE

Distribution.--A border zone of unakite and pink granite lies between the granodiorite-Old Rag granite complex and the Catoctin greenstone. Although it is true that much of the greenstone has been removed by erosion, nevertheless this relationship is striking and significant. This zone is not separated from the other intrusives by definite contact. It is merely a zone within which certain changes have taken place in granite and granodiorite which have caused the development of pink feldspar and more or less epidote. The zone varies greatly in width. It is generally less than a quarter of a mile wide in the region of Thomas Mountain, but along North Creek, Middle River and McFalls Creek, it will average at least a mile and a quarter in width. Not all of the rock of this belt shows this type of alteration. Alteration is developed locally, although quite generally in the belt so mapped. It is more noticable at or near the western margin of the belt.

Megascopic character.--These rocks are granitic and dioritic in general character. Feldspars are pink or red; quartz is the normal color, but sometimes stained red. Epidote occurs in disseminated grains or replaces feldspars or other minerals. Sometimes it occurs in narrow veins and stringers through the rock.

Two general types may be recognized, viz. the granodiorite type and the granite type. The latter is common in this region. In the first case there may be all gradations from normal granodiorite to a rock of similar coarseness in which feldspars are pink or partly altered to epidote. The granitic variety varies from typical Old Rag granite to a red feldspar rock with much epidote. The granitic type may be fine grained and dark red at contact with

greenstone, or may be coarse grained with much epidote, where it occurs as a definite intrusion in granodiorite or as a zone in other unaffected granite. The latter type resembles a pegmatite in texture and composition and is probably produced from the coarser, ductile, intrusive Old Rag granite.

Medium grained to coarse pink, epidote-bearing granite of the latter type is well developed northwest of the head of Gilmore Hollow. Good exposures occur along an old road on the ridge top north of Hoopole Gap upon the Moore place, and also along the road between the head of the hollow and Back Run. The granite ranges between typical blue-quartz granite to the pink epidotic variety. ~~The latter type occur in the former~~. The rock constituents, a fine epidotic granite, are salmon-pink feldspar, milky quartz and much epidote in stringers and desseminated grains.

Red and pink granite is abundant along North Creek and in the region to the south of this stream. Where it is intruded into Catoctin greenstone, it is fine grained and dark red in color. The colored granite of this quadrangle, in general, carries less epidote than it does in other parts of the Blue Ridge to the north.

A narrow band of partly altered granodiorite and granite occurs along the western border of the crystallines between Drummond Hill and North Creek. This rock is coarse-grained with often nearly all bluish quartz and epidote. Specimens of this type may be seen along the trail at the gap in Thomas Mountain.

Origin.--This rock was produced at the time the granodiorite and Old Rag granite were intruded, and it represents in a general sense, a contact zone between greenstone and the intrusives. The granodiorite was less affected by these changes than were the more active granite solutions, for there is very little true unakite in the district.[1] This rock is found locally throughout the area of the southern Blue Ridge most in districts where granodiorite and granite intrude the older greenstone.

[1] The term "unakite" is here restricted to the altered granodioritic facies.

At the greenstone contact the granite is usually fine grained and dark red in color. Such an occurrence has been described on North Creek. The rocks tend to loose color and assume their normal character towards the western side of the belt.

It is not possible to establish a definite species of rock from specimens collected in this zone. All specimens noted appear to be either modifications of the granodiorite or the Old Rag Granite type. The red color is due to inclusions of red iron oxide which may be scattered uniformly through the feldspar or may form red films about quartz grains. It also fills or replaces the rock along fractures, and sometimes a normal granite is pink or red in the vicinity of these filled fractures. Near greenstone contacts, stripes of red oxide sometimes run through granite and granodiorite but only rarely through the greenstone. That the pink and red granite is merely a facies of Old Rag granite may be seen by a study of occurrences about a mile east of Munford on an old road between Lone Field Hill and Southside Ridge. Here typical coarse blue quartz granite of pegmatitic character occurs. The feldspar is locally white or pink.

Geologic age.--Fine grained pink and greenish granite rock with scattered epidote grains intrudes Catoctin greenstone at the northwest end of Cave Mountain. At this point a small opening was made in greenstone and granite about 20 years ago upon the property of Booker Austin. The excavation is in the north bank of Black Run. These stringers and narrow dikes of granite, accompanied with some pyritization, occur in massive greenstone. The granite tends to assimilate greenstone in such a manner as to produce a dark greenish granitic rock with red feldspar which is clearly of an hybrid character. All types from dark greenstone, through hybrid rock to fine grained pink granite, occur here.

It is probable that the peculiar occurrence of granite with greenstone at the pre-Cambrian-Cambrian contact on North Creek was produced by the intrusion of granite into greenstone. Although clearly younger than the Catoctin greenstone, the red granite and unakite is certainly pre-Cambrian in age. It serves as a floor for the deposition of the first Unicoi sediments in this region. Sometimes the basal beds are composed of so completely younger red granite fragments that it is difficult to distinguish between the granite and the sediment, in such localities.

UNAKITE AND PINK GRANITE

Distribution.---A border zone of unakite and pink granite lies between the granodiorite-Old Rag granite complex and the Catoctin greenstone. Although it is true that much of the greenstone has been removed by erosion, this relationship is striking and significant. This zone is not separated from the other intrusives by definite contact. It is a zone within which certain changes have taken place in granite and granodiorite which have caused the development of pink feldspar and more or less epidote. The zone varies greatly in width. It is generally less than a quarter of a mile wide in the region of Thomas Mountain but along North Creek, Middle River and McFalls Creek, it will average at least a mile and a quarter in width. Not all of the rock of this

SUMMARY OF PRE-CAMBRIAN EVENTS

The oldest recorded event of this section is the extrusion of basalt flows. Some of these rocks show columnar jointing and thus may partake of the character of sills. It is probable that these flows were once thick and widespread in this part of the Blue Ridge.

Into the flows in later pre-Cambrian time a batholith of granodiorite was intruded. The granodiorite was closely followed by a granite differentiate of the same magma. These rocks assimilated greenstone, where contact facies were developed resulting in the production of unakite and pink epidote-bearing granite. The more active granite solutions were most productive of these chages.

A profound period of erosion later removed much of the volcanic rock in this section so that Lower Cambrian seas advanced over a surface which consisted mostly of granodiorite and granite. The basal beds of the Unicoi are composed largely of fragments of these rocks.

ECONOMIC RESOURCES.

Stone for general contruction and road building may be obtained in many parts of the region of crystalline rocks. This region however is not favorably located, so that the crystalline rocks can not compete with better and more easilly quarried limestones of the James River Valley. No outcrops of commercially valuable unakite or pink granite were discovered during the course of the work because the rock changes character rapidly and lacks uniformity in color and composition.

Soils and Agriculture

Southeast of James River the land is mostly in forest. Few people live in this section and the land in general is not adapted to agriculture. The principle forest trees of the mountains are Scarlet Oak, Chestnut Oak, white Oak, Pitch Pine, Spruce Pine, Blackjack Oak, Poplar, and Hickory. Chestnut, formerly abundant, has been killed by a blight. Beech, Lin, and White Pine occur on deeper soils in protected localities. The forests are now in the hands of the Forest Service and are well protected against fires. There is less variety to the soils of the mountain sections of the quadrangle. Over the crystalline rocks of the southeastern section, occur the Muskingum stony fine sandy loam, generally of the steep phase, Porter's stony loam, Porters loam, Allen stony fine sandy loam and the Pope stony loam.

1/ Jurney, R.C., Delereux, R.E., and Sheelkum, Ewards, Soil Survey of Rockbridge County, Virginia: U.S. Dept. of Agriculture, Bur. of Chem. and Soils, No.4, Ser. 1931.

The steep phase of the Porter's stony loam occurs on the top and along flanks of Blue Ridge in the extreme southeastern part of the map. Here there is five to eight inches of surface soil consisting of brown loam with 18 to 20 inches of clay subsoil. This land is forested with oak, and is unsuited for agriculture.

The mountains immediately south east of James River are covered with the steep phase of the Muskingham stony fine sandy loam. This soil is thin, poor and rocky; slopes are steep.

The best soils are in Arnold Valley, and Jennings Creek valley between Cove mountain and Floyd Mountain. Arnold Valley is covered with the Pope stony loam. This soil is partly alluvial and partly wash from the mountains.

The surface soil is reported as brown loam 8 to 12 inches thick with fairly

deep friable and silty clay loam.

Considerable land has been cleared in Jennings Creek valley up to a level of about 1500 feet which marks the position of an old dissected erosion surface. This is the only well inhabited section of the crystallin area, being outside of the National forest area.

PALEOZOIC SEDIMENTS

General Statement

Every Paleozoic rock system, except the Pennsylvanian and Permian, is locally represented, and it is probable that the missing systems were once present but have been eroded away. Except in the Blue Ridge, Paleozoic sediments form the familiar bedrock immediately below the soil. They rest unconformably upon the much older pre-Cambrian terranes with a basal contact that is especially interesting to the geologist, for it marks a change in geologic and geographic conditions that might be compared to the historical change from ancient to medieval times. In the Natural Bridge region, additional interest is aroused by the presence, near this contact, of rocks of volcanic origin.

It is possible to separate the Paleozoic rocks into 36 distinct units, or formations, which are recognized as sequences of similar strata possessing uniform lithologic characters and containing distinctive fossil faunas. Each of the local formations is described in the following pages which are designed to form an explanatory text to accompany the geologic map. The various sedimentary members of the bedrock are classified in Table 1 in the chronological order of their deposition, and Table 2 shows their ~~sequence~~, thickness, and ~~correlation~~ distribution in various portions of ~~the rocks of other areas~~ the area.

Cambrian System

Cambrian rocks comprise the oldest Paleozoic sediments exposed in the Natural Bridge district; their outcrop is restricted to the southern and eastern portions of the region as indicated on Figure 21. Only one Cambrian formation, the Elbrook limestone, occupies any conspicuous area north of James River.

The Cambrian system is readily separable into two distinct units--an older arenaceous group, and a younger essentially calcareous group. The Chilhowie group, or older series, crops out along the northwestern face of the Blue Ridge where resistant quartzites add rugged foot-hills to the pre-Cambrian belt. (See Pl. 25A.) The upper or calcareous series crops out along James River which has entrenched its meanders upon the softer members of this group. Cambrian rocks rest unconformably upon the underlying crystalline basement with every evidence that a considerable period of disturbance and erosion immediately preceded their formation. At most points, the basal Cambrian beds contain boulders and other residual debris (Pl. 27A) derived from the weathering and erosion of the basement complex. In some localities an altered lava flow is present in the earliest Cambrian sediments.

By many authors, the Conococheague and Chepultepec formations, herein described as Ozarkian, are considered to be of late Cambrian age: the present author is following the custom of the Virginia Geological Survey in assigning them to the Ozarkian system. (See pp. 107a-107b.)

The total thickness of Cambrian rocks (exclusive of the Ozarkian formations) is more than 7,500 feet, and may reach 8,500 feet.

Arenaceous Division; Chilhowie Group

The Chilhowie group includes the arenaceous division of the Cambrian system of Virginia. Its three members--the Unicoi formation, Hampton shale, and Erwin quartzite--reach a total thickness of about 4,200 feet. The name Chilhowie, derived from Chilhowie Mountain, Tennessee, may be conveniently used for the entire early Cambrian sequence of clastic rocks.[1]

---

1. Woodward, H. P., Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, p. 28, 1932.

Unicoi Formation

The Unicoi formation, named in 1899 from Unicoi County, Tennessee[1], is the oldest Paleozoic unit of the area.

---

1. Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), map, 1899.

Character.--This formation is a thick body of sedimentary rock which, although prevailingly arenaceous, includes almost all varieties of sediments with the exception of calcareous material. Its greater portion consists of alternately bedded gray-brown sandstones and shales that occur in layers averaging 4 inches in thickness. Many thicker ledges are scattered through the formation. Two of these are prominent ridge-making beds of white or gray quartzite that occur about 1,000 feet apart near the middle of the formation. They are prominent in the topography and form the crests of Unicoi ridges. (See Pl. 53, A.) One of them marks the location of the Virginia Public Service Company dam along James River near Balcony Falls. The base of the formation is formed by a heather-colored pebbly sandstone that is commonly arkosic and strongly weathered. At Balcony Falls, the basal conglomerate is very coarse and contains large angular weathered fragments of the underlying crystalline rocks. (See Pl. 27A.) A massive bed forms the top of the formation immediately below the Hampton shale. (See Pl. 27, B.)

The Unicoi formation contains several zones of shales that closely resemble the shales of the overlying Hampton formation; some of these shaly zones reach 100 feet in thickness. Although most of the Unicoi is dark-colored, it becomes tan, or light brown, upon weathered surfaces. The formation disintegrates slowly, but decays much more readily than the Erwin quartzite which is more quartzitic and less distinctly stratified. Rock debris from the disintegration of the Unicoi is seldom rounded even after considerable transportation.

Distribution.--The Unicoi formation crops out in a continuous belt between ~~one~~ 1 and ~~two~~ 2 miles wide from Glasgow southwestward to Fullhardt Knob, near Cloverdale. Its outcrop is immediately northwest of the pre-Cambrian belt and is southeast of the Hampton and Erwin outcrops. The formation is well exposed along Jennings and McFalls creeks, in Bearwallow Hollow (Pl.53,A), and along Sprouts Run and Back Run, all of which cross, or cut through, a continuous Unicoi ridge known as Cove, or Pine, Mountain. In Arnold Valley, the outcrop is truncated by faults which offset its linear continuation.

The width of Unicoi outcrop has been increased by faulting in the Cove Mountain belt; elsewhere, the rocks are tilted but not steeply folded. (See Pl.48,A.) The formation has been slightly altered during its consolidation, with a resulting recrystallization of the quartz and development of secondary mica. One of the distinctive features of its more massive sandstones is a spheroidal weathering that is not conspicuous in any other local formation. This peculiar weathering is prominent along United States Highway 501 near Balcony Falls.

Basal Contact.--Normally the Unicoi formation rests directly upon granites, gneisses, or greenstones of pre-Cambrian age. At several localities, however, a thin series of volcanic rocks and arkosic sediments intervenes between the crystalline terranes and beds readily

assignable to the Unicoi.[1]

---

1. The local occurrence of such a series was described in an abstract prepared by Dr. R. J. Holden and presented by Dr. Arthur Bevan, State Geologist of Virginia, at the Tulsa (1931) meeting of the Geological Society of America.

A short distance east of the crest of the Blue Ridge, along the Laurel Run road ~~five~~ 5 miles south of Buchanan, pre-Cambrian granite is overlain by 34 feet of coarse crumbly sandstone, which is followed by a covered interval of 345 feet in which a few isolated ledges of sandy material are visible. (Section 1.)* This interval is followed by finely laminated blue-gray rhyolitic beds that are strongly altered and metamorphosed. The volcanics are overlain by massive gray-brown pebbly sandstones of the lower Unicoi formation. A similar sequence was examined along State Highway 43 near Powell Gap.

Red granite forms large ledges in the creek near the fire warden's house on the road leading up Jennings Creek toward Munford Post Office. The granite is overlain by a medium-grained, reddish, arkosic conglomerate that is not visible along the creek but is exposed in the cliff southwest of the road. (Section 2.) The conglomerate is 78 feet thick and is overlain by 170 feet of altered

---

* Detailed descriptions of a number of measured sections in the Natural Bridge region are found on pages 192-218. These sections, which represent itemized measurements of various selected exposures, are listed in true stratigraphic, or chronologic, order, with the uppermost, or latest, beds at the top, and the lowermost, or oldest, units at the bottom.

---

volcanic material, the lower part of which is highly crumpled and mashed. Above the volcanic rock is a gray-brown, pebbly sandstone (lower Unicoi) which is visible along the creek. About 1 mile due north, along the road following Middle Creek, there is a similar sequence containing 125 feet of altered volcanic material below the Unicoi and above conglomeratic beds that crop out through an interval of 150 feet directly above pre-Cambrian granites.

One and one-quarter miles directly north of the exposure on Middle Creek is a bridge over North Creek beneath which the lower Unicoi sandstones lie upon rhyolitic material that rests upon a massive bed of dark, blocky basalt. The latter weathers to a brown color, and forms a strong ledge in the hill-slope. A 6-foot zone of brown, pebbly sandstone underlies the basalt and overlies a zone of purplish "paper-shales" having strong, slaty cleavage. The shales rest upon pink, arkosic sandstone and conglomerate. The clastic series, which is 70 feet thick, is strongly cross-bedded, and contains a distinct local unconformity. Beneath the clastic beds are (1) a 13-foot zone in which red, unaltered rhyolite is interbedded with coarse sediments, and (2) a lower horizon containing 83 feet of pink, arkosic conglomerate that rests upon red pre-Cambrian granite. One mile east of this locality, the pebbly Unicoi sandstone overlies 15 feet of strongly amygdaloidal greenstone. Below the greenstone is a covered interval of 88 feet, in which a few ledges of greenstone are visible. Stratigraphically beneath this covered zone is an outcrop of massive black basalt. Fifty feet below the basalt are pink, arkosic, pebbly sandstones and, beyond a covered interval, pre-Cambrian granites.

About 12 miles northeast of the North Creek exposure, at a point along U. S. Highway 501 near Snowden on James River, there is a somewhat similar sequence. (Section 4.), Gray-brown pebbly Unicoi sandstones overlie a 30-foot covered interval in which a few scattered exposures of greenstone occur. Stratigraphically below this horizon is a mass of reddish rhyolite having a thickness of 31 feet and including 7 feet of red, arkosic sandstone. The red rhyolite rests upon an extremely coarse basal conglomerate containing pebbles of granite and rhyolite, some of which are more than 5 inches in diameter. The conglomerate is separated from pre-Cambrian rocks by 11 feet of crushed slaty red and green volcanic material. Two miles northwest of this point along the same road, the crystalline rocks are overlain by 38 feet of coarse sandstone, above which occurs 30 feet of red and green volcanic material. Overlying the latter is a pebbly, brown sandstone, 8 feet thick, which is separated from the Unicoi sandstones by 6 feet of soft rhyolitic shales.

The above sections indicate that a persistent rock sequence, from 90 to 500 feet thick, immediately overlies the crystalline pre-Cambrian terrane. It may be generalized as follows:

c.	Gray-brown, pebbly sandstones (Lower Unicoi)	
	(Green (occasionally reddish) rhyolite	6-175 feet
	(Meta-basalt	0- 50 "
b.	(Pink or brown arkosic conglomerate	38-480 "
	(Red (occasionally greenish) rhyolite	10- 30 "
a.	Pre-Cambrian crystalline rocks, chiefly granites	

~~Lithologically, this sequence has distinctive characteristics.~~ The uppermost rhyolitic beds are slate-green to blue-green; ~~in color;~~ they are very fine-textured, and exhibit a poorly developed cleavage. They vary from brittle and slaty rocks to beds that are dense and tough. Flow structures are present at a few exposures but elsewhere appear to have been obliterated by subsequent metamorphism. The rocks, which weather and erode readily, resemble true sedimentary shales. No red material occurs with the upper rhyolite, save at Snowden. A zone of strongly amygdaloidal rhyolite is exposed along North Creek, 1¾ miles east of Arcadia, where the amygdules consist of augen-like masses of quartz that are surrounded by small zones of metallic minerals which include magnetite and chalcocite. They vary from microscopic masses to areas several inches in diameter and were observed only at this locality.

The meta-basalt is a dark to black dense rock, containing tiny lath-shaped crystals of plagioclase feldspar. It has the customary appearance of basalt and weathers to a brown color. Its ledges disintegrate into blocky masses, but there is no suggestion of columnar jointing or other secondary igneous structures in the fresh rock. It is reported, but unconfirmed, that a boulder of basalt along North Creek exhibits a "pillow-lava" structure.

The clastic sediments associated with the volcanics vary in thickness from 38 to 480 feet, and differ in no essential manner from the beds of the lower Unicoi formation. Where examined, they include cross-bedded pink arkoses, having a wide range of textural variation. The beds vary from dense,

fine-textured sandstones, through pebbly sandstones, into coarse conglomerates, the basal member at Snowden containing pebbles more than 5 inches in diameter. (See Pl. 27, A.) The arkoses have been strongly indurated, and commonly exhibit slickensides. The sandstones and conglomerates are somewhat redder than the gray-brown, or heather-colored, Unicoi sandstones immediately above the rhyolite.

The rhyolitic beds below the sediments and directly above the pre-Cambrian crystalline rocks are commonly red in color. Near the bridge over North Creek, 1 mile southeast of Arcadia, they consist of very dense to glassy, brick-red, felsite through which glistening quartz crystals are scattered. Elsewhere, they are more thoroughly weathered and both cleavage and loss of compactness have developed. The lower rhyolites are commonly interbedded with zones of greenish volcanic material, as well as with true clastic sediments.

The entire series of volcanic rocks and associated sediments is assigned by Woodward to the Unicoi formation of early Cambrian age. This interpretation is made for a number of reasons: (1) Wherever the ~~bottom~~ base of the Cambrian System is exposed, a conglomerate containing fragments of the underlying terranes is invariably present. The pebbly sandstone which rests upon the upper rhyolite does not resemble a "basal sandstone," whereas the lowest member of the arkoses associated with the volcanics contains large pebbles of granite that are clearly the product of the initial erosion and weathering of an ancient land area. (2) There is little or no difference between the character of the lower sedimentary series and the true Unicoi formation, and no analogous sediments of undoubted pre-Cambrian

age are known to occur elsewhere along the Blue Ridge. (3) The igneous material is similar to igneous derivatives known to occur in, or at, the base of the Cambrian system from northern Virginia to North Carolina. (4) The major diastrophic change from pre-Cambrian to Paleozoic ~~time~~ events occurred before, and not after, the deposition of the sediments, clearly associating the latter with subsequent, rather than antecedent, events. (5) The present structure of the lower sediments and associated volcanics is identical with that of the overlying beds of Unicoi age. (6) Although fragments of volcanic material are found with pebbles of granite in the basal conglomerates, there is no good evidence that the volcanics are necessarily much older than the sediments. Indeed, the Cambrian Period may have begun with minor outbursts of vulcanism.[1]

---

[1] Furcron, A. S., and Woodward, H. P., A basal Cambrian lava flow in northern Virginia; Jour. Geology, Vol. 44, 1936, pp. 45-51.

Thickness and Relations.--It is difficult to determine accurately the thickness of the Unicoi formation (Section 1), south of Buchanan, its thickness reaches 3,000 feet; in the gorge at Balcony Falls, at least 1,400 feet occur, although no complete section was measured. So far as it is known, the formation contains no observed or reported fossils. Its lower contact with the pre-Cambrian is sharp; its upper contact (Pl. 27, B) with the Hampton shale, which is gradational, is rarely exposed and has been determined largely by topographic expression, for the overlying Hampton shale furnishes few exposures and weathers readily.

Economic Products.--The Unicoi contains a thin seam of iron ore which occurs midway between the two ridge-making sandstones. It is chiefly restricted to one horizon which varies in thickness from 12 to 50 inches and was formerly mined from several localities on Cove Mountain and along Jennings Creek. The ore, which is known as "Blue Ridge hematite", consists of a sandstone highly impregnated with iron oxide. Fuller description of the ore and local mines occur on pages 294-299.

Correlation.--The Unicoi formation is the northern equivalent of the lower part of the Chilhowie formation of Tennessee and southwestern Virginia. Northward, it is replaced by the Loudoun and Weverton formations of northern Virginia and Maryland.

Hampton Shale

Character.--The Hampton shale, which was named from Hampton, Carter County, Tennessee[1], is a series of sandy sericitic shales some of which approach the character of thinly laminated sandstones. (See Pl. 27, A.) Although their color is gray to gray-black when fresh, the surfaces of exposed ledges are commonly light or even white. Where iron is present, the rock takes on a brown color during weathering. In addition, the formation contains a few black-shale zones. Sandy beds are more abundant at the top, although thin fine-grained sandstone lenses are present throughout the unit. Cleavage and jointing are prominent, the latter being emphasized during weathering by deposition of limonitic material along the joint-planes. The original bedding of the rock has been largely obscured by folding and metamorphism.

1. Campbell, M. R., op. cit., map.

Distribution.--The formation weathers readily and is rarely exposed except in fresh artificial cuts; no natural exposures were observed. It crops out in a narrow belt less than ~~one-half~~ ½ mile wide that forms a topographic depression between the rugged uplands of the Unicoi and Erwin outcrops. The best exposures of Hampton shales occur (1) along the Norfork and Western Railway, 1 mile southwest of Arcadia, and (2) along United States Highway 501 in the gorge at Balcony Falls (Section 5). The formation contains no observed or reported fossils.

Thickness and Relations.--The thickness of the Hampton shale (Sections 1 and 5.) is about 475 feet. Its outcrop is largely covered with debris from adjacent formations and develops no distinctive natural soil. The contact of the Hampton with the overlying Erwin quartzite (Pl. 28, A,) appears to be unconformable, a fact which may have resulted from a difference in its compliance to folding rather than from an original sedimentary structure. The formation contains no materials of economic importance. As it is readily confused with the shaly zones of the Unicoi, it is best identified by its stratigraphic position immediately below the Erwin formation.

Correlation.--The Hampton shale is thought to be the southern equivalent of the Harpers shale of northeastern Virginia and Maryland.

Erwin Quartzite

Character.--Although the Erwin quartzite[1] contains a few fine-

1. Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), map, 1899.

textured shale members, most of the formation consists of white or blue-gray quartzite. After long exposure to the weather, its ~~exposed~~ ledges become brown and sandy, although the fresh rock, which is seldom friable or crumbly, is prevailingly light-colored. A few of the more massive ledges are coarse textured, but much of the formation is fine-grained. Although the Erwin contains several zones of hard ledge-making quartzite, few of these can be traced laterally for any distance, as they occur at different horizons in different parts of the area. At least one bed usually carries the peculiar fossil, Scolithus, which is confined to the thick quartzites ~~but never occurs~~ and is unknown in the thinner members. In places, the quartzite beds are distinctly stratified and cross-bedded; elsewhere, their stratification is less pronounced, and at some points it is entirely obscured by cleavage. (See Pl. 28B.)

The Erwin weathers with difficulty and produces great quantities of loose debris, the fragments of which retain sharp outlines. The massive ledges form rugged cliffs and even the softer zones produce steep slopes. Under long-continued weathering the formation disintegrates to a mass of soft, sandy material, producing a deep-red residual soil that is well displayed near Crawford Creek on State Highway 249.

Distribution.--The formation crops out in a continuous belt from Cloverdale, 18 miles south of Buchanan, to Greenlee, where it forms the northernmost and sharpest line of foot-hills of the Blue Ridge. This ridge is a marked topographic feature (See Pl. 30, A.) between Arnold Valley and Buena Vista. The best local exposures of the Erwin occur (1) in the gorge of James River at Balcony Falls, (2) in Bearwallow Hollow, and (3) in cuts of the Norfork and Western Railway near Arcadia. Throughout most of its outcrop, the Erwin is steeply inclined to the northwest at angles that are rarely less than 40°; (Pl. 29, A) in a few exposures, small folds and minor faults are visible. Several isolated outcrops which are separated from the main belt in Arnold Valley, apparently represent small anticlines protruding through the overlying Shady dolomite. The largest inlier forms Cave Mountain, 2 miles southeast of Gilmore Mills; another which occurs near Crawford Creek north of James River and widens northeastward to form Sallings Mountain, north of Glasgow.

Immediately south of Buchanan, the Erwin outcrop, which is divided by a synclinal valley enclosing the Shady dolomite, produces 2 distinct ridges. The western ridge, which forms Jones and Boyd Mountains, (Pl. 25) ends abruptly 3 miles southwest of Buchanan.

Relations and Economic Products.--At nearly every locality, the contacts of the Erwin are concealed. In an exposure near Balcony Falls, however, (Pl. 28, A) its lower contact seem to be with the Hampton shale is slightly unconformable. (Section 5.) Erwin quartzite is extracted for railroad ballast at the Lone Jack quarry north of Glasgow.

There is no evidence of any iron ore in the local Erwin quartzite. A few prospects of brown iron ore ("Valley limonite") have been opened near its contact with the Shady dolomite in the belt from Lithia northeastward. (See pp. 303-305.) Similar ore-pits are also reported near the Arcadia and Greenwood furnaces.

Fossils.--The Erwin quartzite is sparingly fossiliferous. Its most abundant form, Scolithus linearis, consists of long, slender, vertical tubes that are perpendicular to the bedding of the rock; they are well displayed along U. S. Highway 501, immediately west of the junction of North and James rivers. (Fossil locality 27)*/ The following additional species have also been reported from this formation[1] (localties 28, 28):

Lutorgina species undetermined
Obolella minor (Walcott)
Hyolithes communis Billings
Olenellus sp.

---

1. Walcott, C. D., Cambrian brachiopoda: U. S. Geol. Survey Mon. 51, part I, p. 200, 1912.

Thickness.--The Erwin quartzite is about 775 feet thick in all of its local exposures (Sections 1,5).

---

* A detailed list of fossil localities is found on pages 219-225. Specimens of listed fossils either have been collected at these localities by Doctor Ladd or the author in the course of the present survey, or have been reported by other authors.

Calcareous Division

Shady Dolomite

The Shady dolomite, although largely composed of subcrystalline gray to white dolomite, also contains a few limestone lenses. It is named from Shady Valley, Johnson County, Tennessee.[1.]

---

1. Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranbery folio (No. 90), p. 5, 1903.

Character.--The purest member of the Shady is a massive bed of dolomite which occurs near the base of the middle part of the formation; the upper and lower portions of the Shady consist of dark and relatively impure dolomite. The weathered surfaces of the rock are gray-brown, and flat exposed ledges are commonly deeply furrowed by solution. The fresh rock possesses a sub-conchoidal fracture and is commonly ~~much broken~~ shattered as a result of close deformation. ~~folding.~~ Its somewhat saccharoidal texture is accentuated during ~~by~~ weathering.

The Shady is irregularly bedded (Pl. 49, B) and there is no visible stratification in the purer dolomite; fractures, cleavages, and minor joints are conspicuous in the faces of cliffs and in quarries. (See Pl. 29, B and 62, B.) As the Shady dolomite weathers more readily than ~~does~~ any other formation of ~~in~~ this area, natural exposures are extremely rare. It produces a thick, chocolate-red to red-brown, soil that is unctuous and sticky. The upper surface of the weathered rock below the soil cover is highly irregular. Underground drainage in the Shady dolomite is less common than in nearby younger limestones, and relatively few depressions mark its outcrop which is commonly covered with stream gravels or with quartzitic debris derived from the adjacent Erwin hills. In weathering, a small amount of rounded, slabby, chert

is developed, but the latter is relatively inconspicuous because of the greater abundance of foreign material. The formation is not known to contain any fossils in this area; rare forms, chiefly species of Salterella, have been reported from a few localities in southwestern Virginia.

Distribution.--The chief local outcrop of the Shady dolomite is along James River immediately north of the Erwin outcrop. This belt, which is about ~~one half~~ 1/2 mile wide at Buchanan, increases gradually to a width of 1 mile at Natural Bridge Station. Two other belts also occur; (1) in the synclinal valley southeast of Buchanan between Jones Mountain and the Blue Ridge, and (2) in Arnold Valley, ~~which is floored with Shady dolomite.~~ The best exposures of the Shady occur in the quarries near Buchanan and ~~A large quarry was formerly operated near~~ at Sherwood.

Thickness and Relations.--The thickness of the Shady dolomite ranges from ~~is between~~ 1,200 to ~~and~~ 1,300 feet. (Section 6.) The formation is generally inclined or folded, and its contacts are rarely visible. The lower contact is unconformable; the contact with the Rome ("Watauga") formation is conformable and may be detected by color and lithologic change.

Economic Products and Correlation.--The Shady has been abundantly quarried for lime, road ballast, and iron flux, the chief local quarries being located near Buchanan. (See Pl. 62.) Residual ~~accumu-~~ accumulations of manganese have been reported in Bearwallow Hollow, and small prospects of brown iron ore have been worked along the foothills of the Blue Ridge between Lithia and Arnold Valley. (See pp. 303-305.)

The Shady dolomite is the southern equivalent of the Tomstown dolomite of northern Virginia and Maryland. Although formerly called the Sherwood limestone[1] from its outcrop near Sherwood

---

1. Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Amer. Jour. Sci., 4th series, vol. 20, pp. 445-47, 1905.

(Natural Bridge Station), it is now known by the name, Shady, for which there is prior claim.

Rome ("Watauga") Formation

Definition.-A shaly series of rocks, exposed near Rome, Floyd County, Georgia, was called the "Rome formation" by C. W. Hayes[1] in 1891.

1. Hayes, C. W., The overthrust faults of the southern Appalachians: Bull. Geol. Soc. Amer., Vol. 2, p. 143, 1891.

Later, the name "Watauga"[2] was applied to analogous beds in northern

2. Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranberry folio (No. 90), p. 3, 1903.

Tennessee and southwestern Virginia. Because of the equally wide use of both terms, equivalent beds in this region are described as the Rome ("Watauga") formation.[3]

3. Woodward, H. P., The age and nomenclature of the Rome ("Watauga") formation of the Appalachian Valley: Jour. Geology, Geol., vol. 37, pp. 596-97, 1929.

Character.--The Rome ("Watauga") formation occurs directly above the Shady dolomite and underlies the Elbrook limestone. It is a mass of thin shales that have a characteristic red-purple color; of equal volume, but less conspicuous value, are blue-gray and green shales. A few limestone members are present within the formation, especially in its southwestern outcrop. Zones of red shales, many of which exceed 10 feet in thickness, occur at various horizons that are separated by shales of other colors. The beds are fine-textured and contain little gritty material. Mud-cracks and ripple marks, which give evidence of a shallow-water origin, but are rare, ~~and are restricted in occurrence.~~ The

formation weathers to produce flaky, or splintery, fragments that readily disintegrate.

Stiff red-brown layers are common along hill slopes where no other members crop out (Pl. 31, A); the softer shales may be exposed in gullies at the foot of the slopes. The best natural exposures are in road cuts and along stream bluffs.

The most important local outcrop of the Rome ("Watauga") formation is a narrow belt followed by James River from Buchanan to Natural Bridge Station. The average width of this outcrop is about ~~one-third of a~~ 1/3 mile, and the rocks are highly tilted and closely folded. Exposures are abundant along the two railroads which follow James River, as well as ~~and also~~ along State Highway 249, 3 miles east of Natural Bridge (Section 6.). Another belt of Rome ("Watauga") shale is crossed by Lee Highway, 5 miles southwest of Buchanan. This belt extends from the southern margin of the area to a point near Indianrock where it is cut out by a fault. Typical Elbrook limestones occur between the two belts. Good ~~Good~~ exposures of the Rome ("Watauga") occur also at Garst's Store and near Dillon flag-station on James River.

Topography and Soil.--The formation produces secondary ridges, or knolls, that rise above the lower areas of Shady and Elbrook outcrops. Where well developed, the rounded summits of the knolls ~~these ridges~~ stand several hundred feet above the level of the limestone country, as in the region (Mill) ~~and are rounded and symmetrical. They have pronounced development~~ between Looney and Back creeks near Mill Creek Church (See Pl. 30, B.). The Rome ("Watauga") ~~The~~ formation is highly folded, and at many points is so minutely contorted that a hand specimen of rock will exhibit all phases of fold structures. Cleavage, which is present in many exposures, is conspicuous in the belt near Gilmore Mills. The formation weathers to produce a brownish soil that contains much shale debris. Where the bedrock is some distance below the surface, a red-brown, loamy soil develops; little

or no chert is present.

Thickness.--The thickness of the Rome ("Watauga") is difficult to determine. It is reported to be 1,800 feet thick near Natural Bridge,[1] and 7,500 feet thick between Natural Bridge and Roanoke,[2] ~~A measured~~ although a measured section (Section 6) near Natural Bridge Station shows only 1,100 feet of shale.

1. Campbell, H. D., op. cit. p. 446.

2. Butts, Charles, The southern Appalachian region; Guidebook 3, XVI Intern. Geol. Congress, U. S. A., p. 55, 1933.

Relations.--The contacts of this formation with the rocks above and below appear to be conformable. In a few rare exposures, Rome ("Watauga") shales have been found in conformable position directly upon the Shady dolomite. The upper contact is elusive and has been arbitrarily drawn on the geologic map above the horizons of abundant red shales, although no criteria to determine the exact boundary are available. The formation does not contain any materials of economic importance nor has it been quarried within the area.

Fossils.--Although the Rome ("Watauga") formation contains few fossils, a number of specimens of Olenellus thompsonsi Hall have been found near Garsts Store (Fossil Locality 30). This fossil also occurs in adjacent areas of west-central Virginia and is one of the earliest known Cambrian trilobites. Walcott[1] has reported a species of Ptychoparia from the Rome

1. Walcott, C. D., Notes on the Cambrian rocks of Virginia and the southern Appalachians: Amer. Jour. Sci., 3rd ser., vol. 44, p. 5, 1892.

("Watauga") formation near Natural Bridge. ~~and~~ These fossils determine the formation to be of early Cambrian age.

Elbrook Formation

The Elbrook formation was originally named at Elbrook in southern Pennsylvania,[1] where it rests upon the Waynesboro shale. In the

---

1. Stose, G. W., Sedimentary rocks of South Mountain, Pennsylvania; Jour. Geology, vol. 14, p. 209, 1906.

Natural Bridge region, it lies above the Rome ("Watauga") formation and below the Conococheague limestone.

Character.--This formation which is easily recognized ~~and~~ by its distinctive shaly character ~~is a prominent feature. The Elbrook formation~~ includes a thick series of thin-bedded, shaly limestones, together with minor lenses of dolomites and bodies of true shales. ~~A~~ The few massive limestones ~~members~~ which occur ~~with~~in the Elbrook, ~~but~~ are ~~far~~ much less conspicuous than slabby, shaly, limestones. The lower portion of the formation is thicker bedded than its middle and upper portions and, (as mapped), contains at least one thin zone of red-purple shale which resembles the shales of the underlying Rome ("Watauga") formation. A few blue-green sericitic shales are also present. The Elbrook is prevailingly fine-textured and its bedding is distinct but irregular. The chief color is gray, and weathered surfaces of ledges are light gray. Some of the limestone members are dark, or black. Along State Highway 249 about 1 mile east of Natural Bridge (Section 6), a thin bed of dark-gray, very dense, structureless dolomite was found near the top of the formation, but this horizon was not observed in other exposures. The formation shows some evidence of shallow-water deposition but contains little or no clastic material. ~~Where~~ Exposures are common where the formation is inclined; ~~the beds are apt to be exposed;~~ where the beds are horizontal, ~~exposures are rare.~~ few ledges are visible.

Distribution.--The Elbrook formation has ~~a large outcrop in this area near Buchanan, it forms~~ an extensive local outcrop forming a long, narrow belt extending northeasterly from Buchanan through Indianrock and Rocky Point. About 3 miles southwest of Natural Bridge, the outcrop divides into 2 belts that surround a synclinal inlier of Ozarkian limestones, near the center of which is located Natural Bridge. Northwest of Buchanan, the outcrop extends along James River to Eagle Rock with a deep embayment in the valley of Spreading Spring Branch, and a wide expansion from Cedar Ridge to Hickory Hollow. A narrow belt occurs immediately west of the old Plank Road from a point near Buchanan to the Rockbridge county-line. This belt is truncated at the northwest by a fault along which Elbrook limestones have been overthrust upon Ordovician shales.

The best local exposures of the Elbrook occur (1) along James River near Saltpetre Cave, (2) in the valley of Spreading Spring Branch, (3)on the road leading to Rocky Point, (4) along Lee Highway south of Garst's Store, and (5) on State Highway 249, east of Natural Bridge.

Topography and Relations.--The Elbrook formation produces relatively low country, and forms typical rolling "Valley" land. (See Pl. 17,A.) Throughout most of its outcrop, it has been complexly folded, and it contains many small, local faults. Its brown-red soil is rich and fertile and contains little cherty debris. Both upper and lower contacts have been determined in the field merely on the basis of lithology. As previously mentioned, the basal contact is arbitrarily drawn above the persistent red-shale zones of the Rome ("Watauga") formation. The upper contact is placed beneath the lowest sandstone horizon of the overlying Conococheague limestone. The outcrop of the Elbrook produces no economic products of importance, although a few small stone quarries have been opened for local use.

Thickness and Age.--The thickness of the Elbrook formation is between 1,000 and 1,800 feet; more than ~~1,100~~ 1,050 feet of Elbrook limestone are visible in a continuous section along State Highway 249. (Section 6.) On the basis of its stratigraphic position, the formation is assigned to the Upper Cambrian; it occupies the horizons of the Honaker-Nolichucky formations of Southwestern Virginia.

The Elbrook limestone contains few fossils. Walcott[1] has reported the presence of Obolus matinalis Walcott and Lingulella (Lingulepis) acuminata (Conrad) in ledges on Buffalo Creek, 2 miles southeast of Buffalo Mills. (Fossil locality 32.) No other forms were observed.

---

1. Walcott, C. D., Cambrian brachipoda, U. S. Geol. Survey Monograph 51, part I, p. 218, 1912.

Ozarkian and Canadian Systems

From Maryland to Tennessee the Valley of Virginia is floored with a thick series of calcareous rocks that were formerly grouped together under the names "Shenandoah limestone", "Valley limestone", or "Natural Bridge limestone" - designations which were originally appropriate in view of the uniform behavior and similar appearance of the rocks.

During the last 30 years, detailed studies of the Valley rocks have been in progress, and it has been discovered that various portions of the main calcareous group can be given more precise designations. Thus, the thick dolomite at the base of the "Valley" group is now known to be of Cambrian age; it is called the Shady dolomite, and has been withdrawn from the older, more inclusive grouping. In similar manner, the Rome ("Watauga") and Elbrook formations have been given specific identification, and are no longer properly assigned to the "Valley limestone". At the top of the calcareous series, still other units have been recognized as of Ordovician age. In the course of these more elaborate identifications, the older names "Valley, or Shenandoah" limestone have been dropped from current use.

It is evident that if the lower portion of the old "Valley" series is of Cambrian age and its upper portion is of Ordovician age, a line of separation between the Cambrian and Ordovician systems must occur somewhere within the middle portion of the series. As yet, geologists have not wholly agreed upon the position and character of this boundary. A number of authorities locate the contact at the top of the Chepultepec dolomite and below the Stonehenge limestone, placing the former in the Cambrian and the latter in the Ordovician. Other authorities place the upper limit of the Cambrian system at the top of the Elbrook limestone, and place the base of the Ordovician immediately below

the Stones River horizons. This interpretation excludes a considerable thickness of dolomitic strata from both Cambrian and Ordovician systems, and makes it necessary to erect one or more additional systems between the restricted Cambrian and Ordovician. Various stratigraphic and paleontologic reasons may be brought forward for both interpretations.

The rocks in question locally involve the Conococheague, Chepultepec, Stonehenge, Nittany, and Bellefonte formations, which constitute a more or less uniform series of thick-bedded units that have much in common and can be readily differentiated from the underlying and overlying strata; their fossil faunas are entirely analogous and indicate a distinct evolutional stage between the life of earlier and later epochs.

With the suggestion to group these units into a single distinct geologic system younger than Cambrian and older than Ordovician, the author is in full accord, but he is not aware that this suggestion has previously appeared in print. With the suggestion to form 2 independent systems out of this aggregate of similar strata, the author is not in sympathy. The latter procedure, however, is the present policy of the Virginia Geological Survey which recognizes 2 rock systems--Ozarkian and Canadian--between the Cambrian and Ordovician. In comformity with this policy, post-Elbrook and pre-Stones River formations are here described under the heading of "Ozarkian and Canadian Systems"; their specific separation is as follows:

Canadian	Bellefonte dolomite Nittany dolomite Stonehenge limestone
Ozarkian	Chepultepec limestone Conococheague limestone

The term "Cambro-Ordovician", although not wholly specific, nor having formal stratigraphic sanction, is a convenient designation for the combined Ozarkian and Canadian rocks.

Ozarkian System

Conococheague Formation

The Conococheague formation[1] is named from Conococheague Creek in southern Pennsylvania, where it occurs between the Elbrook and Beekmantown formations. It is the limestone

---

1. Stose, G. W., The Cambro-Ordovician limestones of the Appalachian Valley in southern Pennsylvania; Jour. Geology, vol. 16, p. 703, 1908.

facies of the Copper Ridge dolomite of southwestern Virginia and the northern equivalent of the "Jonesboro formation" of Tennessee.

Character. - In this region, the formation is a thick mass of calcareous material, chiefly composed of limestone. The rock is generally dark gray or gray-brown, and its beds are massive, although finely laminated. Dolomitic zones in the Conococheague are commonly thick-bedded. In certain horizons, the thin limestones and dolomites are intimately interbedded to produce a rock that exhibits a distinctive ribbony appearance upon weathering. (See Pl. 32, A.) Elsewhere, the formation may contain horizons of extremely thin-bedded dolomites that resemble shales. The latter weather to a buff color and are commonly associated with sandy zones. A number of sandstone lenses are scattered through the formation, and their presence is distinctive of the Conococheague, for such material is largely absent in the other calcareous units of the region. One of these sandstones, 2 miles east of Zion Hill Church, has a thickness of ~~over~~ more than 30 feet. The sandstones ~~weather~~ decay readily and produce a red sandy soil; indeed, it is rare to find any of them in fresh, unweathered condition. The texture of Conococheague limestones is ~~very~~ fine and, in places, almost subcrystalline. The limestones weather to a color somewhat lighter than that of the fresh rock, and many contain ripple marks or other evidences of shallow-water origin.

Distribution. - The Conococheague formation crops out in several belts in the Natural Bridge region. A wide outcrop extends from Eagle Rock southwestward along Switzer and Caldwell mountains to the southern margin of the region; ~~and~~ it is connected

with an outcrop that includes the desolate areas of Cedar, Timber, and Little Timber ridges. Another belt forms a synclinal tract ~~area~~ in which Natural Bridge occupies a central position. A third belt is located near Longwood; a fourth extends parallel to Lee Highway from a point 2 miles northeast of Buchanan nearly to Cedar Creek. Other isolated outcrops occur near Fincastle, Garsts Store, and along Beaverdam Creek.

Good exposures occur in ~~the~~ cliffs ~~of~~ along James River ~~from~~ between Eagle Rock ~~to~~ and Salisbury Furnace and in the gorge of Cedar Creek ~~both~~ above and below Natural Bridge. The Conococheague formation is also exposed along Lee Highway north of Buchanan and on the roads leading to Rocky Point and Indianrock.

Thickness and Soil. - The exact thickness of the Conococheague is unknown, but it is estimated to range between 1,200 and 2,500 feet. (Section 7.) The formation produces a red soil that commonly contains fragments of slabby, black chert. Its outcrop (Pl. 9, B) is less fertile than the other "Valley limestones" and forms ~~the~~ a rolling, irregular, country containing many sinks. The rock, which is fairly competent, has been broken by many faults, most of which are ~~very~~ small in displacement and surface extent. The Conococheague is thought to rest unconformably upon the Elbrook limestone; its contact with the Chepultepec limestone is disconformable.

Fossils and Age. - The formation contains very few fossils. A small number of specimens of trilobites (chiefly Tellerina and Sankia) were found in a ledge of buff-colored shales 1.6 miles

north of Natural Bridge along the Lee Highway. (Fossil locality 33.) A few gastropods and cephalopods appear in bas-relief on weathered surfaces of ledges. Specimens of Cryptozoa are not uncommon in the Conococheague, several excellent exposures ~~of them~~ occurring along Lee Highway near the bridge over Rocky Run. (See Pl. 33,A.)

The age of this formation is not precisely known. It belongs to the Ozarkian system of Ulrich, but is commonly considered by other authors to be of ~~Upper~~ late Cambrian age. In earlier studies of Appalachian rocks, this unit was included in the "Shenandoah" or "Natural Bridge" limestone.

Economic Use. - Although the Conococheague formation ~~It~~ has been quarried at several places for local road material, ~~but~~ it contains no other products of economic importance.

Chepultepec Limestone

This formation is named from Chepultepec in Murphrees Valley, Blount County, Alabama.[1]

1. Ulrich, E. O., Revision of the Paleozoic systems; Geol. Soc. America Bull., Vol. 22, p. 638, 1911.

Character and Thickness. - The Chepultepec limestone is similar to the underlying Conococheague limestone, with which it is ~~apt to be~~ readily confused in the field. Indeed, it is largely on the basis of fossil content that the two formations can be separated. It consists of a series of limestones and dolomites that are medium-grained and irregularly bedded. A fairly massive character is distinctive of the freshly exposed rock, although

weathered exposures tend to appear more thinly bedded. Both pure limestone and impure dolomite occur in the formation, the former, however, being somewhat the more common. The formation produces small quantities of chert on its outcrop and possesses a few sandy lenses that are similar to those in the underlying Conococheague formation. Except for minor differences, the two formations comprise an almost unbroken aggregate of variable calcareous rocks, a fact which makes it difficult to determine the relative thickness of each member. It is thought that the Conococheague formation occupies from four-fifths to five-sixths ~~to four-fifths~~ of the joint thickness (1,700 to 3,000 feet) of Ozarkian rocks. If this interpretation is accurate, the thickness of the Chepultepec limestone is between 300 and 500 feet.

Distribution. - The largest local outcrop of the Chepultepec formation occurs along the axis of a synclinal tract that extends from the eastern margin of the area to a point one mile southwest of Natural Bridge. This belt, which is one mile wide, contains few exposures save those in the gorge of Cedar Creek at Natural Bridge. Other outcrops occur at the Ozarkian-Canadian contact along the northwestern slope of Timber Ridge and the southeastern slope of Cedar Ridge. Another belt extends midway between the Plank road and Lee Highway. Natural Bridge is an excellent exposure of this formation. (See Pls. 3 and 20.)

Age and Correlation. - Fossils occur sparingly in the chert of Chepultepec soils. Most common are such forms as Helicotoma, Levisoceras, and Dakeoceras. A brachiopod, identified as Eoorthis newtonensis (Weller),[1] is reported from an abutment of

---

1. Reeds, C. A., The Natural Bridge of Virginia and its environs; p. 53, Richmond, ~~p. 53~~, 1930. Virginia,

Natural Bridge. (Fossil locality 35.)

The Chepultepec formation of the Natural Bridge region is the equivalent of the Chepultepec dolomite of Alabama and the Gasconade dolomite of Missouri. The formation is assigned in this report to the Upper Ozarkian; by some authors it is described as Late Cambrian in age.

Canadian System

Stonehenge Limestone

Character.— Beds of Beekmantown (Canadian) age that are older than the Nittany dolomite occur sparingly in some parts of Virginia, especially in the northern portion of the Valley. They have also been found in isolated outcrops as far south as the Tennessee boundary (Washington County). Where present, they rest disconformably upon the uppermost Ozarkian rocks (normally the Chepultepec limestone) and below the Nittany dolomite. Thick-bedded limestones comprise the most common rock type, and diagnostic species of Eccyliopterus and Ophileta are identifying fossils.

Local Representation.— No beds were examined in the Natural Bridge region that could definitely be assigned to the Stonehenge limestone except a few ledges near the sharp bend in the road leading from Lee Highway to Indianrock (fossil locality 36), and an analogous outcrop on the road to Rocky Point. It is thought that a thin representation of the Stonehenge, not more than 30 feet thick, occurs immediately below the Nittany in this belt, and its position has been indicated on the geologic map, Plate I. If the formation is present elsewhere in the region, it has not been distinguished from adjacent formations.

Nittany Dolomite

The Nittany dolomite, named from Nittany Valley in central Pennsylvania,[1] overlies the Stonehenge and Ozarkian formations throughout the Natural Bridge region where it crops out in several disconnected belts.

1. Ulrich, E. O., Revision of the Paleozoic systems; Geol. Soc. America Bull., vol. 22, p. 658, 1911.

Character. - This formation is a mass of calcareous rock, chiefly dolomite. Commonly it is light gray, rather evenly textured, and massively bedded. Its stratification is distinct, and the beds average several feet in thickness. The purer dolomites break with a sub-conchoidal fracture. On weathered surfaces, the rock is apt to become chalky, but where eroded or dissolved, it exhibits a smooth, water-worn, or furrowed surface. (See Pl. 34, A.) It may be distinguished from the adjacent Elbrook and Ozarkian formations by its massive bedding.

A conspicuous characteristic of the Nittany dolomite is the presence of large quantities of chert upon portions of its outcrop. (See Pl. 35, B.) The chert is gray or white, and is dense, massive, and commonly jagged. It occurs in great abundance on hillslopes where it impedes cultivation of the soil to such an extent that the cherty areas are still uncleared and wooded. Individual chert fragments, which range from a few inches to several feet in diameter, are seldom rounded even after long transportation and weathering. No chert is developed where the formation is exposed in low areas, and none has been observed in the fresh rock.

For these reasons, it is assumed that the chert was developed during weathering, and was not an original constituent of the dolomite. It is supposed that some of the normal silica content of the formation was redeposited during the processes of weathering, and that this redeposition gave rise to the cherty material.[1] The rare fossils, which occur in the cherty fragments, are poorly preserved and difficult to detect. It is unusual to find 1 chert fragment out of 100 that contains a fossil specimen.

Nittany dolomites, unlike Ozarkian rocks, contains no sandy, or arenaceous, lenses, with the single exception of a thin ledge which occurs 3/4 mile south of Hamilton School, along South Fork of Buffalo Creek. This sandstone is very porous, and its original calcareous matrix has been leached by weathering. The sand grains are small and well rounded, and the rock closely resembles the sandy lenses of the Conococheague formation.

A distinctive feature of the Nittany is the common presence of vaughanite which is a fine-grained, smooth, very pure limestone. It is characterized by the absence of lamination, and breaks with a conchoidal fracture; it is often crossed by tiny intersecting calcite veins. Vaughanite is blue-gray or "dove-colored" and resembles lithographic limestone in texture. In fact, certain of the local vaughanite beds have been unsuccessfully prospected for lithographic stone.

Distribution. - The Nittany dolomite crops out in a narrow belt about 1/2 mile wide from a point near Indianrock to a point slightly north of Highbridge Church. This outcrop is

1. Woodward, H. P., Paleozoic cherts of west-central Virginia: Jour. Geology, vol. 39, pp. 285-287, 1931.

truncated at both ends by a fault, and exposures are visible along the roads leading from Lee Highway to Indianrock and to Rocky Point. (Sections 8 and 9.)

A wide outcrop occurs along Cedar and Timber ridges near Fincastle. (Section 7.) An extension of this belt contains excellent exposures in fields near High View School. A narrow belt of Nittany dolomite which occupies a somewhat inaccessible position along the foot of Switzer and Crawford mountains, crosses James River a short distance south of Eagle Rock. Isolated areas also occur near Murat, and east of Howell Mills.

Excellent exposures of the dolomite occur (1) near the limestone mines at Eagle Rock, (2) near Kyles Mills, (3) along the road leading from Fincastle to Springwood, (4) on Catawba Creek, 2½ miles above Salisbury furnace, (5) at the head of Sugartree Hollow, (6) along Colliers Creek north of Murat, and (7) at Highbridge Church.

The axis of Rich Patch valley exposes a narrow belt of Beekmantown dolomite, most, or all, of which may be assigned to the Nittany formation. It is possible, however, that the beds immediately below the Stones River belong to the Bellefonte dolomite of post-Nittany age.

A similar belt of Beekmantown dolomite extends along South Fork of Buffalo Creek from the Rockbridge county-line northeast~~erly~~ward to the northern margin of the area. This belt is nearly 4 miles wide at the north, but is broken by a fault that follows the axis of an anticline along which a narrow zone of Ordovician rocks is exposed. The thickness of the

dolomite was not measured in this outcrop but must equal, if not exceed, that in the Indianrock belt. The rock is well exposed along South Fork of Buffalo, one mile east of Oakdale. As in Rich Patch Valley, ~~it is probable that~~ beds of post-Nittany (Bellefonte) age, are present, but have not been ~~mapped~~ separately mapped.

Topography and Relations. - Where chert is absent, the Nittany outcrop is low, rolling, and ~~is~~ covered with a fertile soil. (See Pl. 9, A.) Where chert is abundant, the outcrop contains hilly ground that is commonly wooded and possesses a sterile soil. The formation has been folded on a large scale, but exhibits no evidence of internal crumpling. The lower contact of the Nittany is rarely exposed and was observed only in the belt of outcrop near Rocky Point, where it appears to be conformable. The upper contact with the Bellefonte dolomite is also conformable.

Thickness. - The thickness of the Nittany dolomite ranges between 500 and 800 feet (sections 7, 8, 9), exact determinations being difficult to obtain.

Fossils and Age. - Fossils are rare in this formation. A few smoothed surfaces of Nittany ledges show faint sections of gastropods and cephalopods, but the fossils can not easily be extracted nor specifically identified; fragmentary gastropods are occasionally found in the chert fragments. The following Nittany species were collected from fossil localities 1-3, 37-43:

Ophileta cf. O. complanata Vanuxem
Ophileta cf. O. subulata
Lecanospira conferta Ulrich
Lecanospira compacta (Salter)
Eccyliopterus cf. E. disjunctus (Billings)
Eccliomphalus cf. E. calciferous Whitfield
Hormotoma artemesia (Billings)
Hormotoma cf. H. artemesia var gigas
Hormotoma gracilis Hall
Hormotoma sp. undetermined
Roubidouxia depressa Butts
Pleurotomaria gregaria Billings
Pleurotomaria sp. undetermined
Coelocaulus cf. C. linearis (Billings)
Raphistoma sp. undetermined
Fususpira sp. undetermined
Cameroceras sp. undetermined
Turritoma sp. undetermined

The age of the Nittany dolomite is commonly described as Beekmantown, or early Ordovician, by most authors. In this report it has been referred to the Canadian System which represents the horizons immediately below the Ordovician System.

Bellefonte Dolomite

Dolomites of post-Nittany age are present in Rich Patch valley and in the valley of South Fork of Buffalo Creek where they lie disconformably below early Stones River (Ordovician) limestones and rest upon the uppermost Nittany beds from which they are separated with difficulty. It is thought that the post-Nittany dolomites are the equivalent of the Bellefonte dolomite of central Pennsylvania.

Character. - The local Bellefonte representatives are blue-gray to gray-white dolomites that are unusually pure, fine-grained, and medium-bedded. Pearl-gray zones are common. Abundant chert is developed upon the surface of these beds under topographic conditions analogous to those of the chert

areas of Nittany dolomite. Bellefonte chert is distinguished from Nittany chert in being more mealy and in resembling the structure of worm-eaten wood; Nittany chert is massive and jagged.

In view of the difficulty of determining the base of the Bellefonte equivalents, it is hazardous to estimate its exact thickness. Possibly 200 to 500 feet of dolomite may be assigned to a post-Nittany age in the northern Natural Bridge region.

Distribution. - Only in Rich Patch valley and along South Fork of Buffalo Creek can the Bellefonte dolomite be separated from the Nittany dolomite, and in the two localities mentioned the identification is based mainly upon differences in the residual cherts ~~residues~~ of the two formations. Exposures of dolomitic beds along the headwaters of Purgatory Creek about ~~three~~ 3 miles northeast of Dunkard Church are thought to belong to the Bellefonte dolomite, and the abundant chert on Saville Hill is probably post-Nittany in age. Chert resembling that of the Bellefonte occurs in Rich Patch valley near the intersection of the Hays Gap road with the road along the valley floor.

Age and Correlation. - Fossils, although sparingly present in the Bellefonte chert, are poorly preserved and difficult to extract. The most common forms are Ceratopea and various species of Hormotoma, and Cameroceras.

On the basis of stratigraphic position above the Nittany dolomite, the local beds are assigned to a ~~Upper~~ late Canadian age (Early Ordovician of many authors).

Ordovician System

Ordovician rocks are widely exposed in this area and reach a maximum thickness of about 4,500 feet. (See Fig. 23.) Three distinct divisions may be recognized; ~~as follows:~~

Upper Ordovician
- Juniata shale
- Martinsburg shale, Maysville division
- Martinsburg shale, Eden division

Middle Ordovician
- Martinsburg shale, Trenton division
- Chambersburg limestone
- Moccasin-Lowville formation

Lower Ordovician
- Athens shale) Blount Group
- Holston limestone)
- Lenoir limestone) Stones River Group
- Mosheim limestone)
- Lower Stones River limestone)

The lower part of the local Ordovician System consists almost entirely of thin, easily recognizable limestones that rest upon the "Cambro-Ordovician" series. Because of their lithologic character and fossil content, most of the Ordovician formations can be readily separated from older units. Basal Ordovician ~~rocks~~ limestones are the oldest abundantly fossiliferous formations within the limits of the area.

The middle and upper portions of the Ordovician System include several calcareous shales that resemble one another in appearance and in topographic expression. Their combined thickness is ~~over~~ more than 2,000 feet, and they form the greater portion of the local Ordovician outcrop.

Ordovician rocks rest unconformably upon the Canadian system, and are separated from overlying Silurian beds by a similar unconformity.

Stones River Group

Lower Stones River Limestone

The earliest Ordovician formation of this region consists of a limestone that immediately overlies the Canadian dolomites and occurs below the Mosheim limestone or, in the absence of the latter, below the Lenoir limestone. This unit occupies the horizon of the Murfreesboro limestone of Tennessee, but differs widely from it in character. It is here called the Lower Stones River limestone in recognition of its stratigraphic position.

Character. - The rock is essentially a dark-blue limestone containing several almost black members. It is medium to thin-bedded and contains zones of very dense, blue-gray, structureless limestone that closely resembles the vaughanite of the overlying Mosheim limestone. Along the road leading to Rocky Point, the Lower Stones River formation includes thin, slaty, black limestones that were not observed elsewhere in the area. The formation produces abundant chert that is conspicuous on its weathered surface, where the chert occurs in knobby, lenticular layers. (See Pl. 35, A.) The rock weathers in a manner similar to the Canadian dolomites; hence, its outcrop is difficult to distinguish from the outcrop of the Nittany and Bellefonte formations.

Natural exposures of this formation are uncommon.

Distribution. - The Lower Stones River limestone occurs in Rich Patch valley, where its outcrop is a long oval, extending for 6 miles in a northeasterly direction. (Section 11.) Near its center is an inlier of Canadian dolomite that is exposed along the axis of a long anticline. Good exposures occur near Rich Patch School, (Pl. 34, B), and along the main valley road for about 1 mile on either side of Mountain Valley School. The Lower Stones River formation is also exposed along the road leading to Rocky Point in a belt that parallels the Nittany outcrop. (Sections 8, 9.) A long, continuous outcrop surrounds the Canadian dolomites on South Fork of Buffalo Creek. Vaughanite beds are well exposed midway between Hooks Mill and Rich Patch School. The formation is absent near Nurat and Eagle Rock, and in the area of the Flatlands syncline. (See p. 238.)

Thickness and Relations. - The Lower Stones River limestone has a measured thickness of 330 feet in Rich Patch Valley (Section 11), and is thought to be about 250 feet thick near Rapps Mill. Its thickness in the Rocky Point belt is less, probably about 100 feet. (Sections 8, 9.) Its contacts are poorly exposed; it is thought to be disconformable to the overlying Mosheim limestone, and to be unconformable to the underlying Canadian dolomites.

Fossils and Age. - Fossils occur sparingly in the chert of this formation. (Fossil localities 4, 44.) They consist chiefly of the remains of bryozoa that have been dissolved, so as to leave a hollow external mold of their colonial skeletons. No identification

of these forms was made, as the fragments are rare and poorly preserved.

The Lower Stones River limestone is thought to be the close correlative of the Bluefield phase of the Murfreesboro formation, but exact ~~correlation~~ identification is not possible until the intervening areas have been more thoroughly studied. It is the lowest member of the Stones River group of Early Ordovician age.

Mosheim Limestone

The Mosheim[1]. is an extremely pure, thin limestone that occurs near the base of the Lower Stones River group; it is absent in some parts of west-central Virginia.

1. Ulrich, E. O., Revision of the Paleozoic systems; Geol. Soc. America Bull., vol. 22, pp. 413-414; 538; 543-544; 557; 636; pl. 27 , 1911.

Character. - The most typical constituent of the Mosheim is a zone of vaughanite - dense, structureless limestone - that varies in color from light blue-gray ("dove-colored") to dark gray-blue. The rock is very brittle and breaks readily with a strong conchoidal fracture; it rings metallically when struck with a hammer. The vaughanite contains tiny blebs and stringers of pure, transparent calcite that are irregularly, but persistantly, scattered through the entire mass of the stone. On weathered surfaces, which are generally smooth and unfurrowed, the Mosheim becomes dirty brown or chalky white. The rock is massively but evenly bedded.

Distribution and Thickness. - The formation is thin and was found only in scattered parts of this area. It occurs (1) in the belt of Ordovician rocks from Indianrock to Highbridge (Section 8,9,13), Church, (2) near Murat, (Section 14), and (3) along Purgatory and South Buffalo creeks. The best exposures occur on the road leading to Rocky Point, and near Dunkard Church. Its thickness at Murat is 6 feet; near Indianrock, 32 feet; and near Rocky Point, 158 feet.

It is not known to be present in the Ordovician outcrops of Rich Patch valley, nor elsewhere in the Eagle Rock quadrangle.

Surface Features. - Mosheim soil is commonly brown, although the rock outcrops are seldom sufficiently large to produce a distinctive type of soil or of topography. It has been quarried near Indianrock for lime.

Age. - Fossils are very scarce in this formation, and the most abundant form is a species of Tetradium. On the basis of its position and fossil content, the Mosheim limestone is identified as ~~Lower~~ early Ordovician in age.

Lenoir Limestone

The Lenoir is a dark, finely crystalline limestone originally named by J. M. Safford[1] in 1876 from Lenoir City, Tennessee.

1. Safford, J. M., and Killebrew, J. M., Elements of the geology of Tennessee: pp. 108, 123, 130-131, 137; 1876.

Character. - This formation is prevailingly knobby, a character ~~shown more distinctly upon~~ which is more evident in weathered ledges than upon fresh surfaces. The rock is medium-bedded, but, where deeply weathered, the massive ~~zones~~ ledges break down into ~~thinner~~ slabby zones, producing a thin-bedded appearance. The Lenoir limestone weathers to a brown color and produces a thin, red to red-brown soil, which is occasionally unctuous, as on the hill slopes near Dunkard Church. (Fossil localities 46, 48.) The Lenoir contains many zones which produce (or contain) chert that is knobby, dark, and lenticular. (See Sections 14, 15, 16.)

In its typical expression, the Lenoir is a black, dense, finely crystalline limestone. Some of the massive beds reach ~~ten~~ 10 feet in thickness, but upon weathering, all exhibit a knotty, reticulate appearance that characterizes this formation. (See Pl. 7C, A.)

Distribution. - The Lenoir crops out near the border of the Athens shale, and ~~near the~~ along the upper margin of the Canadian dolomites. It entirely surrounds the large Athens shale area between Flatwoods and Fincastle (Section 12) where its ledges are exposed (1) along Catawba Creek at Kyles Mills, (2) on Borden Creek about 1½ miles northeast of North Fork School, (3) near Woodville Spring, and (4) along Slate Branch, where it is crossed by the Flatwoods-Kyles Mill road. (Section 10.) The latter road follows the Lenoir-Athens contact for more than a mile, and road-side ledges conveniently expose both formations. A small outcrop of Lenoir occurs at the foot of the hill ½ mile east of Howell Mills. The formation also crops out in a narrow belt along the foot of Switzer and Crawford mountains and in another belt that surrounds Rich Patch valley.

In the eastern half of the area, it has ~~three~~ 3 belts of outcrop: (1) Along the valley of South Buffalo Creek, (2) near Murat, and (3) in the belt of Ordovician rocks near Indianrock and Rocky Point.

Bluff City Member. - Along the road leading to Rocky Point, a light-gray coarsely crystalline limestone which is very similar in appearance to the Holston limestone occurs at the base of the Lenoir. It is 10 feet thick near Indianrock (Section 8) and 38 feet thick along the Rocky Point road (Section 9). It is thought to be the northern equivalent of the Bluff City limestone of Tennessee. As it was not observed elsewhere in the area, it is considered to be a lense,or wedge, that thins rapidly in all directions from the above localities. Other light-colored crystalline limestones are scattered through the Lenoir but are neither persistent nor stratigraphically important.

Relations. - The contacts of the Lenoir with the adjacent formations are apparently conformable but actually represent considerable erosion. Thus, in Rich Patch valley, the formation is overlain by the Lowville limestone, and both the Holston limestone and the Athens shale are absent; it rests upon the Lower Stones River limestone in the absence of the Mosheim limestone. In the vicinity of Eagle Rock and in the Flatwoods synclinal area, the Lenoir limestone appears to rest directly upon the Canadian dolomites. A similar relationship occurs near Highbridge Church and at Murat due to the rapid disappearance of the Stones River formations near the Rockbridge county-line. In the Rapps Mill region, and between Indianrock and Roaring Run, the Lenoir is underlain by the Mosheim limestone and overlain by the Holston limestone without evident unconformity.

Thickness. - The Lenoir limestone varies considerably in thickness. East of Fincastle it is reported by Dr. Ladd to be 85 feet thick. On Slate Branch, northeast of Flatwoods, its thickness is 122 feet; 2 miles farther north it is 164 feet thick. Near Blue Spring Creek in Rich Patch valley, it is 232 feet thick. (Section 11.) Its thickness at Murat is 43 feet; near Rocky Point it is about 200 feet thick. (Sections 8,9,13.)

Economic Use. - The Lenoir limestone is quarried at Rocky Point with the Holston for road metal and other construction stone. It has also been quarried near Indianrock. (See pp. 327-329.)

Fossils and Age. - This formation contains an abundance of fossils, most of which are difficult to extract from the rock. Brachiopods and bryozoa are common, especially a branching bryozoan that is abundant on weathered ledges; it is identified as a species of Monotrypa. The following fossils are reported in the Lenoir limestone near Lexington[1]. (Fossil locality X 45):

1. Bassler, R. S., The cement resources of Virginia west of the Blue Ridge: Virginia Geol. Survey Bull. 2a, p. 107, 1909.

Analotichia impolita
Monotrypa sp. undetermined
Batostoma cf. B. varians
Dalmanella cf. D. subequata (Conrad)
Camarella volborthi var. Billings
Orthoceras olorus Rogers
Bucania sulcatina Emmons
Plaesiomys strophomenoides
Stylarea parva

Other Lenoir fossils include the following species (fossil localities 46-49):

Rhinidictya sp. undetermined
Echinosphaerites cf. E. aurantium (Hisinger)
Orthis tricenaria Conrad
Dinorthis (Plaesiomys) platys (Billings)
Dinorthis pectenella (Emmons)
Camarotoechia plena
Hebertella costalis (Billings)
Maclurea magna LeSueur
Primitia sp. undetermined
Illaenus lautus Raymond
Homotelus cf. H. identus Raymond

The Lenoir is the upper member of the Stones River group of early Ordovician age.

Blount Group

Holston Limestone

The Holston limestone, which is abundantly quarried for lime and crushed stone, forms one of the most important economic resources of this area. It takes its name from Holston River in eastern Tennessee.[1.]

---

1. Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Knoxville folio (No. 16), map, 1895.

Character. - This formation is a gray, coarsely crystalline limestone which has many of the characteristics of a marble. Although massively bedded, it is poorly stratified, and varies from a rough crystalline limestone containing large, distinct calcite crystals, to an equally coarse, but glassy, rock in which the crystals are intergrown and not readily separable. Some ledges show a subconchoidal fracture.

The rock weathers readily to a deep, red-brown or chocolate, soil that is exceedingly fertile where cultivated. Where uncleared, it supports a sturdy growth of hog-weed. Its outcrop is marked by many sinks, springs, and other evidences of underground drainage, all of which are well exhibited in the belt near Murat. At Dunkard Church (Section 16), the Holston is a distinctly arenaceous limestone with thin, sandy stringers that suggest the presence of cross-bedding. The grains of clear sand are only visible where they have become stained by weathering, and largely escape notice in the fresh rock. In many parts of the area, the Holston is slightly pink, although a gray color predominates.

Distribution. - The Holston limestone crops out in several disconnected belts in the area, specifically (1) at Murat; (2) in a belt from Indianrock to Highbridge Church; (3) near Greyledge; (4) along South Fork of Buffalo Creek; (5) along the foot of Switzer and Crawford mountains; and (6) surrounding the Athens shale outcrop between Fincastle and Catawba Creek. Excellent exposures occur at Murat, near Dunkard Church, and at the quarries at Eagle Rock, Indianrock, and Rocky Point.

Natural exposures of the formation are usually rare, but under favorable conditions, the rock is abundantly exposed. ← One of the best exposures ~~of Holston limestone~~ occurs along James River at Eagle Rock where the rock has been extensively quarried from underground mines. At this locality, the Holston is ~~locally~~ involved in a series of overthrust faults and, with the Lenoir, has been thrust upon the upper beds of the Martinsburg shale. (See pp. 244-246.) A large mass of Nittany dolomite, which has been similarly overthrust upon the Holston, forms the roof of extensive underground workings. (See Pls. 55 and 56.)

Thickness. - The thickness of the Holston varies from 4 feet in Sugartree Hollow to 40 feet along James River at Eagle Rock. At the western end of Crawford Mountain, less than 2½ miles from the Eagle Rock quarries, it is barely 3 feet thick. At Dunkard Church and in Tory Hollow it is less than 20 feet thick; at Rocky Point it is 80 feet thick (Sections 9, 13); near Murat it reaches its maximum local thickness of 125 feet. (Section 14.) It is absent in Rich Patch valley.

Economic Use. - As one of the purest limestones of this region, the Holston has been abundantly quarried, especially at Indianrock, Rocky Point, and Eagle Rock. Further description of the quarries and of the commercial uses of the stone ~~will be found elsewhere in this report.~~ occur on pages 326-331.

Fossils. - Although the Holston limestone is meagerly fossiliferous, the ~~fossils~~ specimens are generally broken or macerated, and are difficult to extract from the rock. (Fossil localities 15, 51-53, 55-57.) The most common types are bryozoa, that appear as ramose (branching) and nodular (rounded) forms. Solenopora compacta Billings, which is the most abundant form, may be found in most layers of the Holston. Other bryozoa, including species of Batostoma and Scenellopora, are present, but no specific identifications were made. Several other fossils have been reported from the Holston limestone[1] of this general region. These include the following:

Batostoma sevieri Bassler
Bumastus lioderma Raymond
Bumastus longiops Raymond
Acrolichas (Platymetopus) cf. A. minganensis (Billings)
Platymetopus n. sp. (?)
Illaenus sp. undetermined
Paleoglossa gibbosa Willard

Age. - This formation was formerly called the "Murat limestone" from the fine exposures at the old bridge across Buffalo Creek at Murat Post Office.[2] The name "Murat," however, has been abandoned in favor of the term "Holston" which had been previously applied to the formation in Tennessee. The Holston limestone is of ~~Lower~~ early Ordovician age.

1. Bassler, R. S., op. cit., pp. 105, 108.
Raymond, P. E., Some trilobites of the lower middle Ordovician of eastern North America: ~~Bull.~~ Harvard Coll. Mus. Comp. Zoology vol. 67, pp. 121-122, 1925. (Bull.)
Willard, Bradford, The brachiopods of the Ottosee and Holston formations of Tennessee and Virginia: ~~Bull.~~ Harvard Coll. Mus. Comp. Zoology Bull., vol. 68, pp. 256, 1928.

2. Campbell, H. D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Amer. Jour. Sci., 4th ~~series~~, vol. 20, p. 447, 1905.

The writer is not convinced that the Holston limestone is a true stratigraphic unit. In the type localities of southwestern Virginia and Tennessee, where the "Holston" is well represented, the name is applied to a series of coarsely crystalline, somewhat pinkish, limestone or marbles, while ~~These beds~~ are underlain by the Lenoir limestone, and are overlain by the Ottosee limestone; ~~they are easily recognized. However,~~ pinkish coarse limestones of similar character, and with similar fossils, however, also occur below the top of the Lenoir, and above the base of the Ottosee, and cannot ~~These can in no way~~ be distinguished from analogous beds of the so-called "Holston," except by their position above, or below, the main mass of coarse limestones. When faunal lists of "Holston" fossils are studied, they are found to contain a curious assortment of Lenoir, Ottosee, Whitesburg and even Athens forms.

It is suggested (1) that the "Holston limestone" is merely a lithologic unit; (2) that the name "Holston" has been loosely applied to coarsely crystalline Ordovician rocks of both late Stones River and early Blount age; and (3) that the "Holston limestone" has no precise standing as a stratigraphic unit. As parallel instances, the use of the name "Romney" for any black Devonian shales, and the use of the term "Catskill" for any red Upper Devonian or Lower Mississippian rocks, may be quoted.

Whitesburg Limestone

The Whitesburg limestone,[1] named from Whitesburg, Tennessee,

1. Ulrich, E. O., in Marble deposits of East Tennessee: Tennessee Dept. Educ., Div. Geol., Bull. 34, 1924. 28 p.

occurs at isolated points in the belt of Athens shale from Virginia

to Tennessee. Where present, it immediately underlies the Athens, or is identified as the basal Athens member.

Character and Distribution. - The Whitesburg limestone is a coarse-grained, semicrystalline, dark limestone that is abundantly fossiliferous. It weathers to a rusty-brown color, and resembles the coarser lenses of the Athens with which it can be readily confused. No symbol has been used for this formation on the geologic map, Plate 1, where its local outcrop is included with that of the Athens (Oa).

The Whitesburg limestone is present (1) in the belt of Ordovician rocks that crosses the Rocky Point and Indianrock roads, and (2) near Murat. It is possibly represented at the base of the Athens 1 mile east of Howell Mills. It is not known to be present near Kyles Mill, at Eagle Rock, nor in Rich Patch valley. Where present, its thickness does not exceed 10 feet. Near Dunkard Church, a thin black phosphatic shale occurs directly above the Holston limestone at the horizon of the Whitesburg limestone. This shale, which is about 3 inches thick, is soft, crumbly, and is full of tiny oval phosphatic concretions. It was not observed elsewhere in the region.

Fossils and Age. - The Whitesburg limestone, which is characterized by numerous species of trilobites, especially Ampyx and Homotelus, is best identified by the presence of the tiny trilobite Agnostus, which is normally a Cambrian genus. The formation is of Blount (early Ordovician) age.

Athens Shale

This formation, originally named from Athens, McMinn County, Tennessee,[1] has been traced continuously from eastern Tennessee into northern Virginia.

1. Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), map, 1899.

Character. - In the Natural Bridge (l.c.) quadrangle - the eastern portion of this region - the Athens is essentially a shaly limestone (Pl. 36, B) and contains even-bedded, slaty layers of black limestone that are separated by thin, black-shale partings. (See Pl. 37, A.) Near Indianrock, the shale is almost entirely brownish black and contains few limy beds; both types of rock carry typical Athens graptolites. The shale is very fine-grained and weathers to a brown, splintery soil.

As a whole, the eastern beds of the Athens closely resemble the overlying Chambersburg limestone and are not greatly dissimilar from the Martinsburg shale. Indeed, these three units are difficult to distinguish on other than paleontologic evidence. The limestone members of the Athens, however, are thicker and more fine-grained than those of the Chambersburg limestone; the shales are generally chocolate-black, and the formation is less regularly bedded than the Chambersburg formation. Martinsburg shale is normally gray or light-gray, whereas the Athens is distinctly a dark-colored formation. The Athens shale weathers readily, and its soil is fairly productive. Its outcrop forms a rolling country in which exposures are uncommon.

In the Eagle Rock (or western) portion of the local area, the Athens shale consists of a thick mass of black to chocolate-colored shale, with scattered limy zones interbedded through the series. The black color of the rock becomes lighter upon exposure, and weathered ledges of the rock are dark buff or grayish yellow. The formation readily disintegrates to a thin sterile soil ~~that~~ which is filled with tiny shale prisms ~~which~~ that have thin, sharp edges. The "pencil-weathering" of the Athens shale readily distinguishes it from the "Romney" black shale. So quickly does the formation crumble that a freshly detached slab of Athens shale will crumble to dust within a month's exposure.

The Athens contains an interesting limestone conglomerate, or breccia, that is exposed near Dry Run School.[1] This member

---

1. Quantities of well-formed bipyramidal quartz crystals, about ½ inch long, may be picked up from the loose Athens soil in this vicinity.

---

is a massive gray rock that is made up of limestone fragments held in a calcareous cement. The pebbles are elongated, but show evidence of rounding; some of them are 6 inches long. The longer axes of the pebbles are roughly parallel to the bedding of the rock. Several of these conglomerate, or breccia zones are present, separated by gray shales. The beds vary in thickness from 1 to 20 inches, and the limestone of the pebbles is hard, dense, and blue. About 2 miles due north of Howell Mills, the limestone conglomerate is associated with other calcareous beds that range through at least 200 feet of shale. The associated limestones which are dense and hard, ~~They~~ are blue upon

exposed surfaces, but are dark within. They weather to pillowy masses of rounded limestone that stand in hummocky relief along shale slopes. The western Athens shale also carries a few persistant limestones, one of which is ~~over~~ more than 50 feet thick near Fincastle.

In the Eagle Rock region, the Athens shale has been faulted to a position near the "Romney" black shale, from which, however, it can be readily distinguished. The Athens shales are brittle, readily cleavable, and marked by the so-called "pencil-weathering." "Romney" shales are weak, not especially fissile, and do not produce strong shale splinters upon weathering. Rusty colors are more common on the fragments of "Romney" shale than upon Athens fragments, and the chocolate-colored shales of the Athens have no counterpart in the "Romney". The chocolate beds carry abundant graptolite fossils, but are difficult to split along the surfaces on which the graptolites occur. The Athens shale is seldom slaty except in fresh cuts.

Pebble-Conglomerate Member. - An interesting pebble-conglomerate in the Athens is crossed by ~~the~~ State Highway 12, 1½ miles north of Fincastle, at the western edge of Pine Hills. (See Pl. 37, B.) The road cuts expose a zone of massive conglomerate, sandstone, and interbedded shale lentils, about 120 feet thick. The conglomerate members contain an assortment of pebbles that average 1 inch or more in diameter; some are more than 10 inches thick. The pebbles, which are well rounded, are nearly all of white quartz or sandstone. They are cemented in fine sand which is impregnated with limonite; the latter gives the beds a rusty-brown,

or heather, color. The conglomeratic zones range from a few inches to 15 feet in thickness. Their upper and lower contacts ~~of the zone~~ are vague, for the coarse material grades imperceptibly into the normal Athens shale. The sandstones, which are grayish-brown, dense, and hard, ~~They~~ are composed of sub-round, unfrosted, quartz grains in a limonitic cement. A few green pebbles ~~Some grains which are green~~ have apparently been derived from the crystalline rocks of the Blue Ridge. The conglomeratic beds are very tough and break across, rather than around, the pebbles. The edges of the latter are well rounded, and more than half of them appear to be slightly flattened.

The pebbly zones also cross the road 1 mile farther south on the southern side of the syncline which underlies Pine Hills, where a thickness of 115 feet, exhibiting the same general sequence of beds occurs. This exposure is only a short distance north of a fault along which the Conococheague formation has been overthrust upon Athens shale.

Two other exposures of the pebble conglomerate have been examined. One forms a small syncline near the abandoned Dry Run School. The other occurs in a similar syncline between the North Fork road and Bordens Creek, due west of the Fairgrounds.

It is suggested that the clastic beds were deposited in a local stream delta by distributaries that carried coarse material some distance into the zone of normal shale deposition. As most of the pebbles seem to have come from the Blue Ridge crystalline rocks, it is supposed that the stream came from the east. No fossils were observed in the conglomeratic zones, nor in the shale beds adjacent to them.

Distribution. - The Athens shale crops out along Catawba Creek in a broad synclinal trough called the Flatwoods syncline. Its outcrop has the shape of a woman's shoe, in which the heel is represented by the belt of shale east of Fincastle, the instep by the limestone area between Fincastle and Howell Mills, and the toe by the shale belt west of Howell Mills. The western point of the Athens outcrop extends south of the present area. The maximum width of this outcrop is 8 miles, measured in a northeast direction. It is 4 miles across in a northwest direction. Fine exposures of the shale occur along State Highway 12 north of Fincastle.

A small belt of Athens occurs east of Switzer Mountain and Poplar Hill. It is truncated on both sides by faults, and has a maximum width of less than ½ mile. No Athens shale occurs in Rich Patch valley.

In the eastern part of the area, the Athens has 4 isolated outcrops: (1) around the anticlinal area of Ordovician rocks near Murat; (2) in two belts near Rapps Mill; (3) along Spring Branch and South Fork of Buffalo Creek, near Oakdale; and (4) in the narrow infaulted belt between Indianrock and Highbridge Church. (Sections 9, 13.)

Thickness and Relations. - It is difficult to determine the thickness of the Athens shale in the Flatwoods region. However, it is possible that as much as 1,500 feet of shale is present, and that the greatest local thickness is reached in this belt. (Sections 14, 15.) Near Murat, the thickness approaches, if not exceeds, 300 feet. In the Rapps Mill area, the Athens rapidly thins toward the south. (Section 16). It is 5 feet thick near Dunkard Church, and is completely absent along the headwaters of Purgatory Creek.

As the formation is generally tightly folded, its shales are commonly crushed, and the calcareous beds contain many calcite veins. The lower contact of the Athens and Holston limestone is sharp and unconformable. Its contact with the Whitesburg limestone, where the latter is present, is conformable. The upper contact is disconformable.

Fossils and Age. - The Athens shale contains many fossils which include graptolites, trilobites, and brachiopods. A large list of fossil species is reported from the Athens shale near Lexington[1]. (Fossil locality 62):

1.
Bassler, R. S., op. cit., p. 110.
Raymond, P. E., op. cit., pp. 11, 17, 38, 69, 91, 108, 110, 125, 160.

Christiania sp. undetermined
Hebertella bellarugosa (Conrad)
Dinorthis (?) platys Schuchert
Dinorthis pectenella (Hall)
Triplesia sp. undetermined
Camerella cf. C. varians
Scenella montrealensis
Buchania cf. B. sulcatina Emmons
Tetranota bidorsata (Hall)
Cyclora minuta Hall
Liospira lenticularis
Ampyx camurus Raymond
Eoharpes ottawaensis Raymond
Illaenus fieldi Raymond
Bronteopsis gregaria Raymond
Homotelus obtusus (Hall)
Pterygometopus annulatus Raymond
Remopleurides canadensis Billings
Acrolichas minganensis (Billings)
Sphaerexochus parva (Billings)
Arthrorhachis galba
Ceraurus granolusus Raymond and Barton

The following additional species were collected from localities 5-14, 58-61, 63-64:

Phyllograptus typus Hall
Dicellograptus divaricatus
Dicellograptus sextans Hall
Dicellograptus moffatensis
Dicellograptus smithi
Dicellograptus moffatensis var. alabamensis
Diplograptus foliaceous Murchison
Dicranograptus cf. D. ramosus Hall
Dicranograptus spinifer Sapworth
Dicranograptus ramosus Hall
Dicranograptus nicholsoni var. perangulus Gurley
Retiograptus eucharis Hall
Caenograptus gracilis (Hall)
Climacograptus typicalis Hall
Climacograptus putilus Hall
Climacograptus bicornis Hall
Nemograptus gracilis Hall
Didymograptus serratulus Hall
Dichograptus sp. undetermined
Hebertella vulgaris
Sowerbyella prisa
Parastrophia hemiplicata Hall
Leptobolus (?) ovalis
Cyrtodonta sp. undetermined
Primitia sp. undetermined
Ampyx americanus Safford and Vogdes
Hemigyraspis sp. undetermined
Dionide holdeni Raymond
Triarthrus caecigenus Raymond

The Athens shale belongs to the Blount (l.c.) group of the Chazyan (l.c.) series and corresponds to the Normanskill shale of New York.

Black River Group

Moccasin-Lowville Formation

Beds of upper Lowville age, which occur at two localities in the western half (Eagle Rock quadrangle) of this area, have no equivalents elsewhere in the Natural Bridge region.

Inasmuch as the two exposures exhibit materials of different character, each is described as a separate unit although both are similar in stratigraphic position and in age.

Lowville Limestone. - The Lowville limestone is exposed near the large spring at Hooks Mill in Rich Patch valley, where it is a steel-blue or dove-colored limestone that is crowded with fragments of Tetradium cellulosum Hall. The beds lie immediately beneath the basal Martinsburg shales, and attain a thickness of about 30 feet; they are well exposed along the hillslope a short distance above the spring. The Lowville limestone is very similar to the Mosheim limestone and to the purer beds of the Nittany dolomite.

Several miles southwest of this locality, near Blue Spring Creek, the interval between the Martinsburg and Lenoir is occupied by dark, medium-bedded, crystalline limestones that are interbedded with finer-grained, dark limestones through a zone ~~which is 65~~ that is 24 feet thick. (Section 11.) No specimens of Tetradium were found, but the stratigraphic position of the limestones suggests a Lowville age. The relations of these two outcrops of Lowville limestone to each other are not known; both show the Lowville resting directly upon the Lenoir limestone.

Moccasin Sandstone. - A thin ledge of sandstone occurs between the Martinsburg and Athens shales, midway between the southwestern end of Crawford Mountain and Poplar Hill, along the road through the gap. ~~Because of its lithology and~~ As this outcrop has the lithologic character and stratigraphic position of the Moccasin sandstone, it is correlated with that formation. ~~this outcrop is assigned to the Moccasin sandstone~~. The local Moccasin ~~sandstone~~, as observed, is less than 5 feet thick and consists of a single bed of massive sandstone which is rusty brown on the surface and light brown within. The rock is medium-textured and, so far as is known, ~~is un-~~ carries no fossils. It is absent below the Martinsburg shale 1 mile northeast of this locality and is cut off by a fault 1 mile to

the southwest. The ~~ledge has the position and lithology of the Moccasin sandstone, and it~~ bed is presumed to be the thin edge of a thicker body which formerly lay to the southwest, but which elsewhere has been eroded, faulted, or otherwise concealed from view.

Age and Correlation. - The Lowville limestone and its equivalent, the Moccasin sandstone, are of Black River age; they are correlated with the type Lowville of Jefferson County, New York. These formations occur only in the western half of the area and do not occur where the Chambersburg limestone is present. In the type region of the latter in Pennsylvania, however, the Chambersburg overlies other Lowville horizons.

Chambersburg Limestone

The type locality of the Chambersburg limestone[1]. is at Chambersburg, Pennsylvania.

---

1. Stose, G. W., Sedimentary rocks of South Mountain, Pennsylvania; Jour. Geology, vol. 14, p. 211, 1906.

Character. - In the Natural Bridge region, this formation is a thin, but regularly bedded, knobby limestone that resembles the underlying Athens and overlying Martinsburg shales. At least three different lithologic types occur within the formation. ~~One is prominent~~ Where the rock has been intensely folded, ~~it produces~~ wide, flat, exposures reveal ~~that show the results of intimate deformation. This type, which is~~ such as that a bluish-gray, fine-textured limestone, ~~is well~~ exposed along the southeastern flank of Short Hills. Entirely distinct from the above is a ~~very~~ knobby, blue limestone that weathers to a yellowish color and produces an extremely knotty surface. (See Pl. 38, B.) This phase of the Chambersburg is similar in lithologic appearance to the knotty beds of the

Lenoir limestone. The ~~"cobbly"~~ irregular nature of the weathered ledges is due to a wavy lamination, or parting, that crosses the bedding at a high angle and which, during weathering, produces rounded, lenticular masses resembling rough cobbles. (See Pl. 38, A.)

The Chambersburg is also represented by a dark, blue-gray, irregularly bedded shale that weathers to a yellow color and is similar to the limy shales of the Martinsburg. The shale, however, is less regularly bedded than Martinsburg shales, and ~~lacks~~ fails to contain the extremely fossiliferous limestones that are common in the shales of the Martinsburg. Dark, or black, limestones that occur in the Chambersburg formation are somewhat coarser and more grainy than the limestones of the Athens. The Chambersburg also includes many thin zones of black shales that occur as partings between the limestone members. Near Grayledge, 4 miles north of Buchanan, an extremely pure, massive, gray limestone occurs in the Chambersburg.

Distribution. - The Chambersburg limestone occurs only in the eastern half of this area. It crops out around Short Hills and surrounds the anticlinal valley of South Fork of Buffalo Creek. It is absent in the belt of Ordovician rocks northeast of Indianrock.

The best exposures occur along the valley of Rocky Run immediately west of the Lee Highway. It is also well exposed at Grayledge, and in the vicinity of Green Hill (Pl. 39,A), north of Oakdale.

Soil and Relations. - Chambersburg soil is generally red and fairly thin; it contains abundant limestone debris. The formation produces weathered slopes that are covered with irregular, slabby, ~~shale~~ limestone fragments. These fragments have rounded edges, and

many of them are covered with tiny "chatter-marks".
are platter-shaped; limestone debris from Athens or Martinsburg shales is less rounded and more slabby. Natural exposures of the Chambersburg are abundant; its topographic expression is entirely similar to that of the shales above and below. The formation is intimately folded, and its ~~contacts which are~~ contacts disconformable are difficult to locate because of the similarity of beds above and below them.

Fossils. - The Chambersburg formation is sparingly fossiliferous, the chief forms being Echinospherites and Nidulites, both of which are abundant in the region around Green Hill, north of this area. The following fossils were collected from the local Chambersburg limestone (localities 65-67):

Nidulites sp. undetermined
Echinosphaerites aurantium (Hisinger)
Christiania trentonensis (Ruedemann)
Zygospira cf. Z. recurvirostris (Hall)
Zygospira sp. undetermined
Orthoceras multicameratum Rogers
Leperditia fabulites (Conrad)
Aparchites granilabiatus
Ostracoda sp. undetermined
Isotelus gigas Vanuxem

Economic Use. - Rock from this formation is not used for any commercial purpose within the area, but the very pure limestone which occurs at Grayledge has a possible use for ~~use in~~ lime or cement manufacture.

Thickness. - The maximum thickness of the Chambersburg limestone is about 540 feet (Section 16), from which it decreases until the formation entirely disappears. The thickness is greatest near Lexington (Section 15), where a considerable body of the so-called "Liberty Hall limestone" [1/] belongs to the Chambersburg. The formation is of upper Lowville (Middle Ordovician) age.

1. Campbell, M.D., The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia: Am. Jour. Sci., 4th ser., pp 445-447, 1905.

Martinsburg Shale

The Martinsburg shale, first studied at Martinsburg, West Virginia, was named by Darton[1.] in 1892.

1. Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Amer. Geologist, vol. 10, p.13, 1892.

Character. - The greater part of the Martinsburg formation is soft, thin-bedded, and argillaceous. Its lower portion consists of gray shales and limestone partings; the shales usually carry few fossils, whereas the limestone lenses are full of broken or disjointed fossil fragments. The middle portion of the Martinsburg consists of soft, tan to buff, shales in which fossils are common and which weather readily to form a soft, sticky, yellowish soil. (See Pl. 40, A.) The upper part of the Martinsburg is more massive and contains sandy members that increase both in thickness and in abundance toward the top of the formation. Portions of the Martinsburg are similar in general appearance to the Chambersburg limestone but are less limy and more argillaceous. Smaller areas of limestone outcrop are produced by the Martinsburg shale than by the Chambersburg limestone.

Distribution. - Despite its considerable thickness, the Martinsburg shale is not abundantly exposed. It crops out along the inner flank of the mountains surrounding Rich Patch valley where it overlies the Lowville limestone and is overlain by the Juniata shale. Exposures are common along the road which leads south-southeast from Mountain Valley School down Barber Creek. Other exposures occur on Montgomery Knob (Pl. 13, B), and in the wide recess of Finley Branch between Montgomery Knob, Pine Mountain,

and Shoemaker Knob. A small outcrop also occurs northwest of Porter and Johnson mountains.

There is a narrow belt of Martinsburg shale which crops out along the foot of Crawford Mountain; it crosses the James at Eagle Rock, and widens to flank Rathole and Sheets mountains on the east and south. Good exposures were examined in Limestone and Hickory hollows and on the flank of Purgatory Mountain. (See Pl. 13,A.) An important outcrop of the Martinsburg follows the southeastern slope of Switzer Mountain. The shale extends nearly to the crest of the ridge and is truncated at both ends of the mountain by faulting. Isolated exposures of the Martinsburg occur in the Eagle Rock gap and at the head of the knife-like ravine between Sheets and Rathole mountains. There is no Martinsburg shale in the synclinal area of Ordovician rocks between Flatwoods and Fincastle. The Martinsburg shale forms a wide belt that completely surrounds Short Hills and The Knob (Pl. 18,A) and continues southwestward nearly to Purgatory Creek. Another wide belt that extends northward from a point about 1 mile north of Buchanan to the western and northern boundary of the area, surrounds Purgatory, Gully, Orebank, and Camp mountains. The formation is exposed in Cartmell Gap, along the road leading from the Lee Highway to Dunkard Church, and along the road leading over Pricehouse Mountain.

Subdivisions. - Three lithologic subdivisions may be recognized in the local Martinsburg shale: (1) a lower, limy division that corresponds to the Trenton limestone; (2) a middle shaly division of Eden age; and (3) an upper sandy portion of Maysville age. The Eden division consists of yellow, sandy shales that readily weather to a soft, sticky clay. The Maysville division contains flaggy sandstones and is more highly lithified. In Rich

Patch valley, the Trenton division consists of olive-green, limy shales that are soft and contain a few limestone lentils. ~~This character is dissimilar to~~ the Trenton in the vicinity of Sheets Mountain, where ~~the division~~ is much thicker and ~~was~~ more highly lithified; it consists of thin, flaggy, gray shales interbedded with fossiliferous limestones. The lower division of the Martinsburg thickens toward the northeast; the Eden and Maysville divisions appear to become thinner in that direction.

Metabentonite. - A thin bed of metabentonite, which is associated with the lower Martinsburg shale, was first described by Nelson[1] from a locality along Lee Highway, a few miles north of Buffalo Creek, and was later discussed by Giles.[2] Similar beds have been reported over a wide area in eastern and central North America.

1. Nelson, W. A., Volcanic ash deposit in the Ordovician of Virginia: Geol. Soc. America Bull., vol. 37, pp. 149-150, 1926.

2. Giles, A. W., The origin and occurrence in Rockbridge County, Virginia, of so-called "bentonite": Jour. Geology, vol. 35, pp. 527-541, 1927.

The material consists of a soft, unctuous clay which is a few inches thick and is very smooth and slippery. It contains tiny flakes of mica and, upon microscopic examination, shows shards and other fragments of volcanic glass. It ~~horizon~~ is relatively inconspicuous, and ~~the metabentonite~~ escapes casual observation, although it may be found by careful search in any complete section of the lower Martinsburg shales. It has also been observed at several localities along the eastern flank of Short

Hills, where its presence may be detected by a peculiar pinkish-white, unctuous soil that forms a narrow zone along the streams and roads which cross the lower Martinsburg outcrop.

There is little doubt that the material is of volcanic origin, a fact which gives it considerable importance, for it indicates active vulcanism at a time generally supposed to be devoid of volcanic activity.

Topographic expression. - As the outcrops of Martinsburg shale are commonly located near belts of resistant Silurian sandstone, the topographic expression of the shales is chiefly controlled by adjacent formations. The shales commonly produce smooth, even slopes along mountain flanks that are covered with light, brown soils. Although poorly located for cultivation, Martinsburg outcrops are commonly cleared and farmed or used for pasturage. Gullies develop quickly where natural vegetation and soil cover are removed. Many of the mountain gaps, or cols, such as Cartmell, Alexander, and Heartsblood gaps (Pl. 41, A), are level grassy plots floored with Martinsburg shale.

Relations. - In Rich Patch valley, the Martinsburg shale overlies the Lowville limestone and is conformably overlain by Juniata shales. Elsewhere, the Juniata is absent or poorly developed, and the Clinch sandstone rests unconformably upon the Martinsburg shale. In the absence of the Lowville limestone or its equivalent, the Moccasin sandstone, the Martinsburg shale rests upon the Chambersburg limestone, or, where the latter is absent, upon the Athens shale. The lower contacts of the Martinsburg are disconformable.

Thickness. - Although no exact measurements of the Martinsburg shale were made, its thickness is estimated to range from 1,200 to 1,500 feet.

Fossils. - Although the entire Martinsburg shale is not abundantly fossiliferous, certain horizons carry many fossils which may be ~~are best~~ collected from the surfaces of weathered slabs or in soft, yellow clay-shales such as those found in Rich (fossil localities 16,69) Patch valley or in the gap between Sugarloaf and Grassy (locality 73). mountains. Each phase of the Martinsburg has a characteristic collected from localities 68,70-72,74-75 fossil fauna, and the following species are distinctive:

Maysville Division

Orthorhynchula linneyi James
Lingula nicklesi (Bassler)
Byssonychia radiata Hall
Byssonychia walkerensis Grabau
Modiolopsis modiolaris Conrad

Eden Division

Crinoid stems
Streptelasma corniculum Hall
Plectambonites sericeus (Sowerby)
Dalmanella cf. D. multisecta (Meek)
Dalmanella testudinaria var.
Leptaena tenuistriata
Rafinesquina alternata (Emmons)
Zygospira recurvirostris (Hall)
Ctenobolbina ciliata Ulrich

Trenton Division

Climacograptus sp. undetermined
Lasiograptus cf. L. mucronatus
Prasopora simulatrix Ulrich
Mesotrypa sp. undetermined
Merocrinus sp. undetermined
Dalmanella edsoni Sanderson
Plectorthis plicatella Hall
Sowerbyella curdsvillensis Foerste
Sowerbyella cf. S. rugosa
Hebertella borealis (Billings)

Lophospira medialis Ulrich
Lophospira bicincta (Hall)
Liospira micula
Sinuites cancellatus (Hall)
Orthoceras multicameratum Hall
Orthoceras juncerum
Spyroceras bilineatum
Ceratopsis oculifera
Triarthrus becki (Eaton)
Isotelus gigas Dekay
Cryptolithus tesselatus Green

Age. - The Martinsburg shale ranges from late middle to late Ordovician in age.

Juniata Shale

The uppermost Ordovician formation of this area is the Juniata shale[1].

1. Darton, N. H., U. S. Geological Survey Geol. Atlas, Franklin, West Virginia - Virginia folio (No. 32), 1896.

which directly underlies the Clinch sandstone in the northwestern part of the region. It is not known south or Craig Creek nor east of James River, unless it is represented by a few feet of gray flags opposite the east end of the old James River bridge at Eagle Rock.

Character. - The Juniata shale consists of a mass of pinkish-red sandstone and shale. The sandstones are rather massive, medium bedded, ranging from 6 inches to several feet in thickness. They are separated by shale seams that weathers into small, chunky masses which produce tiny talus cones (See Pl. 42, A.) upon ledges of the underlying sandstones. As a whole, the formation is thinly bedded. Red colors are prominent in the middle of the formation, where the purple, checky, sandy shales resemble those of the Moccasin formation at Newport, Giles County. The red beds disappear near the top of the Juniata, where the upper 20 feet

contain gray-buff and olive, flaggy sandstones.

Near Porter and Johnson mountains, there is a massive gray-green sandstone at the base of the formation which is from 8 to 10 feet thick, and which might be mistaken for a thin ledge of Silurian sandstone. It is probably the equivalent of the "Gray Medina sandstone" of adjacent areas in West Virginia.

Distribution. - The Juniata outcrop is so ~~close to that~~ near of the Clinch sandstone that its topographic expression is largely controlled by the harder Silurian formation. The Juniata shale crops out along the margin of Rich Patch valley, and is commonly exposed along streams that breach the valley rim. Good exposures occur in Hays Gap and also between Porter and Johnson mountains.

The formation does not occur in the eastern half (Natural Bridge quadrangle) of this area.

Thickness and Correlation. - Although accurate determinations of the thickness of the Juniata shale are lacking, it is estimated to reach a maximum of 300 feet.

In adjacent areas of West Virginia, where equivalents of the Juniata shale are largely arenaceous, the West Virginia Geological Survey has described the Juniata as the "Red (and Gray) Medina sandstone", and assigned it to the Silurian System. In southwestern Virginia and eastern Tennessee, the Juniata shale grades into, or is replaced by, the marine Sequatchie formation which carries fossils of Richmond age. Ulrich and Butts have assigned the Richmond group to the basal Silurian, and correspondingly consider the Juniata shale to be of Silurian age.

The author does not concur with either of these interpretations, and, with the majority of workers in Appalachian stratigraphy, places the Juniata shale in the Richmond group, but assigns the latter to the uppermost, or latest, Ordovician. There is no field evidence in the local area to determine the exact age of the formation save the single suggestive fact that the lower contact of the Juniata with the Martinsburg shale is gradational, whereas the upper contact with the Clinch is both lithologically and structurally disconformable.

Silurian System

Rocks of Silurian age produce most of the Appalachian ridges west of the Blue Ridge. The system is represented by a thickness varying from 400 to 970 feet of rock (Sections 17-22), the lower part of which is largely clastic, consisting of hard, quartzitic sandstones and sandy shales. The upper portion of the Silurian is essentially calcareous. The local Silurian formations may be classified as follows:

Upper Silurian
Tonoloway limestone

Middle Silurian
Keefer sandstone } (Clinton)
Cacapon sandstone }

Lower Silurian
Clinch sandstone

The base of the Silurian is a stratigraphic horizon that is easy to detect, for the massive white Clinch sandstones form a striking contrast to the beds at the top of the Ordovician system. The lithologic unconformity is well exhibited by the topography, in which rugged Clinch ledges sharply give way to smooth, flowing slopes developed upon Juniata and Martinsburg shales. The structural relations of the formations above and below this contact are slightly unconformable. A similar topographic break occurs above the arenaceous Silurian rocks and below the relatively weak Tonoloway limestone. The stratigraphic contact between the Tonoloway and Keyser (basal Devonian) limestones appears to be conformable. The local outcrop of Silurian rocks is shown in Figure 24.

Clinch Sandstone

The Clinch sandstone, which is entirely arenaceous, is one of the most conspicuous rocks of this region. It is named from its occurrence on Clinch Mountain[1]. in Tennessee and southwestern Virginia.

---

1. Safford, J. M., A geological reconnaissance of the State of Tennessee; 1st report, Tenn. State Geologist, p. 157, 1856. ← Nashville,

---

Character.--The Clinch is characterized by white to pinkish-white sandstones that are very resistant and are commonly coarse-textured. (See Pl. 40, B.) Many of the beds are so highly indurated that they approach true quartzites. Some outcrops expose ledges that are conglomeratic with white quartz pebbles ~~an~~ 1 inch in diameter scattered through them; other exposures show crossbedding, and still others are fine-grained. Clinch sandstones usually contain well-rounded quartz grains that are cemented by silica and are partially surrounded by iron oxide.

This rock is easily confused with the Keefer sandstone; indeed, it is almost impossible to distinguish hand specimens of the two rocks. In a ledge, however, they may be identified by the fact that the Keefer contains many thin-bedded members, whereas the Clinch generally forms a single ledge. (See Pl. 50, B.) The rock, which erodes and weathers with much difficulty, produces steep crags and cliffs that are normally flanked much angular debris. Abundant natural outcrops occur along the crests and at the ends of ridges. As a whole, the Clinch weathers to a grayish color, and its ~~crags and~~ ledges are usually covered with lichen. Its outcrop supports a sparse growth of timber as ~~its~~ The soil is thin and sterile. It is a ridge-maker of the first magnitude, and its beds are commonly inclined and are often vertical.

Distribution.--The Clinch formation crops out along the crest of Short Hills, Purgatory, Back Creek, Mays, North, Switzer, Rathole (Pl. 57), Sheets, Crawford (Pl. 58), Rich Patch, Carpenter, and House mountains (Pl. 39, B), each of which owes its elevation to the resistant quartzite ledges. Excellent exposures of the formation occur at Eagle Rock (Section 21), along Roaring Run (Section 18), in Hays Gap, and in the gap of James (Jackson) River at Iron Gate (Section 20). The Clinch is also exposed along Cedar Creek at the point where it cuts through the eastern rim of Short Hills, as well as on Back Creek (Pl. 41, B) ~~one~~ mile east of the horseshoe bend of James River. (Section 22.) Possibly the most accessible exposures are those in the great arch at Iron Gate, where the Clinch forms the lower most massive bed. (See Pl. 50, B.) In general, exposures of Clinch sandstone are rather inaccessible and difficult to reach.

Thickness.--The Clinch varies in thickness, but maintains an average thickness of about 170 feet. It is 170 feet thick in the gap at Eagle Rock and 173 feet thick in Cartmell Gap. (Section 19.) Along the road leading west from Collierstown, the Clinch is 197 feet thick. (Section 17.) Over 220 feet of sandstone are assigned to the Clinch in the exposures along Back Creek. It is only 60 feet thick near Hooks Mill. (Section 18.)

Economic Use.-- The Clinch sandstone has no economic use, but would furnish good stone for rough construction.

Fossils and correlation.--Fossils are uncommon in the Clinch sandstone. Peculiar markings, known as Arthrophycus and Scolithus, have been observed (locality 76) but are rarely present; no other forms are known from this region. The Clinch sandstone is of Medinan (~~Lower~~ early Silurian) age and corresponds exactly to the Tuscarora quartzite of northwestern Virginia, Pennsylvania, and Maryland. It is called the "White Medina sandstone" by the West Virginia Geological Survey.

Clinton Group

Cacapon Sandstone

The Cacapon formation, which is largely a red sandstone, also contains a large body of buff and olive-colored shales. It was named in 1896 by Darton and Taff.[1]

---

1. Darton, N. H., and Taff, J. A., U. S. Geol. Survey Geol. Atlas, Piedmont folio (No. 28), map, 1896.

Character.--The Cacapon formation is easily recognized by its sandstones which, when observed in a stream bed, or in a fresh ledge, show a distinctive, deep-red color. (See Pl. 42, B.) Many of the sandstones are interbedded with shales. Some of the latter are red, but more are olive+buff or green. The red color of Cacapon rocks is deeper and more blood-red than the purple-red color of the Juniata or the pinker colors of the Rome ("Watauga") shale.

Many Cacapon sandstones are massive and reach 10 feet in thickness, although, by comparison with adjacent ledges of Clinch and Keefer sandstones, they are insignificant in their effect upon the topography. As the Cacapon shales weather readily, a cliff showing the entire Silurian sequence, is commonly notched at the outcrop of the Cacapon. Some Cacapon sandstones carry worm-like markings of uncertain origin.

Topography and Soil.--The soil derived from this formation although moderately fertile, is thin and loose; its hill-top position renders it productive only in favored localities. Occasionally the Cacapon outcrop can be recognized as a planted strip along the crest of a ridge where ambitious farmers have cleared the softer area between the two resistant Silurian formations. ~~Nevertheless~~ More commonly, the outcrop of the Cacapon is ~~more apt to be~~ wooded or covered with dense undergrowth ~~than outcrops of the other Silurian sandstone~~.

Distribution.--With adjacent Silurian rocks, the Cacapon has been folded into large, open folds that produce most of the ridges of the central and western portions of this area. Natural exposures are common. The Cacapon forms accessible ledges at Hooks Mill, Eagle Rock (Pls. 57 and 58), Iron Gate, Hays Gap, on Short Hills, and along the road over Prisehouse Mountain. An excellent exposure occurs on North Mountain between Colliers town and Longdale (Section 17.). The gap between Sugar Loaf and Gully mountains is floored with Cacapon sandstone, and the rim of Rich Patch anticline exhibits an excellent, inaccessible, exposure.

Iron ore.--Near the top of the Cacapon, there is a thin zone of "Clinton" iron-ore which reaches a maximum thickness of two feet on Rich Patch Mountain (Section 18.). Elsewhere, it is much thinner or entirely absent. It has been prospected at several areas in the Eagle Rock region, chiefly (1) near Roaring Run on the southeastern slope of Rich Patch Mountain and (2) near the crests of Rathole and Sheets Mountains. The ore and its prospects are described more fully ~~in another portion of this report.~~ on pages 300-302.

Thickness and relations.--The Cacapon varies in thickness from 110 to 250 feet (Section 21). At Eagle Rock it is 110 feet thick; at Clifton Forge it is 170 feet thick; at Rich Hill, 177 feet thick (Section 22), and at Hooks Mill, 250 feet thick (Section 19). It is 127 feet thick in Cartmell Gap and at least 250 feet thick on North Mountain (Section 17).

The contacts of the Cacapon sandstone with adjacent beds are conformable.

Fossils and correlation.--A few fossils, mainly ostracodes, occur in Cacapon shales. The following species were found near Hooks Mill (locality 77) and in Hays Gap (localities 17 and 78):

Buthotrephis gracilis Hall
Coelospira sulcata Prouty
Coelospira hemispherica (Sowerby)
Coelospira sp. undetermined
Kloedenia cacaponensis Ulrich and Bassler
Zygolbolba erecta Ulrich and Bassler
Zygobolbina conradi latimarginata Ulrich and Bassler
Dalmanites limulurus (Green)

The Cacapon sandstone is of Clinton age. With the overlying Keefer sandstone, it corresponds to the "Clinton formation" of southwestern Virginia. Noteworthy, however, is the absence of the brachiopod, Pentamerus oblongus, which is abundant elsewhere in the Clinton, ~~is not locally present~~.

Keefer Sandstone

The Keefer sandstone[1.] is the uppermost Silurian sandstone of this region, where, with the Cacapon and Clinch formations, it is a ridge-making member of much prominence.

---

1. Stose, G. W., and Swartz, C. K., U. S. Geological Survey Geol. Atlas, Pawpaw-Hancock folio (No. 179), field edition, p. 38, 1912.

Character.--The Keefer sandstone is an arenaceous series of clastic rocks that are prevailingly white or gray, and are streaked with red. (See Pl. 43, A.) The formation consists of several massive beds of quartzitic sandstone that are separated either by weak shales or by slabby sandstones. (See Pl. 43, B.) In the arch at Iron Gate, (Section 20), the Keefer contains four resistant sandstones that form the upper part of the arch and exhibit continuous ledges on both sides of the gorge. (See Pls. 50, B and 52, A.) As it contains a number of resistant members, the Keefer may be distinguished from the Clinch sandstone, whose members have so nearly the same hardness that they form a single, massive bed.

The sandstone ~~which forms~~ of the Keefer is very similar to that of the Clinch, and it is almost impossible to distinguish between them in hand specimens. It is necessary to rely upon stratigraphic position--above or below the Cacapon--to identify the Keefer and Clinch sandstones in the field. The bedding planes and cleavage surfaces of the Keefer are more commonly coated with red iron-oxide, than are those of Clinch sandstones.

Distribution.--Together with other siliceous Silurian formations, the Keefer sandstone produces many summits of local mountains which are slightly more rugged and broader where the Keefer is present than where it is absent; Clinch ridges are sharp and more barren. Good

exposures of the Keefer occur at Eagle Rock (Section 21), in Hays Gap, at Iron Gate (Section 20), and in Rich Hill, four miles northeast of Springwood (Section 22). It is also exposed along the upper reaches of Penn Branch, west of Cartmell Gap. (Section 19.)

In its outcrop, topographic expression, and soil, the Keefer closely resembles the Clinch sandstone.

Thickness.--The Keefer sandstone is about 250 feet thick at Cartmell Gap (See Pl. 41, B.) and along Back Creek. It is 144 feet thick on North Mountain (Section 17), 330 feet thick at Eagle Rock, and 170 feet thick at Iron Gate.

Economic Products.--It has been reported that a thin seam of red hematite occurs in the lower part of the Keefer sandstone, but none was observed in this region. The formation contains an abundant ~~stone of~~ stone for any type of rough construction.

Fossils and age.--No fossils occur in the Keefer sandstone. On the basis of its stratigraphic position, however, it is assigned to the upper Clinton group of Silurian age.

Tonoloway Limestone

The Tonoloway limestone[1] which overlies the Keefer sandstone is rarely exposed in this region.

---

1. Stose, G. W., and Swartz, CK., op. cit., p. 55.

Character.--The Tonoloway limestone is a black, thin-bedded, slabby, limestone that weathers to a dark-gray color in which a ribbony appearance not unlike that of the Manlius limestone of New York State--is characteristic. Where freshly exposed, the rock appears massive, but upon weathering it rapidly disintegrates into thin zones of banded limestone separated by shale partings. On mountain Tonoloway slopes, the ~~rock~~ produces quantities of thin slabs that possess rude geometric outlines. At Iron Gate, the Tonoloway limestone weathers to a "paper" shale in which the laminae, or layers, of limestone are less than ~~one-third~~ 1/3 inch thick. (See Pl. 48, B.) The rock is extremely fine-grained and even-textured. (See Pl. 44, A.) Near Oriskany, it is somewhat massive and arenaceous, producing prominent water-worn ledges.

Distribution and thickness.--The Tonoloway limestone is negative in surface expression, and rarely produces exposures along its outcrop. Entirely typical is its occurrence at Iron Gate (Section 20), where it forms a ~~definite~~ distinct sag in the crest of the hill between the more resistant Keefer and Helderberg formations. The formation crops out adjacent to the Clinton sandstones, and with careful search its outcrop may be distinguished in most of the important Silurian belts. The best local exposure is in Prices Bluff (Pl. 44, A) at the southwestern end of Big Hill (Section 23), where the end of an anticline has been truncated in such fashion as to expose the Tonoloway, Keyser, and the Helderberg formations. Although 120 feet of the formation can be observed, the base of the Tonoloway is not exposed at Prices Bluff. Its thickness at Iron Gate is ~~more~~ more than 200 feet.

The Tonoloway limestone is also exposed (1) in Kelly Hollow, (2) near Oriskany on Wilson Branch, (3) in the gorge of Roaring Run, and (4) along Back Creek near Rich Hill, (Section 22).

Fossils and correlation.--The Tonoloway is sparingly fossiliferous. Certain zones carry the ostracode Leperditia scalaris var. praecedens Ulrich and Bassler whose oval shells cover the surface of rock ledges. (Fossil localities 79-82) Choneks te cf. C. jerseyensis Weller and Tentaculites gyracanthus Weller also occur in some layers.

The Tonoloway limestone is uppermost Silurian (Cayugan or Monroan) in age. Although it is known to correspond to the Bossardsville limestone of Maryland and New Jersey, its exact correlation with the New York State section is uncertain. It was originally correlated with the Manlius limestone, but is now thought to represent a lower horizon, possibly that of the Cobleskill.

Devonian System

As the Devonian of the Natural Bridge region is similar to the Devonian System of New York, many New York formational names are used in this report. Although minor subdivisions have locally disappeared and other members ~~are changed~~ differ in character and thickness, the similarities between the Devonian of New York and Virginia are ~~more~~ striking. ~~than for other systems~~. The Devonian of this area consists of the following ~~rocks~~ units in descending order:

Upper Devonian

- Catskill formation
- Chemung sandstone
- Brallier shale
- Middle and upper "Romney" black shale

Middle Devonian

- Lower "Romney" black shale
- Onondaga shale

Lower Devonian

- Oriskany sandstone
- Becraft limestone
- Healing Springs sandstone
- Coeymans limestone

} ~~"Helderberg group"~~

- Keyser formation ——— (Upper Keyser limestone
  (Clifton Forge sandstone
  (Lower Keyser limestone

] Helderberg Group.

Local Devonian rocks, having an average thickness of about 6,750 feet, comprise approximately 1/3 of the rock column. They crop out in a wide belt between Switzer-North mountains and Rich Patch Mountain; several small isolated outcrops also occur. (See Fig. 25.) No Devonian is present southeast of the Pulaski overthrust.

Helderberg Group

Keyser Formation

Definition.— The Keyser formation, named from Keyser, West Virginia[1], is the earliest local Devonian formation. It has recently been subdivided by F. M. Swartz[2] into three units - an upper and lower limestone member separated by the Clifton Forge sandstone. The average thicknesses of these divisions are as follows:

1. Stose, G. W., and Swartz, C. K., op. cit.

2. Swartz, Frank M., The Helderberg group of parts of West Virginia and Virginia: U. S. Geological Survey Prof. Paper 158-C, p. 29, 1929.

Upper Keyser limestone	20-35 feet
Clifton Forge sandstone	100±
Lower Keyser limestone	0-50

Lower Keyser Member. - At Clifton Forge (Section 20), the Lower Keyser limestone is a gray, lumpy, arenaceous limestone that weathers brown. It is sandy in texture and nodular in structure, and has an average thickness of about 15 feet. In a measured section along Jackson River (Section 24), 11 miles north of Covington, it is 50 feet thick; at Island Ford (Section 25), it is entirely absent. At Prices Bluff, it may be represented by the lower 30 feet of the Clifton Forge sandstone which contains at its base some 10 feet of massive limestone that rests upon 20 feet of thick-bedded, massive, sandy limestone. (Section 23.)

In the Natural Bridge quadrangle, the lower Keyser is represented by dark-gray limestones and interbedded, brown sandstones that reach a total thickness of 43 feet on Back Creek. (Section 22.)

The limestones, which are thin and platy, are intercalated between dark-gray, dense sandstone lenses that range from a few inches to several feet thick. Near the top is a brown, saccharoidal sandstone ~~that~~ which resembles the Oriskany sandstone.

The Lower Keyser limestone contains abundant fossils, among which are the following (locality 84):

Stenochisma deckerensis (Weller)
Uncinulus convexorus Maynard
Chonetes jerseyensis Weller
Nucleospira swartzi Maynard
Atrypa reticularis (Linneus)
Calymene camerata Conrad

Chonetes jerseyensis is the most reliable index fossil of the Lower Keyser.

Clifton Forge Sandstone. - The Clifton Forge sandstone, which is the middle member of the Keyser, is an assemblage of true sandstones and highly arenaceous limestones. When fresh, the rock is steel-gray, ~~very~~ dense, and hard. Its surface, which weathers easily, is often ~~very~~ crumbly, as the calcareous material is leached ~~out~~ to leave a sandy, skeletal crust. Cross-bedding occurs on many weathered surfaces, although the rock is massively bedded with some ledges more than 20 feet thick. A few thin black partings occur. The rock is resistant by comparison with adjacent units. Its contact with the Upper Keyser limestone is sharp; that with the Lower Keyser is more gradational.

The Clifton Forge sandstone is 65 feet thick at Clifton Forge (Section 20), 80 feet thick along Jackson River 11 miles north of Covington (Section 24), more than ~~over~~ 100 feet thick at Island Ford (Section 25), and 69 feet thick at Prices Bluff (Section 23), where the lower 30 feet may represent the Lower Keyser. The Clifton Forge sandstone is the equivalent of the Big Mountain shale of northeastern West Virginia and represents middle Keyser horizons.

At least one zone of the Clifton Forge sandstone carries fossils, and cross sections of brachiopods, crinoid stems, and bryozoa may be seen on the surfaces of ledges. (Fossil locality 84.) The fossils are difficult to remove from the bed-rock, and no collections were made.

Upper Keyser Limestone Member. - The Upper Keyser limestone consists of heterogenous beds that are largely gray-black, cherty, or nodular, limestones. Its upper portion, although massive, weathers into slabs that resemble those of the Tonoloway limestone. The lower portion is knobby and contains chert in nodular layers that are separated by shale partings. The chert nodules have a central "eye" which weathers brown with black borders, so as to produce a distinctive appearance. The Upper Keyser limestone is 30 feet thick at Prices Bluff (Section 23), 35 feet thick at Clifton Forge (Section 20), 20 feet thick on Jackson River (Section 24), and 12 feet thick at Island Ford (Section 25).

It is abundantly fossiliferous. Many distinct faunal zones may be recognized, and the following fossils are most abundant (localities 83-84):

Stromatoporoids
Favosites helderbergiae var. praecedens Schuchert
Cladopora rectilineata Simpson

Other common forms include the following:

Aulopora schohariae Hall
Striatopora bella C. K. Swartz
Nucleospira ventricosa (Hall)
Meristella praenuntia Schuchert and Maynard

The Upper Keyser is distinctive for the presence of coral and stromatopora reefs that occur at similar horizons over wide areas. Reefs of mixed corals and stromatoporoids are as common as individual reefs of each type. Excellent examples occur in

the ledges at water-level of James River just above the old bridge at Island Ford. (Locality 84.)

The Upper Keyser limestones are also exposed on Back Creek (Section 22), and along James River above Lyle Tunnel (Section 26), where they produce smooth, vertical cliffs near the upper portion of Horseshoe Bend.

Age and Correlation. - According to the present policy of the Virginia Geological Survey, the Keyser formation is placed in the Helderberg group of the Devonian system, where it is considered to be the earliest, or oldest, Devonian formation. Its exact equivalence with the rocks of New Jersey and New York is somewhat uncertain, but there is a prevailing belief that the Keyser limestone of the Appalachian region represents the stratigraphic interval of the Decker Ferry, Rondout, and Manlius beds of New Jersey and the interval from the Wilbur to the Manlius (inclusive) of southeastern New York.

Determination of the age of the Keyser formation is involved in the location of the Devonian-Silurian boundary in North America. In the New York State section - long used as the type for eastern United States - the Manlius limestone was formerly assigned to the Silurian system, and the overlying Coeymans limestone was placed in the basal Devonian group. As the Keyser formation lies below the Coeymans limestone in Virginia and includes Manlius horizons, strict conformity to the standard New York classification demands that the Keyser limestone be considered of Silurian age.

In recent years, however, some authorities have sought to include the Manlius limestone in the Devonian system on the basis of European faunal determinations, but to what extent their

proposal is defensible has not been determined. One of its effects, however, by analogy and correlation, has been to crowd the Keyser formation of the Appalachian region into the Devonian System - a usage with which the author finds no agreement.

The contacts of the local Keyser formation strongly suggest an important structural break above (i.e., after), rather than below (i.e., before), the unit, for the contact of the Keyser and underlying Tonoloway limestone is clearly transitional, and not abrupt. On the other hand, between the Keyser and overlying Coeymans limestone, there is a sharp stratigraphic break which is represented by marked changes in types of sedimentation; it indicates disconformable, if not unconformable, relations. Furthermore, the Coeymans is much more closely allied to the Becraft than to the Keyser limestone, whereas the Keyser resembles the Tonoloway rather than the Coeymans limestone.

The paleontological evidence is more suggestive of Devonian correlatives for the Keyser than the structural relationships, for few if any Tonoloway forms occur in the Keyser, and several Keyser forms have Devonian affinities.

Coeymans Limestone

The Coeymans limestone of New York State appears to have local representation in the Natural Bridge region, where a thin limestone unit occupies its horizon.

Character and Thickness. - The Coeymans limestone is a well-defined lithologic unit. Its upper portion is a massive, pink, crinoidal limestone; the lower 5 feet are gray and more arenaceous. The rock is a tough freestone showing little trace

of bedding or lamination in its massive ledges. Its pink color and crinoidal content are criteria for its recognition. The Coeymans limestone is 70 feet thick on Jackson River above Covington, 26 feet thick at Prices Bluff (Section 23), 24 feet thick at Island Ford (Section 25), and 18 feet thick at Clifton Forge (Section 20).

As exposed along James River near Lyle Tunnel, it consists of 19 feet of dark-blue, cross-bedded, sandy limestone (Section 26.). Its upper third, which is blue, massive, and ~~obliquely~~ strongly cross-bedded, contains numerous unidentifiable fossils, chief of which are corals, crinoids, and brachiopods. The lower 12 feet consist of similar, but less massive, limestone that is more sandy than the upper portion.

Fossils. - The Coeymans contains a small fauna consisting chiefly of brachiopods and crinoids. Stems, or joints, of the latter occur in zones several inches thick in which individual fragments ~~one~~ inch in diameter occur. The following fossils were collected from the Coeymans limestone:

Favosites helderbergiae Hall
Crinoid stems
Rhipidomella oblata (Hall)
Gypidula coeymanensis Schuchert
Uncinulus abruptus (Hall)
Meristella arcuata (Hall)

Relations and Correlation. - The Coeymans limestone lies with an apparent disconformity upon the Keyser limestone and is locally overlain by the Healing Springs sandstone of New Scotland age (See Pl. 44, B.). The Coeymans corresponds to the formation of that name in the New York section. It is of ~~Lower~~ early Devonian age.

Healing Springs Sandstone

The New Scotland limestone of the northern Appalachian region becomes highly arenaceous ~~toward~~ in west. central Virginia, where it is represented solely by a sandstone in the Clifton Forge region ~~to which region. To this sandstone~~ F. M. Swartz has applied the name Healing Springs ~~sandstone.~~[1]

1. ~~Swartz, Frank M.,~~ Op. cit., p. 41.

Character. - At Prices Bluff along James River above Gala, the Healing Springs formation is a highly arenaceous limestone about 15 feet thick (Section 23). The main mass of the rock is gray or slightly pinkish, and thin stringers of black shale run through the beds. (See Pl. 44,B.)

Elsewhere, the formation is poorly exposed in the Natural Bridge region, or has not been definitely identified. It is possibly represented by a ~~five~~ 5-foot sandy zone below the Becraft limestone along James River near Lyle Tunnel (Section 26).

Thickness. - The thickness of the Healing Springs sandstone ranges from 40 feet on Jackson River above Covington (Section 24) to 32 feet at Island Ford (Section 25), and to 15 feet at Clifton Forge (Section 20). It appears to thin toward the southwest, although at Arritts, a few miles southwest of Covington, it is reported to be 20 feet thick. The formation is essentially barren of fossils, although a few indistinct crinoid stems occur in ledges at Prices Bluff.

Age. - The Healing Springs sandstone corresponds to the New Scotland shale of the New York section and is of ~~lower~~ early Devonian, or Helderberg, age. The manuscript name "Kincaid

sandstone" was once applied to it by Nelson.

Becraft Limestone

The Becraft limestone is the thickest and most common member of the local Helderberg group.

Character. - The Becraft formation is a massive gray limestone, containing an abundance of fossils. Its upper portion, assumes a pink color due to the ~~which is pink, is characterized by an~~ abundance of small red flecks ~~spots~~ about the size of sand grains that are scattered through the rock. The middle portion contains black, nodular chert that occurs in horizontal zones, some of which reach 6 feet in thickness. The chert contains fossils of the same species as those occurring in the limestone proper. A section of the Becraft limestone at Prices Bluff is as follows:(See also Section 87)

Oriskany sandstone	1.5 feet
Becraft limestone	
Massive, gray, coarsely crystalline limestone	54 feet
Cherty, gray limestone	15
Massive limestone and porous sandstone..	10
Massive, gray, knobby limestone	28
Healing Springs sandstone	15 feet

In the region east of Eagle Rock and north of Buchanan, the Becraft is a dark, checky limestone that is gray and fine-textured; it is ~~thick~~ thinly bedded and contains some cherty zones. The lower portion ~~is~~ consists of medium-textured, knobby, arenaceous limestone. The middle and upper portions consist of coarse, sandy limestone that contains ferruginous chert. Its topography is negative and is marked by no characteristic soil. The Becraft limestone is responsible for a ~~nother~~ large sink, or depression, on the northwest slope of Biggs Mountain, immediately west of the Rockbridge county-line.

Distribution and Fossils. - Although the Becraft limestone weathers readily, it is more resistant than the other Helderberg formations, of which it is more commonly exposed than any ~~of them~~ save the Clifton Forge sandstone. Good exposures occur (1) at Prices Bluff (Pl. 45, A), (2) opposite the eastern end of James River bridge at Glen Wilton, (3) at the northeastern end of Big Hill (Section 27), (4) along State Highway 42 near Oriskany, and (5) on James River near Lyle Tunnel (Section 26).

The Becraft limestone is abundantly fossiliferous. The following list contains some of the most common species (localities 19-20):

Streptelasma strictum Hall
Pleurodictyon lenticulare (Hall)
Favosites cf. F. schriveri (Herzer)
Favosites helderbergiae Hall
Favosites helderbergiae var. praecedens Schuchert
Edriocrinus pocilliformis Hall
Striatoporella cf. S. bella Swartz
Stenochisma formosa Hall
Stenochisma sp. undetermined
Cyphotrypa corrugata
Rhipidomella assimilis (Hall)
Rhipidomella oblata (Hall)
Leptaena rhomboidalis (Wilckens)
Schuchertella sp. undetermined
Dalmanella perelegans (Hall)
Dalmanella planiconvexa (Hall)
Uncinulus ventricosa (Hall)
Uncinulus abruptus (Hall)
Eatonia medialis (Conrad)
Eatonia sp. undetermined
Spirifer cyclopterus Hall
Spirifer murchisoni Castelnau
Spirifer concinnus Hall
Cyrtina cf. C. dalmani (Hall)
Gypidula cf. G. pseudogaleata Hall
Gypidula sp. undetermined
Meristella arcuata (Hall)
Orthoceras cf. O. longicameratum Hall.
Phacops logani Hall

Thickness and Age. - The Becraft limestone is about 100 feet thick in the Eagle Rock area. It is 75 feet thick at

Island Ford (Section 25), 51 feet thick at Clifton Forge (Section 20), and 200 feet thick on Jackson River north of Covington (Section 24). It is of upper Helderberg age and is the equivalent of the Becraft limestone of Becraft Mountain in New York State, where the formation was first described by Darton in 1894.[1]

1. Darton, N. H., N. Y. State Geol. 13th Ann. Rept. (1st), pp. 245-246, 304; 1894.

~~The~~ Oriskany Sandstone

The Oriskany sandstone, also known as the Ridgely sandstone,[2] is widely present in west-central Virginia. In northern Virginia, it lies above the Shriver chert, also of Oriskany age; in Pocahontas County, West Virginia, it is overlain by the Huntersville chert. In the Natural Bridge region, little chert is associated with this formation.

2. Swartz, C. K., Lower Devonian: Maryland Geol. Survey, p. 91, 1913.

Character. - The Oriskany sandstone, which is rarely exposed in west-central Virginia, is very similar to the Clifton Forge sandstone, with which it has been commonly confused. It is a coarse, brown sandstone that is gritty, cross-bedded, and highly ferruginous (See Pl. 45, A.). The formation directly underlies the olive and buff Onondaga shales, and its belt of outcrop is parallel ~~to~~ with that of the Devonian shales. Oriskany soil is poor, sandy, and usually surfaced with float from the Silurian rocks. In the absence of foreign debris, Oriskany soil is characterized by limonitic sandstone debris, or, more rarely, by white cherty fragments.

In many exposures, the rock has been fractured, brecciated, and recemented with iron oxide. Its topography is low and negative, for the sandstone is both friable and loosely cemented.

Iron Ore. - Together with the arenaceous Helderberg rocks, the Oriskany sandstone has been enriched at many points by iron and manganese minerals. This enriched material, consisting chiefly of brown limonite, is widely known as "Oriskany brown iron-ore." As a result of the similarity of the Oriskany sandstone and other arenaceous Devonian beds, the name "Oriskany" has erroneously been applied to other ore-bearing rocks of early Devonian age than the true Oriskany sandstone. The brown ore and its prospects are ~~more fully~~ described ~~elsewhere in this report~~. on pages 306-321.

Thickness. - The Oriskany sandstone is 18 inches thick at Prices Bluff (Section 23), 6 feet thick at Island Ford and at Arritts, about 11 feet thick at Clifton Forge (Section 20), and 30 feet thick at Jackson River above Covington (Section 24).

Fossils. - Although the Oriskany is sparingly fossiliferous ~~elsewhere~~ in this region, many specimens of a few species occur at Island Ford (fossil locality 88) where the following forms were collected:

Rhipidomella sp. undetermined
Schuchertella pandora (Billings)
Eatonia peculiaris (Conrad)
Spirifer murchisoni Castelnau
Spirifer arenosus (Conrad)
Spirifer cumberlandiae Hall
Rensselaeria cf. R. marylandica Hall
Rensselaeria sp. undetermined
Beachia suessana (Hall)
Actinopteria cf. A. textilis var. arenaria (Hall)
Diaphorostoma depressum (Hall)
Diaphorostoma ventricosum Clarke

Relations and Age. - The Oriskany sandstone rests disconformably upon the Becraft limestone. It is overlain by the Onondaga shale and is of early Middle Devonian age.

Onondaga Shale

A thin, greenish-yellow shale occurs above the Oriskany-Helderberg group. It is identified as the Onondaga shale, and corresponds to the Onondaga limestone of New York and Pennsylvania.

Character. - In the Natural Bridge area, the Onondaga shale is a thin mass of yellow-buff, sandy shales that are commonly stained with red iron oxide. (See Pl. 45, A.) The beds are not fissile, and the more massive layers are extremely tough. The upper portion is somewhat clastic and consists of drab or greenish shales that are slightly calcareous and thinly laminated. The lower portion, which is more massive, consists of clayey beds that are soapy to the touch and are cream-yellow. The Onondaga shale is readily separated in the field from the overlying "Romney" black shale by its color.

Thickness. - The thickness of the Onondaga shale varies from 20 to 60 feet. It is 35 feet thick at the northeast end of Big Hill. (Section 27.)

Distribution and Fossils. - A good exposure of this formation occurs along James River at the northeastern part of Horseshoe Bend, near Rich Hill. Others occur (1) in the shallow synclinal valley at the top of Short Hills, (2) along the road at the

northeastern end of Biggs Mountain, (3) near Smith Flats, (4) in a belt surrounding Big Hill, and (5) along the flank of Rich Patch Mountain.

The Onondaga is very fossiliferous and is characterized by abundant ostracodes and trilobite fragments. The following fauna is typical of this region (localities 21, 88-98):

Cladopora sp. undetermined
Anoplia sp. undetermined
Leptaena rhomboidalis (Wilckens)
Chonetes buttsi
Amboecoelia cf. A. umbonata (Conrad)
Anoplotheca acutiplicata (Conrad)
Buchiola halli Clarke
Paleoneilo sp. undetermined
Platyceras sp. undetermined
Loxonema hamiltoniae Hall
Styliolina fissurella (Hall)
Tentaculites sp. undetermined
Coleolus sp. undetermined
Phacops rana (Green)
Odontocephalus aegeria Hall
Bollia ungula Jones
Bythrocypris sp. undetermined
Beyrichia sp. undetermined
Kloedenella sp. undetermined
Kloedenia sp. undetermined
Paraparchites sp. undetermined
Primitiopsis favulosa

Age. - This formation is the southern equivalent of the Onondaga limestone of the northern Appalachians and New York. Its name was derived from Onondaga County, in central New York State.[1].

---

1. Hall, James, N. Y. Geol. Survey, 3rd Ann. Rept., pp. 309-310, 1839.

"Romney" Black Shale

Definition.— A persistant zone of black shale which occurs throughout west-central Virginia at Middle and early Upper Devonian horizons has been widely correlated with the Romney shale[1] of Hampshire County, West Virginia.

1. Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Amer. Geologist, vol. 10, p. 17, 1892.

It is not clear that the local Devonian black shale is the exact equivalent of the true Romney shale. In fact, it seems probable that many shales designated in Virginia as "Romney" do not agree, except in physical character, with the true Romney shale. To indicate that it is a convenient, but not exact stratigraphic designation, the name "Romney" is here placed in quotation marks.

Character. - The "Romney" shales are black, very weak, and easily weathered; they disintegrate readily into soft flakes that do not "snap" when sharply broken. Many of the shale fragments are discolored by red iron oxide - a character not present in the black, or chocolate, Athens shales. There are no massive lenses within the "Romney" shale, which is a thin-bedded, fine-grained rock.

Many concretions and septaria occur in the "Romney" shale. The latter are known as "turtle-stones," for they are round, slightly flattened, concretions whose surface has been cracked into polygonal segments, that have been recemented by calcite so as to resemble the markings on the back of a turtle. Concretions and septaria occur in zones that are abundant near the base of

the "Romney" black shale; some concretions are nearly ~~three~~ 3 feet wide, although most are less than ~~a~~ 1/2 foot in diameter. The concretions which are very tough and difficult to break generally consist of limy material containing tiny crystals of pyrite. ~~Some~~ Others have hollow centers filled with soft, black, carbonaceous clay. One contained a large, well-formed crystal of gypsum (selenite); ~~Others contain fossils that form a~~ a few were found to contain a fossil nucleus. ~~of accumulation.~~

Structure and Soil. - As "Romney" shales are highly contorted and crushed, much cleavage has been developed. The formation is topographically weak, and has yielded, under folding, to a greater degree than most other formations; its folds have collapsed and are intimately crushed.

The shales are easily eroded, and the "Romney" outcrop is marked by low country. Its soils, which are generally unproductive, support a scraggly growth of pine, laurel, and other small trees. It is responsible for the "poor valleys" of the central Appalachian Mountains.

Distribution. - The "Romney" shale, which crops out in an oval entirely surrounding Big Hill, is well exposed along State Highway 12 east of the hill. Another outcrop, which flanks Rich Patch and Deisher mountains, extends from Oriskany to Iron Gate. State Highway 42 follows this belt from a point 2 miles west of Horton to Oriskany. A long, narrow belt of "Romney" shale is also infolded between Rich Patch Mountain and the secondary ridge of which Deisher Mountain and Iron Knob are summits. "Romney" shales crop out along the northwestern flank

of Switzer, Rathole and North mountains, with an adjacent belt that extends up Mill Creek valley to surround Biggs Mountain. Isolated outcrops also occur (1) in the valley of Karnes Creek, (2) along Potts Creek, (3) in the synclinal basin at the top of Short Hills, (4) in the valley between the two Camp Mountains, and (5) along a narrow belt between James River and Purgatory Mountain.

Thickness. - The "Romney" black shale has been locally dug for coal, but contains no true coal nor any combustible material. Its thickness can not be measured, for no continuous, undisturbed sections were observed. Its belt of outcrop is generally about 3,000 feet wide. As the shale is everywhere tilted, this width must considerably exceed the true thickness of the formation, which is estimated to be about 1,000 feet.

Fossils. - The "Romney" shale is sparingly fossiliferous. The most distinctive form is the tiny fossil Styliolina fissurella (Hall) which has the shape of a phonograph needle that is slightly corrugated; it is about 1/20 of an inch in length. Brachiopods and pelecypods are other fossils included in the following list of "Romney" species from localities 23-25, 87-91:

Plant fragments
Orbiculoidea cf. O. lodiensis Hall
Lingula delia Hall
Ambocoelia virginiana Conrad
Liorhynchus limitare (Vanuxem)
Anoplotheca acutiplicata (Conrad)
Buchiola halli Clarke
Buchiola retrostriata (von Buch)
Nucula cf. N. corbuliformis Hall
Nucula cf. N. bellistriata (Conrad)
Nuculites triqueter Conrad
Aviculopecten sp. undetermined
Goniophora sp. undetermined
Styliolina fissurella (Hall)
Tentaculites cf. T. bellulus Hall
Bactrites aciculus Hall
Orthoceras cf. O. subulatum Hall

Age and Correlation. - The horizons represented by the "Romney" black shale of this region are not identical with those of the true Romney shale, at Romney, Hampshire County, West Virginia, where the shales are of Marcellus and Hamilton age. In the local region, there is no representative of the Hamilton; Genesee and Portage equivalents are probably present in the upper beds.

Brallier Shale

An extensive development of Upper Devonian shales and thin, flaky sandstones is called the Brallier shale[1] from Brallier, Bedford County, Pennsylvania.

1. Butts, Charles, Geologic section of Blair and Huntingdon Counties, central Pennsylvania: Amer. Jour. Sci., 4th series, vol.46, p. 523, 1918.

Character. - The Brallier is a thick body of greenish-gray to olive-green shale. Sandy lenses are numerous near the top, and dark to black shale zones occur near the bottom. Brallier shales are more olive or green than the dark shales of the "Romney" and are also more fissile and brittle. Indeed, they will "snap" briskly when broken, whereas "Romney" shales lack this resilience. The upper third of the formation is more massive than the lower part and contains many thin sandstone or flagstone layers, some of which reach several inches in thickness (Pl. 52, B) and persist over wide areas. The flagstones, which are somewhat darker than the shales, are micaceous and show evidence of shallow-water deposition.

Shales and sandstones of this formation are commonly covered with peculiar markings that represent impressions formed by swirling currents, rills, ripples, the dragging of rafted material, ice crystals, and possibly by the tracks or trails of organisms.

County roads built on the outcrop of, or surfaced with, Brallier shales are smooth and generally superior to similarly constructed roads of other material.

Relations. - The Brallier shale appears to grade upward into the Chemung formation, and downward into the "Romney" formation. Neither of its contacts can be located at a definite horizon.

Distribution. - The Brallier shale has a wide outcrop, occupying nearly all of the area between Rich Patch Mountain and the Eagle Rock Range. This belt, which is about ~~five~~ 5 miles in average width, contains ~~two~~ 2 inliers of other rocks, (1) the Big-Rocky Hill anticline, and (2) the Patterson Mountain syncline. A small synclinal arm of Brallier shale occurs between Carpenter Mountain and Potts Creek.

The main Brallier outcrop is drained by James River and by Craig, Patterson, and Sinking creeks. It is a well-dissected area of rolling hills which is covered with a sandy, barren soil that supports a sturdy growth of pine. Both Brallier and "Romney" shale areas make poor farmland in which steep, mural bluffs wall the outside of river curves. (See Pl. 45, B.) The Brallier shale has been folded symmetrically into a broad, shallow, synclinorium. One of its smaller folds is clearly visible on the south side of Craig Creek valley, 1 mile southeast of Strom. (Pl. 50, A.)

Thickness. - As it has been strongly folded, there is no point where a measured section can be obtained, and the estimated thickness of 2,000 feet for the Brallier shale may only approximate the actual thickness.

Correlation and Fossils. - Most of the Brallier shale is unfossiliferous, and corresponds to the Gardeau beds of the New York State Portage group. The lower few hundred feet of the Brallier shale correspond to the Naples member of the New York State Portage and are sparingly fossiliferous. A collection of fossils from the lower portion of the Brallier yielded the following species (localities 26, 95-97):

Plant fragments
Atrypa hystrix Hall
Buchiola livoniae Clarke
Buchiola halli Clarke
Buchiola retrostriata (von Buch)
Pterochaenia fragilis (Hall)
Diaphorostoma lineatum (Conrad)
Styoliolina cf. S. fissurella (Hall)
Bactrites aciculus (Hall)
Coleolus tenuicinctus Hall
Probeloceras lutheri Clarke

Chemung Formation

Character. - The Chemung formation consists of brown or gray sandstone interbedded with shales that weather to a red-brown color. The sandstones are thin-bedded, or flaggy, near the base, but are resistant and ~~heavy~~ thick-bedded in the middle and upper part of the series; some of the massive beds exceed 15 feet in thickness. They are commonly micaceous and even-grained, with greenish-buff or brown colors, and they weather to shades of red or red-brown. Near the top of the Chemung, there are conglomeratic sandstones that contain numerous white quartz pebbles. The shaly layers, which are thin-bedded and fissile, extend through the entire formation,

but are more numerous in the lower part of the formation. Most of them are yellow or red.

As a unit, the Chemung is a rather dense and resistant formation, producing ridges of considerable magnitude. Decay proceeds slowly, so that exposures of the rock are common and the outcrops are ledgy. Chemung soils are thin, sandy, and support a sturdy growth of pines and hardwoods. Where cleared, Chemung outcrops form good pasturage, but they are unfavorably located along the crests and flanks of mountains. Some of the sandstones show evidence of shallow-water deposition in the form of ripple marks and mud cracks.

Upon weathering, many of the massive ledges exhibit a spheroidal surface that suggests the presence of concretions. In other exposures, a finely laminated shale or a shaly sandstone may weather so uniformly as simulate a single massive bed. Although a few massive sandstones occur within the formation, the uniform appearance of many thinly laminated beds has given a ~~heavy~~ thick-bedded ~~appearance~~ character to the formation that it does not entirely deserve.

Distribution. - As an oval inlier upon the Brallier shale, the Chemung formation underlies Patterson Mountain. Both Price and Caldwell mountains are also formed by the Chemung formation, and there is a small, isolated inlier of Chemung at the northeastern end of Price Mountain. No local outcrops occur north of Craig Creek nor east of James River.

The Chemung formation is well exposed along the road leading over Price Mountain from Fincastle to Craig Creek ~~Po Oa~~ Post Office. Other exposures occur along the headwaters of North Fork of Catawba Creek.

Thickness. - The Chemung formation is 2,890 feet thick on Price Mountain. (Section 28.) It has a similar thickness in adjacent areas in West Virginia, but thins toward the south.

Fossils. - Certain zones of the Chemung are abundantly fossiliferous; others are barren of fossils. Plant remains, crinoid stems, and various species of Spirifer are scattered in zones throughout the entire thickness of the unit. Other forms, including Ambocoelia umbonata and Atrypa hystrix, are characteristic of the lowermost beds only. The following collections were made from the local Chemung formations (localities 98-100):

Plant remains
Crinoid stems
Lingula sp. undetermined
Schuchertella chemungensis (Conrad)
Chonetes cf. C. scitulus Hall
Camaratoechia cf. C. congregata (Conrad)
Camaratoechia cf. C. eximia (Hall)
Atrypa hystrix Hall
Spirifer (Delthyris) mesacostalis Hall
Spirifer cf. S. disjunctus Sowerby
Spirifer cf. S. mesastrialis Hall
Spirifer sp. undetermined
Ambocoelia umbonata (Conrad)
Productella cf. P. hystricula Hall
Productella sp. undetermined
Pterinea cf. P. nodocosta Clarke and Swartz
Pterinea cf. P. chemungensis (Conrad)
Paleoneilo cf. P. plana Hall

Correlation. - The Chemung of Virginia is the equivalent of the Chemung formation of New York State; it is of ~~Upper~~ late Devonian age.

Although no exact correlation is possible, it is thought that the upper 30 feet of the Chemung formation on Price Mountain (See Section 28.) corresponds to the Hendricks sandstone of West Virginia. About 580 feet below this member, there is a strong red-brown sandstone unit that may be the equivalent of the Valley Head sandstone of adjacent areas in West Virginia.

Catskill Formation

Upper Devonian rocks, probably of Catskill age, occur on Price and Caldwell mountains, but are not known elsewhere in this area.

Character. - The Catskill formation consists of red shales that are interbedded with gray or brown sandstones and olive or yellow shales. The formation, which is transitional between the overlying Pride and underlying Chemung formations, is similar in lithology to Catskill beds of adjacent areas.

Distribution and Thickness. - This unit is restricted to the crests of Price and Caldwell mountains where it overlies the Chemung formation. (Section 28.) It is about 500 feet thick but thins toward the southwest. Elsewhere in northwestern Virginia, it reaches a thickness of from 1,000 to 1,800 feet.

Age. - No fossils occur in this formation, which, on the basis of its lithology and stratigraphic position, is identified with the Catskill formation of New York State. The age of the latter has recently been questioned, but is commonly considered to be ~~Upper~~ late Devonian.

Mississippian System

The Mississippian System, which is locally represented by the Price formation, has the smallest surface area of any system, occurring only in the southwestern part of this region. (See Fig. 26.) The total thickness of the Price formation is estimated to be about 1,000 feet; only its lower part is present in the local area.

Osage Group

Price Formation

The Price[1] formation is the youngest sedimentary bedrock formation in the Natural Bridge Region; it is of ~~Lower~~ early Mississippian (Osagian) age.

1. Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 25, 1925.

Character. - The Price formation consists of coarse grayish-brown or white sandstones that are interbedded with greenish-gray and red-brown shales. Some of the beds are strongly conglomeratic and produce abundant debris along the mountain slopes. Pebbles in the conglomerates are generally flattened and average ½ inch in width. Similar, but smaller, pebbles occur in the uppermost (Hendricks) sandstone of the Chemung formation. The lower part of the Price formation is not strikingly different from the underlying Catskill formation, and the Devonian-Mississippian contact has been drawn below the lowest conglomerate of the Price and above the highest red shale of the Catskill formation.

Coal. - Thin seams of coal, which occur near the middle of the Price formation, have been prospected in the extreme southwestern corner of the Eagle Rock quadrangle and in Stone Coal Gap. The coal is very thin, bony, and occurs in ~~two~~ 2 small seams. Additional data about the workings ~~will be found elsewhere in this report.~~ occur on pages 338-339.

Distribution. - The Price formation is limited to ~~three~~ 3 synclinal outcrops on Caldwell and Price mountains. The formation

follows the crest of Price Mountain, but occurs along the southeastern flank of Caldwell Mountain. The only readily accessible exposure is along the road over Price Mountain. (Section 28.)

Thickness and Relations. - Although the total thickness of the Price formation is estimated to be about 1,000 feet, only a small portion of the formation is locally present. The formation is very resistant, and its ledges contribute to the ruggedness of Price and Caldwell mountains. Its soils are thin, rocky, and unfavorable for cultivation. No collections of fossils were made, although a few fragmentary plant remains were observed.

The Price sandstone is the stratigraphic equivalent of the Pocono sandstone of West Virginia and Pennsylvania.

QUATERNARY DEPOSITS

Quaternary rocks are represented by unconsolidated surface materials, chief of which are gravels, sands, clays, and travertine.

Character. - Quaternary gravels and sands are largely composed of the insoluble residue of older rocks, together with those products of stream waste that have not been comminuted to fine size or carried away by surface drainage. The gravels consist of chert or quartzite in the area of Paleozoic rocks, and granite and other igneous rock boulders in the area of pre-Cambrian rocks. Most of them are half-round or sub-round, although some are angular. The valleys descending the northwestern face of the Blue Ridge are choked with boulders of granite and quartzite, and streams on the Appalachian ridges transport abundant coarse debris from the Silurian sandstones.

Local sand deposits are chiefly composed of pure quartz grains derived from the weathering and erosion of ancient sandstones or granites. In the sands derived from crystalline rocks, magnetite is a common accessory, and black grains of this heavy mineral are conspicuous in tiny placer-like masses. No magnetite normally occurs in sand derived from the Paleozoic rocks.[1.]

---

1. A preliminary investigation of sediments from James River (Amer. Mineralogist, Vol. 15, pp. 528-533, 1930) was made by Stow for the purpose of studying the "heavy-mineral" content of the sands. The heavy-mineral grains are sorted by gravimetric methods from the main body of quartz sand, and the various proportions of different heavy-minerals are determined. In many instances, the heavy-mineral content of stratigraphic units is sufficiently constant to furnish a guide in identification or correlation of the beds.

James River sand at Eagle Rock furnished the following content of heavy-mineral grains: (percentage of total heavy-minerals)

Limonite	91%
Ilmenite	5
Zircon	2
Rutile	1
Tourmaline	1

Smaller quantities of fine detrital material occur separately or with the sand or gravel. The floodplain areas of James River, Craig, Catawba, and Looney creeks are covered with such deposits. (Pl. 26), (See Pl. 46, A.)

Residual soil, clay, and loam, of Quaternary origin are best developed in valleys chiefly on the outcrop of the "Cambro-Ordovician" limestones. They are typical products of limestone decomposition and, when free from chert or other foreign debris, are fertile and productive. Over the outcrop of Canadian dolomites, considerable angular chert is developed, and its presence greatly impairs the fertility and usefulness of Canadian soils. (Pl. 7[illegible], B.) The residual limestone debris varies in thickness from a few

inches to tens of feet, and the soil merges imperceptably with the sub-soil which, in turn, grades into solid bed-rock. Residuals on shale outcrops form a much thinner soil and are filled with tiny splinters of shale that detract from their fertility. Shale soils are apt to be sterile and subject to ready drought.

The calcareous fluvial deposits consist chiefly of travertine - a surface deposit of calcium carbonate - which is precipitated from solution by ground and surface waters. Travertine, which is cellular, or frothy, in structure, is a common deposit in channel of streams at, or near, small waterfalls, where it tends to increase the size of the falls. Deposits of this kind may be observed along Lapsley Run (Pl. 47), a few miles south of Eagle Rock and in the area south and southwest of Springwood.

Organic Remains. - Mastodon and other mammalian fossils are infrequently found in residual clays or transported surficial deposits of west-central Virginia, but none has been reported from this district. Shells of modern snails and plant leaves are common in recently-formed travertine deposits. (Fossil localities 101-102.) Indian flints and arrow-heads are sometimes found in the surface deposits but are of comparatively modern origin.

Mention should be made of important Indian relics that have been unearthed from mounds in the vicinity of Gala. (Fossil locality 103.) During the building of the Chespeake and Ohio railroad, several large Indian mounds were cut through, or opened, and additional excavations were made by Gerard Fowke for the Bureau of American Ethnology for the Smithsonian Institution.[1] A strip of land 180 feet long

1. Fowke, Gerard, Archeological investigations in James and Potomac valleys, Bureau Am. Eth., Bull. 23,

(I cannot complete this reference.)

and 20 feet wide, which was dug up along the railroad at Gala station, and yielded several thousand specimens of pottery fragments, mortar stones, celts, awls, arrow-heads, and similar relics. The specimens were found at depths ranging from 6 inches to 3 feet below the present surface in a loose black deposit partly of fluvial origin, and partly the refuse of an Indian settlement. More than 200 skeletons were unearthed, and the total collections indicated that an Indian village of large proportions was once located at Gala. A cursory search near the present station in 1932 yielded a handful of pottery fragments and broken bone implements. It is reported that small cairns of stone, which have been found in Rich Patch valley, indicate guide markers along an old Indian trail.

IGNEOUS ROCKS OF UNCERTAIN AGE

Two bodies of igneous rock are known to occur in the Paleozoic outcrop midway between Mt. Pisgah and Pine Knob, about 3 miles southwest of Oakdale.

One consists of a circular mass, an acre in extent, that is crossed by the road leading from South Fork of Buffalo to the upper end of Tory Hollow. It was first called to the writer's attention by Doctor Charles Butts of the United States Geological Survey. Subsequently, a second, linear outcrop was discovered ½ mile north and west of the road. One appears to represent a dike; the other mass is a stock. The observed length of the dike is about ¼ mile; its width is about 20 yards; and its strike is N. 15° W.

In both intrusions, the rock is so ~~highly~~ deeply weathered that a fresh, solid, unaltered specimen could not be obtained. It ~~be~~ appears to be greenish-gray, fine-grained, and granular, and is tentatively identified as a basic igneous type, probably an olivine-diabase ~~or basalt.~~ or peridotite in which sub-rounded grains of olivine are distributed generously throughout ~~the rock which is largely~~ a matrix of plagioclase feldspar, ~~probably labradorite~~. Glittering flakes of mica occur in the residual soil of both dike and stock, and magnetite is an accessory mineral. The rock is strongly decomposed, and secondary serpentine, chlorite, and amphibole have been developed; the feldspar is extensively altered to kaolin. The soil produced by the intrusives is brownish-black and is ~~commonly~~ well known to local residents as a distinct ~~type.~~ variety It is fertile, but "cuts," rather than "turns," when plowed. It washes readily and is reported to be especially ~~good for fruit trees.~~ adapted to orchards. No contacts nor any fresh rock were observed along the outcrop of the dike, and its limits are determined solely on the basis of residual soil. (See p. 46, B.) It is significant, however, to find its strike to be almost identical with the strike of similar dikes reported in Augusta County, 40 miles farther north.[1]

---

1. Watson, T. L., and Cline, J. H., Petrology of a series of igneous dikes in central western Virginia: Geol. Soc. America, Bull., vol. 24, p. 304, 1913.

The circular intrusive, or stock, forms a low, rounded, and wooded knoll a little over an acre in extent. ~~Although~~ The igneous rock has been used in the repair of the country road, but even the recent excavations are deeply weathered. Along its contact, the intruded limestone is greatly brecciated, and fragments of the

country rock occur within the stock at distances of 10 feet from the contact. The igneous rock is likewise mashed along its margin, but no other contact-metamorphic effects were observed. There is no perceptible change in lithology from the margin to the center of the igneous mass.

Intrusions of this nature have been reported from adjacent counties to the north, but are always unusual and interesting, to the geologist, for the sedimentary rocks of the Appalachians are remarkably free from igneous intrusions of any sort. Little is known about the age of the intrusions; the country rocks are Stones River limestones near, ~~to the Chambersburg limestone~~ or at the Beekmantown contact. On the basis of their structural relations, similar dikes in Augusta County are regarded as post-Paleozoic. By analogy, the Natural Bridge dikes are assumed to be equally recent. It is thought that they may be related to the numerous diabase dikes associated with Triassic rocks of the eastern United States.

It should be pointed out that the discovery of such small igneous masses is generally accidental. Because of their limited areal extent and highly weathered character, dikes or stocks may be entirely overlooked in regions where their presence is not suspected.

Section No. 1.

Laurel Run Section

Section of Lower Cambrian arenaceous ~~rocks~~ along old road leading up Laurel Run to crest of the Blue Ridge and thence into Goose Creek valley.

CAMBRIAN

	Feet
Erwin quartzite	~~845~~ +
Largely covered; coarse white quartzite and sandstone	157
Largely covered; gray-white sandstone and shale	156
Largely covered; white quartzite and shale	180
Coarse, white quartzite and shale	48
Single ledge of brown-red, cross-bedded sandstone	15
Medium-bedded sandstone and shale	85
Thin sandstone and shale	38
Massive, white quartzite; ~~heavy~~ thick-bedded; ledgy	71
Thick ~~Heavy~~-bedded quartzite; some shale partings	75
White, cross-bedded quartzite	20
Hampton shale	489
Grayish shale with many 8-inch sandstone lenses	108
Thin shale and soft interbedded sandstone	31
Fissile shale, weathering tan, and sandstone	350
Unicoi formation	3005
Medium ~~Rather thin~~-bedded shaly sandstone	50
Dense, white quartzite	12
Interbedded brown sandstones and shales	372
Rather massive, ~~heavy~~, brown, laminated, resistant sandstone	100
Irregularly bedded, crumbly, brownish-white sandstone	202
"Blue Ridge hematite" (See page 294-300)	4
Interbedded brown sandstones and shales	450
Thick ~~Heavy~~-bedded pebbly quartzite	18
Covered	23
Massive, pebbly quartzite; at crest of Blue Ridge	15
Largely covered; much sandstone debris	300
Rather massive, pebbly sandstone; pinkish	56
Largely covered; much shaly debris	120
Brown sandstones and interbedded shales	192
Coarse, massive, grayish sandstone; some shaly zones	93
Largely covered; probably shaly	222
Massive brown sandstone	15
Largely covered; medium-bedded sandstones and shales	295
Rather massive, pebbly, brown sandstone	60
Dark blue-gray laminated rhyolite	26
Rather massive, crumbly, pebbly sandstone	346
Coarse ~~basal~~ conglomerate	34

Pre-Cambrian crystalline rocks, in normal contact

Section No. 2.

Jennings Creek Section

Section at base of Paleozoic system, measured near fire warden's house along road leading from Jennings Creek to Munford Post Office. (Note: Section is measured at point named "Munford" on the Natural Bridge quadrangle. Munford Post Office is located 2 miles farther south.)

CAMBRIAN

Unicoi formation ..... not measured

	Feet
Heather-colored conglomerate	20
Greenish, laminated rhyolite	150
Mashed rhyolite	20
Largely covered; some conglomerate	78

PRE-CAMBRIAN

Coarse red granite .....

Section No. 3.

North Creek Section

Section at base of Paleozoic system, measured on North Creek, 2½ miles east of Arcadia.

CAMBRIAN

Unicoi formation	not measured
Coarse, heather-colored, pebbly conglomerate ..	not measured
	Feet
Amygdaloidal, rhyolitic ~~material~~	15
Covered	40
More massive, dark-colored rhyolite or greenstone	15
Covered	33
Massive, checky basalt	27
Covered	50
Pink arkosic conglomerate	150+

PRE-CAMBRIAN

Red granitoid igneous rock .....

Section No. 4.

Snowden Section

Section measured at base of Paleozoic system along U. S. Highway 501 near bridge over James River, ½ mile south of Snowden. (See also Pl. 27, A.)

CAMBRIAN

Unicoi formation ..... not measured

Heather-colored, pebbly conglomerate.... not measured

	Feet
Covered; rhyolite or greenstone float	30
Red rhyolite	5
Red arkosic conglomerate	7
Red rhyolite	9
Arkosic conglomerate	15
Very coarse, ~~basal~~ conglomerate	10
Red-green, crushed, shaly material	6
Slaty, Red rhyolite	5

PRE-CAMBRIAN

Coarse, red-purple, hypersthene granodiorite .....

Section No. 5.

Balcony Falls Section

Section of Lower Cambrian arenaceous rocks along U. S. Highway 501 near Balcony Falls. Strike North 55° East, dip 55° Northwest. Section measured along road north and west of James River. (See also Fig. 27, B and C.)

CAMBRIAN

	Feet	Feet
Erwin quartzite		711
Dense, resistant, gray-white, irregularly bedded quartzite	80	
Sandstones, gray, pink, and brown	141	
Very massive, blue-gray, jointed quartzite	42	
Sandstone; largely striped brown; some shales	106	
Massive, rough-bedded, gray-white quartzite; with Scolithus	88	
White, blocky sandstone	8	
Massive, gray-white quartzite; bedding obscured	18	
Thin shales	3	
Pinkish, blocky quartzite; Scolithus	39	
Brown shales and sandstones	72	
Very massive, dark-blue quartzite; abundant Scolithus	42	
Gray shales and thin sandstones	4	
Massive blue-white quartzite; Scolithus at top	40	
Irregularly bedded, brown, rather massive sandstone	28	
Hampton shale		474
Very thin-bedded, brown sandstone; shale partings	19	
Micaceous, gray, sandy shales	27	
Thin-bedded, friable, brown sandstone; shale partings	13	
Largely shales; gray, sandy, micaceous, thin.	415	
Unicoi formation		not measured

Section No. 6.

Natural Bridge Station Section

Section of Cambrian rocks along Virginia State Highway 249, 2 miles southeast of Natural Bridge. Strike North 50° East; dips nearly ~~rocks largely~~ vertical.

OZARKIAN

	Feet
Conococheague formation, top not measured	94
Dolomite; thin shale partings, red-brown sandy soil	85
Massive, blue, coarse, sugary limestone	9

CAMBRIAN

	Feet
Elbrook formation	1093
Thin, shaly, ocherous limestone	36
Light-gray, dense dolomite and interbedded limestone	21
Dark-blue limestone	14
Thin-bedded, blue and gray limestone and dolomite	85
Largely covered	215
Gray shales; somewhat sandy	60
Largely covered; thin shaly limestones	285
Entirely covered	216
Largely covered; thin shaly limestones	161
Probably Elbrook	362
Sandy, ocherous shales; a few red shaly zones ...	80
Covered	132
Yellow, ocherous, sandy shale; some blue-green ..	150
Rome ("Watauga") shale	1093
Rusty, red and green, mixed shales	290
Covered	47
Thin, fissile, red and purple shales	55
Massive, dark-blue, dolomitic limestone, weathering shaly	11
Thin, gray-blue and brown shales	41
Red and purple, thin shales	33
Yellow, sandy, ~~and~~ ocherous, shale; partly covered.	146
Thin, black, calcareous shale	5
Soft, ocherous, yellow-brown shale	73
Covered	160
Thin, red, gray, and green shale	20
Soft, ocherous shale; a few green shales	62
~~Typical~~ Stiff, mixed red and purple shale	23
Soft slates; largely blue-green	35
Soft ocherous shales	7
Rather sandy, brittle, cherty shale	34
Blue-gray limestone	9
Thin, gray-brown fissile shale; partly covered ...	42
Shady dolomite	1295
Thin-bedded, blue-gray laminated dolomite and shales	47
Covered; stratigraphic interval to quartzite 1248	

Section No. 7.

Cedar Ridge Section

Section measured along old course of ~~Virginia~~ State Highway 17 (now 12), 1 mile north of Flatwoods School. Strike South 70° West; ~~rocks largely~~ dips nearly vertical.

ORDOVICIAN

	Feet
Athens shale	not measured
Lenoir limestone	124
~~Rotten,~~ Black, knotty, rotten limestone; largely covered	8
Black, fossiliferous limestone	3
Largely covered (interval includes Mosheim?)...	113

CANADIAN

	Feet
Canadian dolomite	718
~~Pure,~~ Dark, dense limestone; weathers light blue	34
Covered	30
Massive blocky light-blue dolomite	108
Largely covered; thinner gray dolomite	342
Do.	112
Rather massive light-gray dolomite	92

OZARKIAN

	Feet
Ozarkian dolomite (base not measured)	1211+
Coarse gray sandstone; weathering brown	3
Massive blue-gray dolomite; water-worn surfaces	120
Mostly covered; thin-bedded dolomite	248
Gray dolomite and shale layers	45
Thin-bedded, dark-blue limestone	70
Coarse dark dolomite	3
Thin-bedded, dark-blue limestone	59
Interbedded limestone and dolomite	98
Thin gray calcareous shales	16
Interbedded limestone and dolomite	298
Thin gray calcareous shales	85
Massive dolomite and interbedded limestone	166
Covered	

Section No. [illegible].

Indianrock Section

Section along Rocky Run and road leading to Indianrock. Strike North 48° East, dip about 52° Southeast. Section extends from fault at northeast to bridge over creek at southeast.

ORDOVICIAN

	Feet
Lenoir (probably containing several small faults)	165½
Dense, finely crystalline, blue-gray limestone ...	45
Dark-blue limestone; more crystalline below; cherty	48
Do.; slightly pinkish; some crypto-crystalline limestone	39
Blue, crystalline, finely laminated limestone	24
Bluff City member; coarsely crystalline, gray marble	9½
Mosheim limestone	32
Dense, blue-gray limestone; conchoidal fracture ..	3
Do.; crypto-crystalline; brittle; bluish gray	20
Blue-gray, finely knotty, ~~very~~ dense limestone; fossils	3
Dense, dove-colored vaughanite	6
Lower Stones River formation	92
Blue-gray, coarsely crystalline, massive limestone	10
Fine and coarse blue limestone, ~~rather flinty, thick~~-bedded	24
Do.; some dolomitic, other zones coarse	17
Vaughanite; ~~some~~ chert; ~~some~~ crystalline limestone	11
Massive cherty vaughanite; some dark-blue limestone	8
Dark and gray crystalline limestone; much chert ..	22

CANADIAN

	Feet
Beekmantown (chiefly Nittany dolomite)	562
Massive dolomite	9
Covered	3
Massive blue-gray dolomite	32
Do.; partly covered	253
Dark limestone and interbedded dolomite; ribbony .	38
Thinner-bedded dolomite	40
Covered	59
Thin to medium-bedded dolomite and limestone	115
Covered	13

OZARKIAN .....not measured

	Feet
Covered; presumably Chepultepec formation	45
Massive dolomite; gastropods	

Section No. 9.

Rocky Point Road Section

Section measured along road leading from Lee Highway to Rocky Point. Strike North 75° East, dip 85° Southeast. Section measured northwestward from fault.

ORDOVICIAN

	Feet
Athens shale, top faulted out	249
Gray-black fissile shales	20
Shales; several lenses of dark, crystalline limestone	22
Contorted gray-black fissile shales; a few limestones	103
Gray-black knobby limestone; lower 8' single ledge forms	73
Limestone; less knobby, zones of lenticular chert	16
Coarsely crystalline massive, dense limestone; no chert	15
Holston limestone	81
Coarse, gray, crystalline marble; irregularly bedded	45
Dense, blue-gray, massive, laminated limestone	36
Lenoir limestone	239
Coarse gray-black limestone	64
Black cherty knobby limestone	47
Gray crystalline limestone	45
Dark cherty, knobby limestone	45
Bluff City member; coarse, gray, crystalline marble	38
Mosheim limestone	158
Dense, structureless, gray vaughanite	68
Do.; becoming darker below; brittle	90
Lower Stones River formation	133
Dark, dense limestone; distinct chert lenses	30
Same; black; vaughanite, ~~more~~ very cherty	58
Thinly knobby or checky, blue-gray limestone	45

CANADIAN

	Feet
Canadian dolomite (bottom not measured)	329
Thin-bedded dolomite	38
Thicker-massive ~~Heavier~~-bedded, gray dolomite	33
~~Heavy~~ chert zone	3
Irregularly bedded, gray dolomites	255

Section No. 10.

Slate Branch Section

Section of Ordovician rocks measured along Slate Branch, 1½ miles northeast of Flatwoods, near small bridge. Strike North 40° East; ~~beds largely~~ dips nearly vertical.

ORDOVICIAN

Athens shale; ~~with~~ graptolites ..... not measured

	Feet
Lenoir limestone, ~~black, knobby crystalline limestone.~~ .	122
Rather ~~heavy,~~ massive dark limestone; weathers bluish, slightly knotty	112
Softer, black limestone, or calcareous shale ...	1
Single massive bed of dark limestone; finely crystalline; dense; weathers bluish	7.5
(Sharp unconformity) ⟶	
Blue-black limestone conglomerate; with dolomitic pebbles	1
Sharp unconformity upon a water-gouged surface.	

CANADIAN

Canadian dolomite (base not exactly located) 625

Section No. 11

Blue Spring Creek Section

Section measured along Blue Spring Creek at extreme southwestern end of Rich Patch valley, near edge of Eagle Rock quadrangle.

ORDOVICIAN

	Feet	Feet
Martinsburg shale, Trenton division (top not measured)..		192
Thin, platy, buff limy shales	40	
Coarse, crystalline limestone; shale partings.	7	
Buff and greenish shales	47	
Gray and green calcareous shales and dark fossiliferous limestone lenses	98	
Lowville limestone		24
Medium-bedded, dense, ribbony dark limestone..	12	
Coarser, medium-bedded black limestone	12	
Lenoir limestone		232+
Massive, knobby, dark crystalline limestone ..	42	
Irregularly bedded black crystalline limestone	23	
Knobby, blue-black limestone	12	
Knotty, dark limestone (estimated)	155	
Lower Stones River limestone (estimated thickness)		320±
Coarse dark, cherty limestone	320	

CANADIAN

Canadian dolomite ..... not measured

Blue-gray Bellefonte dolomite .....

Section No. 12

Catawba Creek Section

Section of Lower Ordovician rocks measured along country road and tributary of Catawba Creek, ½ mile northwest of latter, and 3½ miles northeast of Flatwoods School. (Note: This exposure was partially obliterated in the re-locating of State Highway 12, formerly No. 17.)

ORDOVICIAN

Athens shale	not measured
	Feet
Lenoir limestone	164

	Feet
Massive knobby or knotty limestone	41
Do.; ~~Similar, but~~ softer, limestones.....	6
Medium-bedded, knobby limestone	47
Massive, blue, knobby limestone	42
Very massive, blue, knobby limestone	28

CANADIAN

Canadian dolomite ..... not measured

Section No. 17

Rocky Point Quarry Section

Section of Lower Ordovician rocks measured in the Rocky Point quarry of the Liberty Limestone Corporation. Strike North 50° East, dip 40° to southeast.

ORDOVICIAN

	Feet	Feet
Athens shale (top faulted out)		155+
Dark chocolate-brown fissile shales, graptolites	100	
Fine, very dark, crystalline limestone	31	
Coarse, gray, crystalline limestone; Holston type	4	
Coarse, black crystalline limestone	20	
Holston limestone		82
Intermediate gray-black coarse crystalline limestone	3	
Massive, coarse, gray marble	43	
Thinner-bedded, splintery, gray crystalline limestone	36	
Lenoir limestone		117
Dark, knobby, thin-bedded black limestone	36	
Massive to blocky gray-black crystalline limestone	28	
Dark, knobby limestone; reticulate	18	
Very fine-grained black crystalline limestone	35	
Mosheim limestone		25+
Dense, black vaughanite	25+	

Section No. 14

Murat Post Office Section[2]

Section at Murat Post Office, measured by R. S. Bassler[1]; interpreted by present author.

ORDOVICIAN

Martinsburg shale		not measured
		Feet
Lower Martinsburg, Chambersburg, and Athens shales ...		1000
Holston limestone		125
	Feet	
Gray, coarsely crystalline marble	125	
Lenoir limestone		43
	Feet	
Dark-blue pure limestone	20	
Laminated drab limestone	14	
Thin-bedded dark limestone; slabby; solid chert	9	
Mosheim formation		6
	Feet	
Massive dove limestone	6	
Lower Stones River and Canadian beds		not measured

---

1 Bassler, R. S., Cement resources of Virginia west of the Blue Ridge; Virginia Geol. Survey Bull. 2A, ~~1908~~, pp. 125-127, 129, 1909.

Section No. 15

Section at Lexington

Section near Lexington, measured by R. S. Bassler[1], interpreted by present author.

ORDOVICIAN

Martinsburg shale		not measured
		Feet
Chambersburg limestone		500
	Feet	
Thin-bedded, argillaceous, and calcareous shales	500	
Athens shale		300+
	Feet	
Fine-grained, dark, massive, argillaceous limestone; conchoidal fracture	250	
Argillaceous, knotty limestone; many fossils	40	
Crystalline limestone[2]; very fossiliferous	10	
Holston limestone		100
	Feet	
Massive, gray, crystalline limestone	100	
Lenoir limestone		
Massive, somewhat cherty limestone		not measured
Mosheim limestone		not measured

---

[1] Bassler, R. S., op. cit., pp. 106, 125.

[2] It is possible that this unit, described by Bassler as "often absent from sections," represents the Whitesburg limestone.

Section No. 1[illegible]

Dunkard Church Section

Section of Ordovician ~~rocks~~ measured along road from point near Dunkard Church to Purgatory Creek. Strike North 55° East, dip 15° to southeast.

ORDOVICIAN

Martinsburg shale ..... not measured

	Feet
Chambersburg shaly limestone	541
Gray shale; thin lime partings	130
Limestone with shale partings; Isotelus	35
Covered; yellow shale float	8
Interbedded limestone and shale	80
Gray calcareous shale; many limy zones	43
Do.; fewer limy zones; fossils	13
Gray-brown, chocolate shales	22
Thin-bedded shale; slabby float	86
Gray shale; several limy zones; cleavage	24
Do.; more limy zones	42
Thin-bedded, shaly limestone	28
Splintery brown shales, knobby	30
Athens shale (See Pl. 36, B)	5
Finely crystalline, black limestones and shales ..	5
Holston limestone	18
Coarse, crystalline, cross-bedded, sandy, pinkish marble	18
Lenoir limestone (base not measured)	171+
Covered; probably Lenoir	38
Massive, dark, reticulate limestone; shaly	11
Covered	8
Massive, nearly black limestone; much chert	42
Do.; cherty lenses	8
Thin-bedded, knobby, cherty limestone	12
Dark, knotty limestone; some chert	15
Gray-black to dark limestone	2
Dark, knotty limestone; thinly laminated	35
Coarse, crystalline, dark-blue, massive limestone	not measured

Section No. 17

North Mountain Section

Section of Silurian rocks measured along State Highway 251, midway between Collierstown and Longdale Furnace, on southeastern slope of North Mountain. Strike North 52° East, dips between 40° and 50° northwest. The Keefer sandstone forms the crest of the mountain.

SILURIAN

	Feet
Keefer sandstone (top not measured; section includes minor faults)	144
Coarse, white, resistant sandstone	4
Pinkish-white, grainy sandstone	2
Spongy, hematitic, sandstone; tubular markings	7
Thick ~~Heavy~~-bedded, coarse, resistant, quartzitic sandstone; forming crest of mountain	25
Less massive; white sandstone	40
Very massive, ledgy, white quartzite; weathering brown	38
Less massive, checky, gray-white sandstone	28
Cacapon formation	256
Thin-bedded, red sandstone; typical Cacapon	16
Buff, pencilly, sandy shales; Buthotrephis	16
Thin and thick, ~~heavy~~, ledgy, red Cacapon sandstone	44
Buff, sandy shales and thin, red sandstone	33
Less massive, thin-bedded, gnarly, red sandstone	53
Red and buff shales and brown sandstones	84
Rather thin-bedded typical Cacapon sandstones	10
Clinch sandstone	197
Irregularly bedded, brown sandstone	8
Buff shales; many sandstone lenses	14
Same with several quartzite lenses	9
Heavy cross-bedded, brown-white sandstones	5
Yellow-gray shales	1
Massive, ledgy quartzitic sandstone; stained brown	20
Pinkish sandstone	4
Friable, checky, irregular sandstone; shale seams	25
Brown, resistant, cross-bedded sandstones; shale seams	76
Same; less massive	30
Thick ~~Heavy~~, brown sandstone	5

ORDOVICIAN

Martinsburg shale (Maysville division) ..... not measured

Greenish-brown sands and shales, Orthorhynchula

Section No. 18

Hooks Mill Section

Section of Silurian rocks near Hooks Mill, measured along State Highway 43 at crest of Rich Patch Mountain, on headwaters of Roaring Run. Strike North 10° East, dip about 55° North. (Note: The exposed beds of Keefer sandstone are somewhat displaced by minor faults.)

DEVONIAN

	Feet
Helderberg Monroan limestone	95+

SILURIAN

	Feet
Keefer sandstone	159
Massive vitreous, reddish sandstone	55
Shales and thin sandstones	33
Thick Heavy-bedded, reddish sandstones	11
Massive, gray sandstones; Scolithus	60
Cacapon sandstone (See Pl. 42, B)	255
Slabby, ferruginous, red shales	37
Buff, knotty shales; a few sandstone lenses ...	27
Thick Heavy-bedded, typical hematitic sandstone	28
Gray, green, and yellow shales; fossiliferous..	36
Thick and thin-bedded, red and olive shales ...	49
Massive, red sandstone	16
Red and olive shales; buff sandstones below ...	58
Gray clay shales	4
Clinch sandstone	60+
Gray-white, quartzitic sandstones	10
Gray, thin-bedded sandstones	50+

ORDOVICIAN

Juniata shale (largely covered)	not measured

Section No. 19

Cartmell Gap Section

Section of Silurian rocks measured along Penn Branch in Cartmell Gap, 3¼ miles northeast of Springwood. Strike North-South, dips between 65° and 75° West. Section extends from crest of gap to Pulaski Fault, along western slope of mountain.

SILURO-DEVONIAN

	Feet	
Covered interval to Pulaski Fault	351	
Helderberg and Monroan	249	
Dense, gray, ferruginous, calcareous sandstone ..	12	
Covered	67	
Massive ~~Heavy~~, white and brown, crumbly sandstone	68	Top of Eagle Rock ss
White quartzite	8	
Covered	34	
Thin-bedded, coarse, brown sandstones	60	

SILURIAN

	Feet	
Keefer sandstone	248	
Covered; much heavy float	104	
Thick ~~Heavy~~-bedded, coarse, white sandstone, craggy ...	113	
Dense, white quartzite and sandstone	31	
Cacapon formation	127	
Covered; abundant red sandstone float	122	
Do.	5	
Clinch sandstone	173	
Covered; Clinch but no Cacapon float	37	
White, medium-grained, ~~heavy-bedded~~ massive sandstone ...	39	
Pinkish gray-brown sandstone and quartzite	97	

ORDOVICIAN

Martinsburg ..... not measured

~~Typical~~ Greenish-brown sandstones and shales

Section No. 20.

Iron Gate Section

Approximate section of Devonian and Silurian rocks as exposed along James (Jackson) River in Iron Gate near Clifton Forge. (See Figs. 50,B and 50,A.)

DEVONIAN

	Feet
"Romney" black fissile shale	not measured
Onondaga drab and greenish sandy shale	45
Oriskany coarse, brown sandstone	12
Becraft limestone	51
Massive, thick-bedded, cherty, crystalline limestone	45
Gray, nodular limestone; chert nodules	6
New Scotland gray, sandy limestone	16
Coeymans gray, crinoidal, crystalline limestone	18
Keyser formation	114
Upper Keyser gray, coralline limestone	34
Clifton Forge gray to white calcareous sandstone	65
Lower Keyser nodular, shaly limestone	15

SILURIAN

	Feet
Tonoloway limestone (largely covered)	200
Keefer sandstone	280
Massive, resistant quartzitic sandstone	40
Interbedded sandstone and shaly sandstone	125
Largely massive, gray-white sandstone	115
Cacapon formation	170
Chiefly interbedded red sandstone and shale ..	170
Clinch sandstone	50
Massive ledge of hard, white quartzite	50

Section No. 21

Eagle Rock Section

Composite section measured along James River in gap through Crawford-Rathole mountains at Eagle Rock.[1] The Silurian sandstones are complexly folded in this gap, and have been duplicated by at least one major fault. It is possible to measure all three Silurian units at two points on each side of the river, but it is difficult to obtain similar measurements in any two of the four exposures. This section is a composite of two measurements of the various exposures, one made in 1929, the other in 1934, before and after excavations for the new bridge and highway at this point. In view of the complex structure, it is difficult to evaluate the measurements. (See Pls. 57 and 58.)

DEVONIAN

Onondaga shale ..... not measured

	Feet
Helderberg and Monroan	~~200~~
Covered interval	195
Massive to shaly, gray to pinkish sandstone; possibly belonging to Keefer sandstone	74

SILURIAN

	Feet
Keefer formation (See Pl. 43, B)	324
Massive gray and white, streaked ridge-making quartzite	55
Medium-bedded sandstone; thin quartzitic ledges	56
Massive rusty-gray to pinkish quartzite	54
Shaly zone	5
Thick ~~Heavy~~-bedded resistant ridge-making quartzite	95
Interbedded reddish sandstone, shale, and brown sandstone	35
Massive ledge of white quartzitic sandstone	24
Cacapon formation	102
Red and brownish shaly sandstone	50
Massive hematitic red sandstone	7
Thin, slabby red sandstone and interbedded brown shale	45
Clinch formation	168
Hard, gray, quartzitic sandstone	97
Massive, grayish-white sandstone	28
Irregularly bedded gray-white sandstone	28
Dense gray sandstone	15

ORDOVICIAN

Juniata shale (?) ..... not measured

---

[1] Compare with analogous section reported by Stose and Miser; Virginia Geol. Survey Bull. 23, [1922, p. 31,] The section measured by Stose and Miser, unfortunately, does not allow for the unusual faulting present in the gap.

Section No. 22

Back Creek (Rich Hill) Section

Section of Devonian and Silurian rocks exposed along Back Creek immediately north of Rich Hill, ¾ mile due east of Horseshoe Bend of James River. Section measured westward from axis of anticline. Strike North-South, dips range from 50° West to 90°. (See Pl. 11,B.)

DEVONIAN

	Feet	
Romney shale		not measured
Lower Romney, Onondaga, Oriskany, Upper Becraft		150
Covered	150	
Lower Becraft		8
Coarse, crystalline, reticulate limestone	8	
Healing Springs, Coeymans, Upper Keyser		52
Covered	40	
Thin-bedded, dense, dark limestone	12	
Clifton Forge sandstone		145
Largely covered	28	
Rather massive, granular, ferruginous sandstone.	57	
Hard, knobby, gray-brown sandstone	10	
Cross-bedded, crumbly, ferruginous sandstone ...	2	
Hard, gray sandstone, quartzitic	7	
Covered	7	
Dense, white quartzite	2	
Gray, ferruginous, calcareous sandstone	18	
~~Shaly,~~ Calcareous shale	2	
Massive, sugary, gray-brown, ferruginous sandstone	12	
Lower Keyser formation		50
Limestone and interbedded, brown sandstone	19	
Thin-bedded, gray limestone	28	
Dark-gray sandstone	3	

SILURIAN

	Feet	
Tonoloway limestone		75
Brittle, ribbony, thinly laminated, shaly limestone	50	
Covered; probably same	25	
Keefer sandstone		260
Sugary, brown sandstone	18	
Hard quartzite and sandstone	130	
Very massive, ledgy, gray-white quartzite	112	
Cacapon formation		177
Covered interval; Cacapon float	73	
Massive, red sandstone; typical Cacapon	34	
Covered; much Cacapon float	70	
Clinch sandstone, bottom not exposed		221
Thin, white sandstones and shales	42	
Shaly zone, some black shale float	7	
Thick ~~Heavy~~, irregularly bedded white sandstone and quartzite	172	

Section No. 37

1 Prices Bluff Section

Section of Upper Silurian and Lower Devonian ~~rocks~~ at Prices Bluff along James River at southwestern end of Big Hill, 2½ miles above Gala. Strike South 50° West; dips ranging from 45° to 0°. (See Pl. 11 and 15,A.)

DEVONIAN

Onondaga shale		not measured
		Feet
Oriskany brown, friable sandstone		1.5
Becraft limestone		107
	Feet	
Massive, gray, coarsely crystalline limestone...	54	
Cherty, gray limestone	15	
Limestone and porous sandstone	10	
Knobby ~~and~~ to massive, gray limestone	28	
Healing Springs sandstone; dense, hard		15
Coeymans limestone		26
	Feet	
Limestone and black shale	1	
Pinkish, crinoidal, crystalline limestone, fossils	20	
Massive, gray, sandy limestone	5	
Upper Keyser limestone		30
	Feet	
Massive, knobby, cherty limestone; corals	23	
Blue, sandy, cherty limestone	7	
Clifton Forge sandstone		70
	Feet	
Brown sandstone	5	
Very massive, arenaceous limestone	35	
Massive ~~Heavy~~ limestone; weathering blue-gray	10	
~~Heavy,~~ Sandy limestone; very massive	20	

SILURIAN

Tonoloway limestone		119
	Feet	
Paper-thin, limestones; weathering gray	30	
Gray and yellow sandstones; weathering dark ...	5	
Thinly laminated, slabby limestone	40	
Covered; presumably same as above	24	
Thin, dark limestone; carrying abundant Leperditia	3	
Gray-black, fine, slabby limestone	17	
Covered to railroad tracks.		

---

1 Compare with analogous section reported by F. M. Swartz; U. S. Geol~~ogical~~ Survey Prof. Paper 158C, 1929, p. 68,

Section No. 21

Jackson River Section

Section of Helderberg and Monroan ~~rocks~~ in the gorge of Jackson River between Kinkaid and Greenwood, 11 miles north-northwest of Covington.[1]

DEVONIAN

	Feet
Oriskany sandstone	30
Becraft and New Scotland knobby and cherty limestone.	200
Healing Springs quartzitic white sandstone	40
Coeymans limestone	70
Massive ~~Heavy~~ pink crystalline limestone	50
Thin limestones and sandstones; Gypidula	20
Clifton Forge heavy-bedded sandstone	80
Lower Keyser limestone	50
Knobby limestone; Cladopora	5
Massive ~~Heavy~~ limestone thick-bedded, coarse	40
Shaly limestone	5

SILURIAN

Tonoloway shaly limestone; bottom not exposed	40

---

1 The main headwaters of James River above Lick Run are called Jackson River.

Section No. 25

Island Ford Section Jackson (James)

Section of Lower Devonian ~~rocks~~ exposed along ~~James~~ River near Island Ford. Section measured on western side of river at water-level.

DEVONIAN

	Feet
Oriskany sandstone	6
Becraft coarse, crinoidal limestone	75
New Scotland knobby, cherty limestone	50
Healing Springs quartzitic sandstone	32
Coeymans limestone; Gypidula	24
Upper Keyser limestone	12
Massive, sandy limestone; crinoids, corals ...	3
Stromatopora bed	1
Coral zone, in massive limestone	8
Clifton Forge sandstone	100

Section No. [illegible]

Lyle Tunnel Section

Section of Lower Devonian rocks ~~along~~ James River, ½ mile north of Lyle Tunnel. Rocks approximately horizontal. Section measured to water-level.

DEVONIAN

	Feet
Becraft and Healing Springs formations	50
Dark-gray, rather cherty, fine-grained limestone	8
Cherty coarse ferruginous sandstone	8
Medium-textured, sandy limestone; fossils	15
Same; Spirifer, etc.	19
Coeymans (?)	19
Dark-blue limestone; cross-bedded, sandy, fossils	7
Do.; more sandy, less massive	12
Upper Keyser limestone	38
Rather fine, dark-gray limestone; Cladopora	17
Massive, sandy limestone; many Stromatopora	21
(To water-level	7)

Section No. 27

Big Hill Section

Section of Lower Devonian rocks at northeastern end of Big Hill on northern side of country road, ½ mile north-northwest of Grange School. (Note: This section was measured in 1929. Subsequently the exposure was opened by a quarry in the Becraft limestone to supply stone for the re-grading of State Highway 12.)

DEVONIAN

	Feet
"Romney" shale	not measured
Onondaga shale; yellow crumbly clay-shales; Phacops, etc.	35+
Oriskany sandstone; gray dense sandstone; rusty-brown weathering	4
Becraft limestone	109
Massive gray-blue limestone; few fossils	20
Rusty-brown granular sandstone	3
Dark crystalline limestone; weathers blue-gray, massive; many fossils	60
Medium-bedded, dark, crystalline limestone; weathers gray	8
Dark, finely crystalline, dense limestone; much chert; corals	18

Section No. 28

Price Mountain Section

Section of Upper Devonian ~~rocks~~ on Price Mountain, measured from crest of ridge northwestward down road connecting Fincastle and Craig Creek ~~P.O.~~ Post Office. Section begins near Craig-Botetourt county-line, and ends near Sulphur Spring. Strike North 75° East, dip about 30° to southeast.

	Feet
MISSISSIPPIAN	
Price formation (top not measured)	50
	Feet
Coarse, gray, thin-bedded sandstone	16
Thicker ~~Heavier~~-bedded, gray sandstone	22
Fine conglomerate; quartz pebbles; plant remains..	2
Lumpy yellow sandstone	10
DEVONIAN	
Catskill formation	525
	Feet
Pink, olive, and buff shales and pinkish sandstone.	340
Massive, yellow, irregularly bedded sandstone	31
Massive, arkosic, brown sandstone; weathering slabby	36
Red shale and sandstone; some yellowish	68
Massive, white, quartzitic conglomerate	11
Thin, red and yellow, slabby shales and sandstone..	39
Chemung formation	2886
	Feet
Very massive, white sandstone and conglomerate (Hendricks sandstone)	33
Red-brown and yellow, flaky shales; sandy lenses..	110
Yellow and pinkish-gray pencilly shales	58
Olive, flaggy sandstones; Spirifer; crinoids	413
to	
Massive, slabby, red-brown sandstones (Valley Head sandstone?)	68
Slabby sandstone and thin shale; Spirifer	133
Red, pencilly shale; sandstone lenses	40
Flaggy, buff sandstone; weathering red-brown	72
Yellow-buff, chunky shale; some olive	94
Knotty and slabby red-brown shale and sandstone...	96
Yellow pencilly shale	10
Massive, olive-buff, arkosic sandstone; conglomeratic	22
Irregularly bedded, slabby, red-brown sandstone ..	44
Very massive, light-brown sandstone; weathering dark	33
Pencilly red and yellowish shale	35
Irregularly bedded, red, flaggy sandstone	20
Pencilly and chunky, red and yellow shale	34
Irregularly bedded, buff and red shale and sandstone ..... to	112
Pencilly, red and yellow shale; some sandy lenses.	161
Yellow, chunky shales; stained pinkish	175
Gray and yellow, knotty sandstone; Spirifer	131
Pencilly and flaky clay shales; Ambocoelia	151
~~Heavy~~ Light-colored, massive sandstone; Spirifer.	73
Sandstone and chunky shales; many fossils	54
Massive, dark-olive sandstone .. ~~thick~~	26
Chunky shales, interbedded with ~~heavy~~ and thin sandstone lenses; crinoids, Atrypa, Spirifer, and Ambocoelia	688
Brallier shale	not measured

FOSSIL LOCALITIES

Collections of fossils have been made from the following localities within the Natural Bridge region.

Collections made by Dr. Harry S. Ladd, 1927.

1. Along road near New Hope School, 1 mile northwest of Flatwoods School. Nittany chert. Field No. L67.

2. Along road from Fincastle to Botetourt, ¼ mile east of Bradshaw Branch. Nittany chert. Field No. L90.

3. Along main road in Rich Patch valley, near junction of road leading down Hays Gap. Nittany chert. Field No. L94.

4. A few rods southwest of Locality 3. Lower Stones River limestone. Field No. L85.

5. At Dry Run School on Eagle Rock-Fincastle road (old State Highway 17), 2.5 miles north of Fincastle. Athens shale. Field No. L22.

6. Along road 3/4 mile due west of Fairgrounds. Athens shale. Field No. L24.

7. About ¼ mile south of Eagle Rock quadrangle, along road leading south along foot of Caldwell Mountain, near canning factory. Athens shale. Field No. L33.

8. In road gutter, 1 mile southeast of North Fork School. Athens shale. Field No. L25.

9. Along ~~road~~ State Highway 12 north of fault near old mill, 1 mile due north of Fincastle. Athens shale. Field No. L37.

10. Along road at north wall of Catawba Creek Valley, 1 mile northwest of Kyles Mills. Athens shale. Field No. L40.

11. Along road at north wall of Catawba Creek near swinging foot-bridge, 2.5 miles due north of Kyles Mills. Athens shale. Field No. L41.

12. Along Fincastle-Eagle Rock highway, 2½ miles north of Fincastle, near Dry Run School. Athens shale. Field No. L47.

13. Along main Eagle Rock-Fincastle highway near Fairgrounds, 0.2 mile south of Locality 12. Athens shale. Field No. L48.

14. Along Catawba Creek, ½ mile south of quadrangle, 1½ miles southwest of Howell Mills. Athens shale. Field No. L49.

15. Abandoned quarry, southeast slope Crawford Mountain, ½ mile southwest of James River, north of main highway. Holston limestone. Field No. L8.

16. Along main road leading up Roaring Run near Hooks Mill. Martinsburg shale. Field No. L86, also No. L75.

17. Along Rich Patch-Covington road in Hays Gap, 0.2 mile northwest of house shown on map. Cacapon sandstone. Field No. L81, also No. L84.

18. Along road on west side of Big Hill, ¼ mile south of Locust Bottom Church. Becraft limestone. Field No. L59.

19. Along road northwest end of Big Hill, ½ mile northeast of Locust Bottom Church. Becraft limestone. Field No. L60.

20. Along road in gap between Bearwallow and Pine Mountain near county-line. Becraft limestone. Field No. L76.

21. Along road on west side of Big Hill, 1 mile due east of Woods Island. Onondaga shale. Field No. L95.

22. Along road at northeast end of Big Hill near church, 0.2 mile west of Eagle Rock-Clifton Forge road. Helderberg limestone. Field No. L61.

23. Along road north side of Rathole Mountain, due north of Eagle Rock. "Romney" shale. Field No. L3, also No. L2.

24. Along road at junction with Eagle Rock-Clifton Forge highway or Sinking Creek road. "Romney" shale. Field No. L62.

25. Along road up Roaring Run, 0.2 mile east of county-line. "Romney" shale. Field No. L73.

26. Along Rich Patch-Covington road, just north of bridge over Hays Creek. Brallier shale. Field No. L80.

Collections made by Herbert P. Woodward, 1929-34.

27. Ledges along U. S. Highway 501, immediately west of the junction of North and James rivers. Erwin quartzite. Field No. W282.

28. Sandstone ledges on southwest side of Sallings Mountain, about ~~half a~~ ½ mile northeast of Natural Bridge Station. Erwin quartzite. Reported by Walcott; U.S. Geol. Survey Mon. 51, pt. 1, p. 200, 1912.

29. Sandstone ledges along small creek meeting James River nearly opposite Gilmore Mills. Erwin quartzite. Reported by Walcott; [illegible].

30. Along Lee Highway, immediately east of small bridge, 1/8 mile east of Garsts Store. Ledge is on north side of road below house. Rome ("Watauga") shale. Field No. W15-7; W58; W226-8.

31. Along road 2 miles southeast of Natural Bridge. Rome ("Watauga") shale. Reported by Walcott; Am. Jour. Sci., 3d ser., vol. 44, p. 5, 1892.

32. Ledges on Buffalo Creek, 2 miles southeast of Buffalo Mills. Elbrook limestone. Reported by Walcott; U.S. Geol. Survey Mon. 51, pt. 1, p. 218, 1912

33. Soft, ocherous sandstone and clay on southeast side of Lee Highway, 1.6 miles northeast of road junction at Natural Bridge. Conococheague formation. Field No. W404.

34. Weathered surfaces of limestone along Cascade Creek, 1 mile due north of Natural Bridge. Conococheague formation. No specimens collected. (See Pl. 33, A.)

35. Ledges of southeastern abutment of Natural Bridge beneath the bridge. Chepultepec limestone. Reported by Reeds; "The Natural Bridge of Virginia and its environs", Richmond, Virginia, 1930.

36. Sloping ledges just north of sharp western bend in road leading from Lee Highway to Indianrock, about 0.8 mile southeast of Lee Highway. Stonehenge limestone. Field No. W279.

37. Loose chert, along east side of road, 1 mile southwest of Rapps Mill. Nittany dolomite. Field No. W278.

38. Loose chert, along secondary road about ½ mile south of Hamilton School and ½ mile east of Rapps Mill-Murat road. Nittany dolomite. Field No. W302.

39. Along road in Sugartree Hollow, 1 mile northwest of the Eagle Rock-Fincastle highway. Nittany chert. Field No. W126; W129.

40. Loose chert, on western slope Mt. Pisgah, 3 miles southwest of Oakdale. Canadian dolomite. Field No. W403.

41. Near house at end of road, north of Mt. Pisgah. Canadian dolomite. Field No. W493; also W600.

42. Along hill-slope ¼ mile north of Forest Grove School. Nittany chert. Field No. W39.

43. Along road in Rich Patch Valley, 2½ miles northeast of Mountain Valley School. Canadian chert. Field No. W69.

44. Along road in Rich Patch valley, 0.1 mile south of Rich Patch School. Lower Stones River limestone. Field No. W72.

45. Ledges, 1 mile west of Lexington. Lenoir limestone. Reported by Bassler; Virginia Geol. Survey Bull. 9A, p. 107, 1922.

46. Knobby ledges on west side of hill, ¼ mile south of Dunkard Church. Also loose float. Lenoir limestone. Field No. W394.

47. Knobby ledges along road leading to Karnes Spring, ¼ mile southwest of Dunkard Church. Lenoir limestone. Field No. W396; also W496.

48. Knobby ledges along Rocky Run road, 100 yards north of Dunkard Church near Bench Mark 1587 A.T. Lenoir limestone. Field No. W289.

49. Face of cut, quarry of Liberty Limestone Corporation along Roaring Run, 1.4 miles north of Rocky Point. Lenoir limestone. Field No. W443.

50. Limestone, at Lexington. Holston limestone. Reported by Raymond; op. cit., p. 105.

51. Upper surface of ledges along Rapps Mill road, 0.8 mile south of road fork to Oakdale, on South Buffalo Creek. Holston limestone. Field No. W275.

52. Along secondary road following small tributary of North Buffalo Creek, immediately east of Mt. Pisgah, 2¼ miles southwest of Oakdale. Holston limestone. Field No. W276.

53. Ledges along northern part of Spring Branch, immediately south of Sanford Hill, 4 miles southwest of Oakdale. Holston limestone. Field No. W277.

54. Ledges along south side of road between Murat P. O., and bridge over Buffalo Creek. Holston limestone. Field No. W296. Also reported by Bassler; op. cit., p. 109.

55. Ledges immediately southeast of junction of Broad and Buffalo Creeks, 5 miles southeast of Murat. Holston limestone. Field No. W306.

56. Face of cut, quarry of Liberty Limestone Corporation along Roaring Run, 1.4 miles north of Rocky Point. Holston limestone. Field No. W442.

57. Moore Lime Company quarry, west bank of James River at Eagle Rock. Holston limestone. Field No. W99.

58. Along main road ¼ mile north of Flatwoods School. Athens shale. Field No. W37; W110; W613.

59. Along Flatwoods-Kyles Mill road, near Slate Branch. Athens shale. Field No. W74.

60. Ledge on northwest end of Poplar Hill along abandoned secondary road. Athens shale. Field No. W116.

61. Shale along creek, southeastern slope of The Knob, 1.2 miles due west of junction of Rocky Run road with Lee Highway. Athens shale. Field No. W397.

62. Shaly limestone, near Lexington. Athens shale. Reported by Bassler; and Raymond; Harvard Coll. Mus. Comp. Zoology Bull., vol. 67, op. cit., p. 110; op. cit. 11, 17, 38, 69, 91, 108, 110, 125, 160, 1925

63. Shale along Roaring Run, immediately south of Liberty Limestone Corporation quarry, 1.4 miles north of Rocky Point. Athens shale. Field No. W463.

64. Hillslope ½ mile south of Dunkard Church, Athens shale. Field No. W405.

65. Bare limestone surface, near intersection of secondary roads, along southeast slope of The Knob, 1.2 miles due west of junction of Rocky Run road with Lee Highway. Chambersburg limestone. Field No. W393.

66. Ledges and slabby float rock along Rocky Run road, 200 yards southeast of Dunkard Church. Chambersburg limestone. Field No. W286-7.

67. Ledges and slabby float rock along hill-slope opposite, and 100 yards southwest of, Locality 66. Chambersburg limestone. Field No. W395.

68. Ledge in ravine on Crawford Mountain on southwest face of the Eagle Rock Gap. Martinsburg shale. Field No. W244.

69. Ledges along road from Rich Patch valley to Barbers Creek, at extreme western edge of quadrangle, 2.5 miles southwest of Mountain Valley School. Martinsburg shale. Field No. W220-1.

70. Ledges along west side of Plank Road, 1/8 mile west of intersection with road from Highbridge Church. Martinsburg shale. Field No. W438.

71. Soft, buff shales along Rocky Run road, 2 miles southeast of Dunkard Church at south end of Short Hills. Martinsburg shale. Field No. W288.

72. Gray shales along Prisehouse Mountain road, ½ mile due west of sharp bend in county-line, 1 mile west of Sloans farm. Elevation about 2,500 A.T. Martinsburg shale. Field No. W292.

73. Limestone slabby float, immediately south of crest of Alexander Gap, between Wildcat and Grassy Mountains at head of Sloan Branch. Martinsburg shale. Field No. W293.

74. Buff shales, along eastern slope of Short Hills near road, ¼ mile east of Spring Gap. Martinsburg shale. Field No. W301.

75. Shales, along east slope of Back Creek Mountain, ¼ mile due west of old Retreat Furnace on abandoned road to Retreat Mines. Martinsburg shale. Field No. W294.

76. Quartzite ledges in gap at Eagle Rock, opposite west end of bridge. Clinch sandstone. Field No. W611.

77. Along road near Hooks Mill, ¼ mile southeast of county-line. Cacapon sandstone. Field No. W70.

78. Along road from Rich Patch valley to Covington in Hays Gap, opposite southwest end of Little Mountain. Cacapon sandstone. Field No. W160-1, W177.

79. Along southwest bank of James River at Iron Gate. Exposures along road. Tonoloway-Keefer formations. Field No. W3.

80. Cliff on south side of Wilsons Branch near loop of narrow-gauge railway, 1 mile south of Lignite. Tonoloway limestone. Field No. W194.

81. Railroad cut at southwest end of Big Hill, near base of Prices Bluff. Tonoloway limestone. Field No. W93, also No. W79 and W610.

82. High cliff, Prices Bluff, southwest end of Big Hill along railroad. Tonoloway through Upper Keyser formations. Field Nos. W80, W81, W91, W94, W95, W96, W97, W156.

83. Weathered surface of ledges near bottom of cliff along east bank of James River at Horseshoe Bend, 1 mile due south of Calvin School. Upper Keyser limestone. No specimens collected.

84. Southwest bank of James River, north of bridge at Island Ford. Keyser limestone. Field No. W64.

85. Along Eagle Rock-Newcastle road, in old quarry north of road, 2 miles east of Oriskany. Becraft limestone. Field No. W50.

86. Along road and hill-slope, northeast end of Big Hill, near church. Becraft limestone. Field No. W77. Cf. No. 22 (Field No. L60, L61).

87. Weathered surface of ledges near top of cliff, at Locality ~~40~~ 86. Becraft limestone. No specimens collected.

88. Along James River, and new railroad cut, Island Ford. Oriskany sandstone. Field No. W62, also W63.

89. Along road on west side of Big Hill, 3/4 mile northeast Locust Bottom Church. Onondaga shale. Field No. W38.

90. At junction of Rich Patch-Lowmoor road and ~~Federal~~ U.S Highway 60. Onondaga shale. Field No. W54 and W55.

91. Along road at northeast end of Big Hill, due north of Grange School. Onondaga shale. Field No. W78.

92. Buff shales, $\frac{1}{4}$ mile farther up mountain and west of Locality 36. Onondaga shale. Field No. W295.

93. Black shales near small ore-pit, $\frac{1}{4}$ mile west of Locality 37. "Romney" shale. Field No. W298.

94. Along road in gorge of Roaring Run, $\frac{1}{2}$ mile east of county-line. "Romney" shale. Field No. W51.

95. Along road, at southwest end of Crawford Mountain, near church. Brallier shale. Field No. W73.

96. Along road, on north side of Craig Creek Valley, due north of Junction School. Brallier shale. Field No. W68.

97. Along Little Patterson Creek, ledges in creek bottom, 2 miles upstream from junction with Sugartree Hollow. Brallier shale. Field No. W125.

98. Along east bank of creek in Kelly Hollow, southwest end of Switzer Mountain near ford. Chemung sandstone. Field No. W59, W127.

99. Along road, 10 yards north of crest of Price Mountain on Fincastle-Craig Creek road. Chemung sandstone. Field No. W13.

100. Along Warm Springs Road, on north side of Price Mountain at various ledges from crest of hill to a point 0.3 mile east of Sulphur Spring. Chemung sandstone. Field No. W184-93.

101. Along Lapsley Run near main highway, 1.8 miles south of Stovers Gate School. Recent deposits; travertine. Field No. W113. (See Pl. 17, A.)

102. Along branch of Little Patterson Creek in ravine on east side of Sugartree Hollow, opposite the end of Switzer Mountain. Recent deposits; travertine. Field No. W117.

103. Indian mound, etc., at Salt Station, Chesapeake and Ohio Railway. Recent deposits.

GEOLOGIC STRUCTURE

GENERAL FEATURES

Whereas the casual visitor is largely concerned with the scenic features of an area, the geologist is keenly interested in the less obvious features of its internal structure. The rocks of any region normally ~~have undergone~~ undergo long stages of development in the course of which they may become altered in character and changed in position. During such stages, various geologic structures are produced that may exert no apparent influence upon the landscape, but which, nevertheless, are of considerable importance to the economic geologist or the prospector. It is a sane dictum that no development of natural resources should be undertaken without a careful study of adjacent rock structures.

The structure of the Natural Bridge area is characteristic of the central Appalachian region. Most of the local rocks were deposited as sediments upon the floor of an ancient sea that occupied a long narrow basin extending approximately along the site of the present Appalachian mountains. The rock-floor of this basin was formed by a still more ancient series of crystalline rocks upon which the sediments accumulated in a nearly horizontal position. Since their deposition, however, they have become tilted, folded, or otherwise displaced during at least one epoch of crustal distortion.

The essential structural elements of this region involve a series of waves, or folds, that cross the region from southwest to northeast. Erosion has removed a large volume of folded rock, and the undulating surface of the original warped structure can be visualized only by

mentally restoring the part that has been destroyed. The arches, or uplifts, are called anticlines; corresponding troughs, or downfolds, are known as synclines. (See Pl. 48.) The latter have largely escaped erosion, for they extend downward into the ground; the elevated and exposed anticlines have suffered greater destruction. The major folds are internally modified by smaller wrinkles, or minor folds, as well as by rock fractures, or faults. (See Pl. 53, B.) The magnitude of the large folds is measured in miles; some are several miles wide and scores of miles long. In such large structures, the upturned eroded edges of resistant strata cause long parallel ridges to appear in the topography.

As most of the folds were produced by pressure from the southeast, the anticlines were thrust farther northwestward than the more deeply imbedded synclines. Hence, the northwestern limbs of many anticlines are overturned to a position wherein lower rocks rest upon higher rocks and the normal sequence is upside down. Some of the folds were literally stretched apart under continued pressure, and large blocks were bodily thrust forward along planes of displacement known as overthrust faults. In time, however, by wearing away the overturned and upthrust masses of rock, erosion has brought the land surface to a condition wherein almost all evidence of the former displacement is now below ground. With very few exceptions the planes of the displacements are inclined toward the southeast; most of them dip at angles parallel to the bedding of the rocks. Many of the faults sliced through rock strata thousands of feet thick, and some blocks have moved forward (northwestward) 10 or more miles. The larger faults may be traced for hundreds of miles along the surface of the ground, and evince large-scale dislocation of the earth's crust.

It is convenient to separate the local geologic structures into the two types, folds and faults. The former are of two kinds which differ only in size--(1) open folds whose dimensions are measured in miles, and (2) small local wrinkles whose width is measured in feet. Minor crumplings, such as those which deform the Devonian formations of Craig Creek valley, represent the second type; Short Hills has been produced by the larger folds. Two classes of faults are recognized--those resulting from pressure, and those caused by tension. All faults observed in this region are pressure, or overthrust, faults; no tensional, or gravity, faults are known to be present.

The local geologic structures are the result of lateral compression, which was directed toward the northwest from some unknown southeastern source. The force of this compression was effective early in the history of the region and the folding recurred at various intervals. It culminated in a vast mountain-forming revolution at the close of the Paleozoic Era.

Southeast of James River, ancient crystalline rocks are exposed in the Blue Ridge. They, too, have been altered as a result of pressure, and, in addition, have been intruded by masses of granite and related rocks. Their history antedates that of the Paleozoic rocks, for they were ancient when the earliest sediments were deposited.

MAJOR FOLDS

Rich Patch Anticline

Geographic Description

The Rich Patch anticline, which crosses the northwestern corner of the area, is the most striking geologic structure of the region. It forms a small mountain chain that extends from Wilson Hill, 2 miles northeast of Clifton Forge southwestward for a distance of more than 15 miles. Its northeastern extremity is a single ridge cut by Jackson (upper James) River at Iron Gate. (See Pl. 15.) Four miles southwest of Iron Gate, the main mountain splits abruptly into two parallel ridges that border a deep canoe-shaped valley which extends southwestward for 12 miles along the axis of the fold. This trough-like valley, long known as the "Rich Patch" because of its fertile soil, is terminated at the southwest by Nichols Knob. The southeastern rim of the valley, which is loftier and more continuous than the northern rim, is formed by Rich Patch Mountain (Pl. 8,B), and contains many local summits, including Bearwallow Mountain and Showmaker, Bald, and Montgomery knobs. (Pl. 13,B.) Its southeastern flank is bounded by a line of foothills that reach conspicuous elevations in Deisher Mountain and Iron Knob. (See Pl. 51.)

The northern rim of Rich Patch valley is a double ridge, of which the southern part includes Johnson, Porter, Little, and Mud Run mountains; the northern part is called Middle Mountain. Secondary ridges, including Horse and Carpenter mountains and Howard Knob lie along the northwestern side of the Rich Patch anticline.

Geologic Structure

Although the general structure of Rich Patch anticline is comparatively simple, differential erosion has complicated the areal pattern of the bedrock. (See Fig. 27.) Whereas only one fold is present at Iron Gate (Pl. 50, B), at least two subsidiary anticlines separated by synclines occur on either side of the main central arch in the Eagle Rock area. The smaller folds, which appear as minor units in the general structure a few miles southwest of Iron Gate, become important structures as they extend southwestward.

An imposing line of foot-hills is produced along the southeastern flank of Rich Patch Mountain by a small arch which first appears a short distance northeast of Roaring Run. (See Pl. 51.) The anticline, which is visible in the gorge of the stream, attains greater size toward the southwest where it forms a series of foot-hills that rise more than 1,000 feet above Craig Creek valley. The anticline is separated from Rich Patch Mountain by a long, narrow syncline that widens southwestward; the latter is floored by "Romney" black shale and is wild, inaccessible, and densely forested. It has been cleared for pasturage at its southwestern end in the pleasant glade where Grace Ellen iron mine and Grace Furnace were once located. The gently plunging crest of this anticline is reflected in the topography, where the tops of the ridges slope evenly southwestward as if bevelled by an erosion level or peneplane. The valleys of Roaring Run, Deisher Branch and Crawford Branches, Stony Run, Coles Run, Lemon Branch, and Furnace and Wilson branches, successively traverse the anticline at right angles to its axis. Each stream has cut a small watergap through the arch so as to expose an anticline that is equally as regular as the better-known

"Rainbow Arch" at Iron Gate. Each exposure of the anticline produces a small oval outcrop on the geologic map.

Another upfold along the southeastern flank of Rich Patch Mountain has been deeply eroded to form a narrow recess that is occupied between Montgomery Knob and Pine Mountain by Finley Branch. It has been cut by a tributary of Furnace Creek due north of Lignite, and is well exposed along the abandoned trail that leads from Lignite across Rich Patch Mountain. ~~follows the eastern wall of Furnace Creek valley; from it the arch is clearly seen.~~ Montgomery Knob is a narrow syncline in which Clinch and Cacapon sandstones are infolded in Juniata and Martinsburg shales (pl. 13, B.). The strike of the syncline extends parallel to the crest of Rich Patch Mountain for a short distance, but progressively diverges from the main ridge toward the southwest.

The central axis of the main Rich Patch anticline is split, near Mountain Valley School, into two subsidiary folds by a syncline that reaches its deepest point in Nichols Knob, a short distance west of the Eagle Rock quadrangle.

Folds analogous to those southeast of the main Rich Patch arch occur on its northwestern flank where Johnson and Porter Mountains, which are synclinal in structure, are uphelt by ~~masses of~~ Clinch and Cacapon sandstones infolded in Juniata and Martinsburg shales. A narrow anticlinal fold extends between Johnson and Porter Mountains and the Middle Mountain ridge. It is responsible for the shale valley northwest of the former mountains, as well as for two recesses of Cacapon sandstone that appear below a cover of Keefer sandstone between Middle and Little Mountains. A synclinal valley of Devonian shale lies to the north between the main Rich Patch ridge and Horse Mountain. It is drained by Carne Creek, and contains the mines and mining camps of Lowmoor and Rich Patch.

All ridges of this range are upheld by Silurian sandstones of which abundant exposures are visible along ~~each stream as~~ Raleigh Branch, Carne Creek, Laurel Branch, Hays Creek, and Blue Spring Creek and other streams that flow northward into Potts Creek or Jackson River. Roaring Run, which breaches the southeastern rim, flows southward into Craig Creek. The central portion of Rich Patch valley is underlain by Canadian dolomites that crop out from a point near Rich Patch School to Hays Gap. A small isolated outcrop of dolomite occurs a short distance northeast of the school. Concentric belts of Lower Stones River, Lenoir, Lowville, Martinsburg, and Juniata formations surround the Canadian dolomites. The valley has a rolling floor at an average elevation of 2,100 feet above tide. Its bounding ridges rise more than ~~one thousand~~ 1,000 feet higher to reach a maximum elevation of 3,728 feet above sealevel in Rich Patch Mountain. The average elevation of the lowland that surrounds the ~~Rich Patch~~ Range, is about 1,000 feet above sealevel.

The general trend of Rich Patch anticline is ~~North 40 East.~~ N. 40° E. It is ~~actually~~ an anticlinorium, composed of a central anticlinal axis with several minor folds on its northwest and southeast flanks. It is remarkably symmetrical to its central axis and plunges northeastward. Except for Rich Patch valley, it is densely forested (Pl. 10, A) and difficult of access. It is bounded at the southeast by the broad Craig Creek syncline. (See p. 239.)

Iron Gate Watergap

The gap of Jackson (upper James) River at Iron Gate is a striking feature of Rich Patch anticline. (See Pl. 15.) The exposed "Rainbow Arch" of Silurian rocks is remarkably regular in the gap, where it presents one of the finest exhibits of anticlinal structure in the central Appalachians. (See Fig. 28.) Upper Ordovician (Martinsburg and Juniata) shales are exposed in the center of the arch, where they occur below a massive span of Clinch sandstone. (See Pl. 50, B and 52, A.) The central wooded slopes of the gap are developed on Cacapon sandstones and shales; 4 massive ledges of Keefer sandstone form the uppermost crest of the arch. Near the northwestern summit, a small underthrust fault slightly displaces the Keefer ledges. (See Pl. 52, A.) The northwestern limb of the anticline is more sharply flexed than the southeastern limb, and the fold plunges rapidly northeastward to disappear in "Romney" and Brallier shales 2 miles northeast of the gorge. Nearby mines of Clinton iron-ore are responsible for the appropriate name of Iron Gate.

Rapps Mill Anticline

An anticlinal structure somewhat resembling Rich Patch anticline occurs in the northern part of the Natural Bridge quadrangle between Short Hills and the James River Range. This anticline lies along Purgatory Creek and South Fork of Buffalo Creek; it is named from Rapps Mill which is located near the axis of the fold. The anticline, which is about 4 miles wide at the northern part of the area, narrows regularly to the point, a few miles south of Dunkard Church, where it disappears. The rocks exposed along its axis are Canadian dolomite which are bounded by outcrops of Ordovician and Silurian rocks. A fault, which appears near the center of the fold, extends northeastward along its axis, and is crossed by U.S. ~~United States~~ Highway 60, near Kerrs Creek. A subsidiary central syncline of Ordovician rocks is broken by this fault near the northern margin of the area. (See Pl. 49, A.)

Big Hill Anticline

Big Hill forms a prominent topographic and structural feature of the northern part of the broad shale basin northwest of the Eagle Rock range. Together with Rocky Hill, it represents a symmetrical anticline capped by Helderberg sandstones. (See Fig. 29.) A few ledges of Silurian sandstones protrude through the Devonian cover on Rocky Hill. (See Pl. 15.) "Romney" and Onondaga shales completely surround the structure which extends southwestward for 3 miles from the northern border of the area. Its maximum width is slightly less than 1 mile. The southwestern tip of the arch has been cut by James River so as to reveal at Prices Bluff an excellent section from the Tonoloway limestone through the "Romney" black shale. (See Pl. 44,A.) The fold has a strike of N.60°E.

Spreading Spring Anticline

An anticline, named from Spreading Spring Branch which flows northeastward along its axis, extends from a point 2 miles east of Fincastle to James River. The Rome ("Watauga") shale and Elbrook limestones are exposed in the center of the fold which plunges toward the southwest. The axis is followed by the Fincastle-Springwood highway. A central V-shaped outcrop of Elbrook limestones is bounded on the northwest by Timber Ridge and on the south by Little Timber Ridge, both of which are developed upon cherty Ozarkian and Canadian outcrops. The center of the anticline underlies a wide fertile limestone valley. (See Fig. 31.) The strike of the fold is about N.45°E.

Flatwoods Syncline

The Flatwoods syncline, which is named from Flatwoods School, 4 miles north of Pincastle, is a broad but comparatively shallow structural basin. It extends southwestward for more than 15 miles from the mouth of Catawba Creek, and attains a width of at least 5 miles. The central outcrop of Athens shale, is roughly shaped like a woman's shoe, with the heel is represented by a narrow shale belt east of Pincastle, and the toe is formed by the long pointed outcrop west of Howell Mills. The Athens outcrop is surrounded by belts of Lower Ordovician, Canadian, and Ozarkian formations. One mile north of Pincastle, a local fault has overthrust Ozarkian dolomites upon the shale along a zone about 3 miles wide. (See Pl. 32.)

The strike of the Flatwoods syncline is N. 60° E. For 8 miles of its course, Catawba Creek flows along the margin of the Athens outcrop, having apparently adjusted its position so as to follow the weak shale belt near its contact with the Ordovician limestones. The central part of the syncline is a wide, open valley, developed by Catawba Creek and its tributaries. It is rimmed by chert hills of the Canadian outcrop which merge with the upland surface of Ozarkian ridges. The floor of the valley, although comparatively level, contains numerous low elevations of which Pine Hills are the most conspicuous. (See Pl. 7.) No younger Paleozoic rocks than Athens shale occur within the syncline, although the eastern side of the central valley has a thin covering of floodplain material spread out by Catawba Creek and its tributaries.

Craig Creek Syncline

A broad rolling lowland which contains several higher ridges, occupies the area between Rich Patch Mountain and the Eagle Rock Range. Drained by Craig, Patterson, and Sinking creeks, this belt is underlain by Devonian shales (Brallier) and sandstones (Chemung) that are gently folded into a synclinal structure. The name Craig Creek syncline is appropriate, for the creek follows a meandering course along and across the structure. (See Fl. 22, A.)

At least 2 smaller synclines occur within the larger basin. A long oval structure forms the mountainous tract between Craig and Patterson creeks. It is emphasized on the geologic map by an outcrop of Chemung sandstone which produces Patterson Mountain. Northeast of Patterson Mountain, the Chemung outcrop disappears, and the axis of the fold becomes lost in the Brallier shale belt between Big Hill and Rich Patch Mountain.

Price Mountain, which extends between Patterson and Little Patterson creeks, is produced by Chemung, Catskill, and Price formations along a second structural trough in the Craig Creek fold. Its axis continues northeastward into the Brallier shale belt between Big Hill and North Mountain.

Caldwell Mountain, in the extreme southwestern corner of the Eagle Rock quadrangle, is also part of the Craig Creek syncline. It is the northeastern extension of North Mountain which crosses the northern part of Roanoke County. Its structure, which is sharply synclinal, involves a small lateral infold of Catskill and Price formations including thin coal seams formerly prospected in Stone Coal and Lees gaps. (See pages 338-339.) The main mass of the mountain is formed by resistant Chemung sandstones which produce

a rugged ridge. It is suspected that the synclinal structures of Caldwell and Price mountains are separated by a fault which may be the northeastern extension of the Miller overthrust of Craig and Montgomery counties[1], a branch of the Pulaski overthrust, which bounds Caldwell Mountain on the southeast, separates it from Switzer Mountain.

1. Woodward, H. P., Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, p. 90, 1932.

Short Hills Syncline

Short Hills, which occupies a narrow synclinal structure, rises conspicuously above the Valley of Virginia west of Natural Bridge. (See Pl. 6.) Its strike, which is parallel to the valley, is about N.50° E. The fold that underlies the mountain is more than 12 miles long and extends northeastward from Purgatory Creek to Murat. It includes a section of Ordovician to Devonian rocks, and has an average width of about 2 miles. The structure is analogous to Massanutten syncline which occupies a similar position in the valley between Harrisonburg and Winchester, 100 miles to the Northeast.

Natural Bridge Syncline

A gentle syncline occurs in the valley lowland east of Short Hills, where it extends northeastward from Rocky Point to Buffalo Creek. It is outlined by the outcrop of the Conococheague and Chepultepec dolomites, and contains Natural Bridge which is located along its axis. (See Pl. 3.) Near the center of the fold, the rocks are horizontal, and the structure is comparatively shallow. This syncline is crossed by Cedar Creek which has developed a fine gorge in the flat Ozarkian limestones and dolomites. The latter are surrounded by an outcrop of Elbrook limestone, and contain an inlier of Chepultepec limestone. The fold strikes N.50° E. along the

valley lowland.

MINOR FOLDS

The many minor folds differ from the major folds only in size; they are seldom more than a few rods in width. As they closely resemble the larger folds, they afford a convenient minature of structures that are difficult to examine on a larger scale. A small anticline is exposed along Craig Creek, 5 miles northwest of Eagle Rock, and 1 mile southeast of Strom. The fold stands in bold relief along the southern bank of the valley where it has been sharply truncated by lateral erosion of Craig Creek. (See Pl. 50,A.) A number of minor folds occur in the Brallier shale along Little Patterson Creek about 1 mile upstream from its junction with Patterson Creek. (See Pl. 52,B.) Somewhat less symmetrical folds occur in the Brallier shales along the road from Hays Gap to Covington.

The Erwin quartzite is tightly folded in the belt followed by James River. (See Pl. 29,A.) Excellent exposures occur along the Norfolk and Western Railway opposite Dillon flag-station, southeast of Arcadia. A symmetrical arch of Cambrian dolomite occurs along James River 1 mile below Buchanan. (See Pl. 49,B.) Contorted folds in the Unicoi formation are visible on Cove Mountain in Bearwallow Hollow, south of Buchanan. (See Pl. 53,A.)

Possibly the most interesting of all minor folds are those which occur in the Rome ("Watauga") shale and Elbrook limestone. Many of these tiny plications are visible along the faulted belt from Garsts store to Roaring Run, where hand specimens of rock can readily be found that contain many types of fold structures. The analogy between these minute crumplings and such large folds as Rich Patch anticline is almost exact.

FAULTS

Pulaski Overthrust

General Description

The Pulaski overthrust, which crosses the southern and central portion of this area, has been traced as a continuous fracture from the vicinity of Greenville, Tennessee, to Greenville, Virginia, a total distance of 300 miles. It is one of the longest displacements of the northern Appalachian region. Its name has been appropriately taken from Pulaski, Virginia, which is located on the outcrop of the fault in Pulaski County[1].

1. Campbell, M. R., and others, The valley coal-fields of Virginia: Virginia Geol. Survey Bull. 25, p. 76, 1925.

The trace of the Pulaski overthrust enters the Eagle Rock quadrangle from the southwest along the foot of Caldwell Mountain. It is crossed by Lees Creek at an elevation of 1,500 feet above tide, and crosses North Fork of Catawba Creek immediately east of Kelly Hollow. Midway between Lees and North Catawba creeks, the fault outcrop is split into separate displacements that surround the highly disturbed area of Switzer-Crawford-Rathole mountains. The western displacement reaches the surface along the northwestern slope of Switzer Mountain. It crosses Sugartree Hollow near Little Patterson Creek, swings to the east of Poplar Hill and continues northeastward to follow the crest of Crawford Mountain and cross James River in the center of the gap at Eagle Rock. This branch of the Pulaski overthrust continues between Sheets and Rathole mountains, and swings eastward between Scurff and North mountains to disappear in the Devonian black shales of Mill Creek valley.

The southern branch of the Pulaski overthrust is the main displacement. It follows the southern slope of Switzer mountain and swings eastward into the limestone country between the mountain and Cedar Ridge. Its trace may be followed northeastward to James

River where the fault-plane is exposed in ~~the Holston~~ limestone quarries near Eagle Rock. The displacement may be traced in an easterly direction to the head of Allen Creek, whence it assumes a general southwest trend to the tip of Purgatory Mountain, having crossed the loop of Horseshoe Bend of James River. (See Pl. 13, A.) From Purgatory Mountain the fault-trace swings northeastward and passes near Indianrock, Highbridge Church, and Longwood. It crosses Buffalo Creek near the Lee Highway bridge, 9 miles northeast of Fancy Hill.

A branch of the Pulaski overthrust extends from a point near Buchanan northeastward to Cedar Creek; it merges with, or extends beneath, the main overthrust at both ends. The fault-plane is exposed at a number of points. It is crossed (1) by Purgatory Creek 1 miles south of Gray Ledge, (2) by Rocky Run, one-half mile west of Lee Highway, and is crossed (3) in two places by the Plank Road, west of Highbridge Church. An elongated oval block 8 miles long and 2 miles wide, lies between this fault and the main Pulaski overthrust. The rocks within the block are in normal stratigraphic sequence, and range from Elbrook limestone on the northwest to Athens shale on the southeast. A small subsidiary block of Ordovician limestones, about one square mile in area, occurs along this fault near Gray Ledge.

Fault-line Phenomena

The Pulaski fault-plane may be observed at several points in the eastern half of the area. One of the most striking is in an abandoned quarry along Lee Highway about one-half mile southeast of Highbridge Church, where thin, slabby Elbrook limestones are overthrust upon weak Athens shale. (See Pl. 54, A.) The contrast in structure and lithology is conspicuous. The fault-plane is also exposed along the roads that lead from Lee Highway to Rocky Point and to Indianrock. It is crossed by Penn Branch, west of Cartmell Gap, and crosses James River in two places near Horseshoe Bend.

The most conspicuous exposures of the fault-plane occur at Eagle Rock in a series of open quarries and an underground mine in Holston limestone, immediately west of James River. The main openings occur at 2 levels in a wooded slope that rises several hundred feet above the river. The floor of the southern-most working, which is an open quarry along a tributary creek, is not far above river-level. The central quarries, or mines, are one hundred feet higher and extend underground from the face of the cliff for some distance into the hill. The northermost quarries are at slightly higher levels and extend back from the river along both sides of State Highway 12 which crosses the James at Eagle Rock.

The Pulaski overthrust passes through the middle quarry group, at a point where the Holston limestone, which is approximately horizontal, rests normally upon Lenoir limestone. (See Fig. 33.) At the mine entrance along the cliff face, the Holston is about 20 feet thick. (See Pl. 56, A.) It is sharply truncated above, however, by the plane of the fault, along which a mass of Nittany dolomite has overridden the Ordovician limestones so as to rest directly upon the Holston. (See Pl. 55.) The limestone available for economic use lies between the undulating

Lenoir foot-wall and the faulted overburden of Nittany dolomite. Except for supporting pillars, it has been entirely removed, leaving the under surface of the overthrust block as the hanging wall of the mine. The plane of the fault has a true inclination of about 30° toward the south. As a result of this inclination, the fault slices downward through various beds of the Holston until it completely deletes the limestone at the inner, or western, face of the mine. (See Pls. 56, B and 64, B.)

The under surface of the Pulaski fault-block can be examined in the hanging wall of the mine under conditions that are not known elsewhere along the trace of the fault.[1] The major displacement, for there are several others visible in the cliff, is extremely sharp and clean, being so distinct and definite as to appear almost artificial. The Nittany dolomite, which is nearly horizontal, has sliced tranversely down through the upper layers of the Holston, and the contact is no more irregular than a normal bedding-plane, and might well be mistaken for such. (See Pl. 55, B.) In fact, the abnormal relations at this point could easily escape notice in a casual examination.

The ~~under surface~~ plane of the fault is exceedingly smooth and exhibits few grooves or striations. It is somewhat slickensided, but there is no more evidence of polishing than occurs between normal bedding-planes a few feet below the fault-plane. There appears to be no crushing or mashing of either overthrust or overridden masses at the exact contact where the line of demarcation could not be more sharp if the rocks had been cut with a knife.

---

1. Woodward, H. P., Fault-line phenomena near Eagle Rock, Virginia: Am. Jour. Sci., 5th ser., vol. 31, pp. 135-147, 1936.

In the lower open quarry south of the central mine the thrust-plane emerges at the foot of the cliff at an angle of about 45°. Erosion by a small tributary of James River has removed the overburden of Nittany dolomite, and subsequent quarrying has removed the Holston, thereby exposing the underlying Lenoir limestone. The fault-plane originally arched over this open quarry to enter the cliff about 100 feet above the river as an upper limit to mining operations in the central quarry group previously described. (See Fig. 34.)

North of the underground mine, a large quarry face, which is exposed in an east-west direction, contains several imbricating fault-planes that exhibit undulations in the direction of strike. The presence of additional fault-planes may be noted along the north-south face of the hill at the entrance of the central openings, but all appear to be within the overthrust mass of Canadian dolomite. It is possible that minor shear zones may have existed in the Holston limestone, but no evidence of them occurs in the supporting pillars.

Four miles southeast of Eagle Rock the plane of the Pulaski overthrust is also visible. The exposure occurs about ~~one-quarter~~ 1/4 mile east of James River and about ~~three-quarters of a~~ 3/4 mile southeast of Saltpeter Cave, along the road between Eagle Rock and Buchanan. The road follows the surface trace of the fault for a distance of about ~~one~~ 1 mile along a zone where both have a ~~southerly~~ west strike, and where Elbrook limestones have been thrust upon dark "Romney" shales. The road crosses the trace of the fault several times, for the latter, through erosion, has a sinuous outcrop. At one point, a thin mass of limestone strikes across the road and is visible in a low cut which exposes the fault contact on both sides of the limestone wedge. The mass of limestone, which is about 14 feet wide, has been overthrust upon the shales, and is

the only remaining portion of the fault-block. The weak shales are highly crumpled and mashed along their contact with the limestones where extreme differences in color and lithology sharply demarcate the two formations. (See Pl. 54, B.)

It is probable that the sole of the overthrust was locally undulating, and that the limestone wedge represents a downwarp in the overthrust block, the rest of which has been eroded away. Pressure accompanying, or following, the thrusting has forced the incompetent shales to well upward, or flow, around the edges of the limestone wedge, which is partially surrounded by shales.

Note: if it is necessary to conserve space, this section may be omitted

Salem Fault-block

The presence of a large rectangular overthrust block along the Pulaski fault has recently been discussed[1]. This block,

---

1. Woodward, H. P., Salem block of the Pulaski overthrust: Pan-American Geologist, vol. 63, pp. 321-333, 1935

---

known as the Salem block, extends for approximately 70 miles in a northeasterly direction between Altoona Mills, Pulaski County, and Eagle Rock. Its northern end occupies the south-central portion of the Natural Bridge region between the Eagle Rock and James River ranges. The block is a distinct physiographic and structural unit that contains many elements of strong symmetry. It includes the greater portions of Pulaski, Montgomery, Roanoke, and Botetourt counties, and lies between the Blue Ridge on the southeast and the Valley Ridges on the northwest. One distinct mountain group, the Catawba Range of Roanoke County, lies within the block and compares in elevation with the Valley Ridges farther to the northwest. The geography of the Salem block is surprisingly symmetrical. The area is crossed at the north by James River, which drains the northeastern third of the area. New River, flowing northwestward, crosses and drains the southwestern part of the block. The central portion is drained by Roanoke River which flows southeast through the Blue Ridge east of Roanoke. Along the northwestern side of the block, long parallel tributaries of the three rivers occupy various linear valleys, and the valley lowlands at the two ends are drained by irregular, but more or less dendritic, tributaries of James and New rivers.

The greater part of the block lies in the Valley of Virginia, which is notably constructed at both ends. At Buchanan, the Valley is scarcely one mile wide, for Purgatory Mountain reaches nearly to the foothills of the Blue Ridge. Near Draper, along the southern edge of the block, the Valley similarly narrows between the foothills of the Blue Ridge (Macks Mountain) and Draper Mountain.

The local portion of the block lies north of Tinker Mountain and is one of the largest sections of Valley lowland in west-central Virginia. It is nearly rectangular and has been eroded to the Fincastle level of the Valley-floor peneplane. (See Pl. 7.) The southwestern quarter of the Salem block lies southwest of Paris Mountain and is an analogous area of valley lowland eroded to the Dublin level of the Valley-floor peneplane. A lowland connection between the terminal areas occurs on either side of the central Catawba Range. Salem Valley, wide, level, and fertile, extends south of the range; Catawba Valley, narrow, rocky, and partially timbered, lies north of Catawba Mountain.

The block is bounded at the south, west, and north by the trace of the Pulaski overthrust. A smaller displacement, known in Roanoke County as the Salem overthrust,[1] bounds its southeastern margin. The outcrop of the Pulaski fault, which extends in a general northeasterly direction from Tennessee to Pulaski County, Virginia, encircles the southeastern end of Draper Mountain to pass near Pulaski. It turns northwestward to Alterna Mills, whence its trace swerves abruptly to the northeast along the foot of Little Walker Mountain. As a result of this offset, the trace of the fault at the base of Little Walker Mountain is more than 10 miles northwest of its general strike south of Draper Mountain.

---

1. Woodward, H. P., Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 74, pp. 97-1, 1952.

Northeastward from Altoona Mills, the Pulaski fault may be followed approximately in a straight line to Eagle Rock. Throughout the greater part of this distance, the fault trace lies at, or near, the base of a broken mountain ridge, the several sections of this mountain, from southwest to northeast, being called Little Walker, Brushy, North, Caldwell, Switzer, and Crawford mountains. In this belt, the fault line parallels the strike of local structures, although at Cove Mountain (between Brushy and North mountains, Roanoke County) and also near Poplar Hill, 5 miles west of Eagle Rock, it cuts across various complicated structures. In consequence of the sharp turn in the fault trace between Eagle Rock and the southern tip of Purgatory Mountain (Pl. 13, A), the strike of the fault is offset to the southeast a distance of about 10 miles in a manner analogous to its northwestern offset between New River and Altoona Mills.

The geologic structure of this block is essentially that of a great synclinorium, in whose deepest portion lies the homogeneous unit of the Catawba syncline. Competent early Paleozoic limestones and dolomites now form the floor of the synclinal area, and it is probable that the sole of the Pulaski fault lies immediately beneath, or within, them. The shallow Flatwoods syncline, floored with Athens shale occupies part of the northeastern end of the block. The limbs of this synclinorium maintain a regional dip toward the central axis, although as a result of the general folding and compression of the region, the rocks are locally warped and disturbed.

In order to account for the synclinal nature of the Salem block along its northeastern axis, it is necessary merely to invoke the original folding of the Appalachian region, of which deformation the Pulaski fault was a significant part. Development of great wave-like folds was undoubtedly part of a series of events

taking place during late Paleozoic time, and the faulting that accompanied the Appalachian revolution resulted from stretching and ultimate shearing of some of these anticlines during long-continued and irresistable pressure.

It is not equally easy, however, to account for the fact that the entire Salem Block appears to be broadly synclinal in a direction parallel to the direction of overthrusting; for it is evident that the sole of the fault must be deeper in the center than near the ends of the block. Indeed, it was sufficiently elevated near the ends for much of the overthrust mass to be worn away by subsequent erosion. The block, therefore, not only is synclinal in a linear direction parallel to the strike of the Appalachian structures, but also is equally synclinal in a direction normal to the prevailing structure and thus parallel to the impelling force.

There is no necessary reason for the sole of a low-angle fault emerging at, or transgressing toward, the surface, to become or remain an even plane, although most faults are assumed to have this property. A displacement of such proportions as the Pulaski overthrust--which extended for a lateral distance of at least 300 miles--might easily emerge at the surface as an undulating plane, in which minor axes of undulations could parallel the thrusting force. Indeed, it is difficult to see how such undulations could exist in any other direction than parallel to the direction of pressure. It is therefore concluded that the Salem block represents a downwarp in the original sole of the Pulaski fault between two corresponding upwarps that carried the fault plane over the Draper Mountain structure on the southwest, and over the Purgatory Mountain structure on the northeast. Such undulations as these might be compared with plications on the shell of a scallop that radiate in all directions from a distant point, which in this case, should be the source of the thrusting force.

It should be remarked that the block is not a "fault-block" in the sense of a segment down-dropped or uplifted between two or more faults; it does not partake of the characteristics of either a graben or a horst. Rather, it is a block-like, quadrilateral area that has uniformly passed through a similar sequence of geologic events, and that has isolated itself from the remainder of the overthrust mass by reason of its structural symmetry and physiographic history.

Amount and Date of Displacement

The horizontal displacement along the Pulaski overthrust is difficult to determine. Apparently Purgatory Mountain acted as a wedge pointed toward the oncoming overthrust, and the lateral movement must at least equal the distance, measured in the direction of pressure, from Purgatory Mountain to the trace of the fault at Eagle Rock. This distance is slightly more than 10 miles and there is every reason to believe that it is a minimum rather than a maximum horizontal displacement. It is estimated that equal displacements have occurred along the same fault in Roanoke County.[1]

The exact date of Pulaski faulting cannot be determined, although the facts fully warrant the conclusion that it was produced after the folds and faults to the north and west had originated, for these other structures could scarcely have been formed beneath the overthrust mass of the Pulaski fault, below which they may now be traced. Thus the date of faulting can not antedate the early Mississippian. It is further probable that the faulting took place at the same general time as the formation of the major structures of this region. Faults of apparently similar age in other parts of the Appalachian region involve beds as young as Pennsylvanian. It

1. Woodward, H. P., op. cit., p. 85.

would thus appear that the Pulaski overthrust may have been developed during the late Pennsylvanian or early Permian Period. As suggested by the writer[1], its formation was probably intermediate

1. Woodward, H. P., Thrust faults of the Roanoke area, Virginia: Geol. Soc. America, Bull., vol. 40, pp. 185-86, 1929.

between the faulting of the Blue Ridge overthrust, and the formation of the Saltville fault.

Blue Ridge Overthrust

A persistent fault, or line of faults, roughly follows the western border of pre-Cambrian rocks throughout the entire Appalachian region. Its most common position is near the west foot of the Blue Ridge where it usually separates pre-Cambrian and (or) Chilhowie rocks from ~~other lower~~ early Cambrian or later formations.

In the Natural Bridge region, the Blue Ridge overthrust crops out on the southeastern side of the Cove-Pine Mountain ridge. It has been traced across Jennings and North creeks about ~~one-half~~ ½ mile above their junction; it crosses Sprouts Run 100 yards above the main fork. The outcrop of the fault is inconspicuous and for the most part has little or no topographic expression. It enters the Natural Bridge district from the southern side of Goose Creek valley, and crosses the road from Buchanan to Bedford at the crest of the Blue Ridge. From this point nearly to Sprouts Run, the fault crops out in the wide belt of folded Unicoi sandstones and shales. (See Pl. 53, A.) Two small oval masses of pre-Cambrian rock occur along the fault-line between Cove Mountain and Cove Creek, and between Jennings and North creeks. From the northern end of Thomas Mountain to Arnold Valley, the fault-line forms the boundary between crystalline pre-Cambrian rocks and the Unicoi formation.

The most important surface feature produced along the Blue Ridge overthrust is Arnold Valley, which is a deep embayment into the Blue Ridge immediately south of James River and east of Cave (Sic.) Mountain. The rock floor of Arnold valley is largely Shady dolomite, of which, however, few exposures can be found, for the valley-floor is deeply covered with both residual and transported debris. Erwin quartzite protrudes through the Shady at several places. The valley is bounded on two sides by the Blue Ridge overthrust,

which swings around the southern margin of the valley to continue eastward toward Balcony Falls.

Arnold Valley (Pl. 8, A) is analogous in structure to the valley of Narrows Creek, immediately south of Roanoke city, where a similar embayment into the Blue Ridge is floored with Shady dolomite and bounded on three sides by an overthrust fault. In both embayments, faults carry crystalline pre-Cambrian rocks upon Cambrian sediments to the northwest.

Kerrs Creek Fault

A displacement of some magnitude has been traced from a point near Rappa Mill northeastward to Kerrs Creek, west of Lexington. (See fig. 35.) It develops along the axis of the Rappa Mill anticline about one-½ mile west of Rappa Mill. Four miles northeast of the mill, (now in ruins), the fault crosses the road traversing the valley of Spring Branch; the fault contact is exposed east of Oakdale, and on the road leading from Buffalo Creek to Collierstown.

For 2 miles northeastward, from Rappa Mill, the fault is entirely within the Canadian dolomite outcrop. Elsewhere, Nittany dolomite has been overthrust upon Athens shale and Ordovician limestones. The vertical and horizontal displacements along the fault are small, but become much greater to the north near Kerrs Creek.

Minor Faults

(See Pl. 53, B.)

Several minor faults occur in the Natural Bridge area. A local overthrust has developed near the axis of Flatwoods syncline west of Howell Mills. It may be traced eastward across State Highway 12 one mile north of Fincastle. One-half mile east of the highway, its trace swings southward to leave the Eagle Rock quadrangle. Immediately south of the quadrangle, it becomes involved in other displacements, one of which occurs at the contact of Athens shale and older limestones. Another crosses State Highway 12 one mile south of Fincastle and continues northeasterly, passing a short distance south of High View School, and disappearing in Kibrook limestones along David Run, near James River. (See Fig. 32.)

A displacement of unknown proportions occurs at the northeastern end of Flatwoods syncline. It is present near Catawba Creek, three miles east of Zion Hill Church, and may be traced in a northeasterly direction into Hickory Hollow where it appears to offset the outcrop of the Pulaski overthrust. The same or an analogous displacement may be traced in the same strike between Grassy and Wildcat mountains, and is thought to pass through Heartsblood (Pl. 41, A.), the gap between Camp and Panther mountains; it crosses Moores Creek near the northern margin of the Natural Bridge quadrangle. The southernmost exposure of this displacement, near Catawba Creek, exhibits a mass of Athens shale that has been locally underthrust beneath Canadian dolomites. The exposure, which is located on the western side of a country road along Catawba Creek, is a short distance south of the mouth of the small creek followed by State Highway 12 from the crest of Cedar Ridge to Catawba Creek valley.

Another local displacement is exposed ~~three-quarters of a~~ 3/4 mile west of Highbridge Church, where it extends for ~~two~~ 2 miles parallel to the easternmost trace of the Pulaski overthrust. This fault offsets the western Pulaski displacement, and duplicates the outcrop of Ozarkian rocks along the road leading west from Highbridge Church.

Several minor faults are present along the main Blue Ridge overthrust in Arnold Valley, and a minor displacement enters the extreme southwestern corner of the Natural Bridge quadrangle, whence it extends northeasterly to disappear beneath the Pulaski overthrust near James River.

The northwestern contact of Erwin quartzite and Shady dolomite in Jones and Boyd mountains, immediately south of Buchanan, is a minor overthrust which cuts out the quartzite southwest of Laurel Run. The displacement has been traced as far north as Dillon quarry, northeast of Buchanan. A similar small displacement occurs along the northwestern edge of an Erwin quartzite hill - the continuation of Sallings Mountain - north of Natural Bridge Station.

STRUCTURE OF THE EAGLE ROCK-JAMES RIVER RANGES

General features

The internal structure of the Y-shaped mountain mass of the central Natural Bridge region is sufficiently complicated that it can not readily be resolved into simple folds or faults. As previously described (see pages 20-21), the term "Eagle Rock Range" is applied to the mountain group which includes Sheets, Rathole, Crawford, Switzer mountains, and Poplar Hill. The term "James River Range" is applied to the group which includes the two Camp Mountains, Grassy, Garden, Mays, Back Creek, and Purgatory mountains. The broad limestone lowland which intervenes between the Eagle Rock and James River ranges forms the northeastern end of the Salem block of the Pulaski overthrust. This fault truncates both ranges at the south, and is responsible for small minor displacements within the mountain areas. The general strike of the Eagle Rock-North mountain range is N.45°E.; the James River range strikes due south. All of the ridges in both ranges are formed by Silurian sandstones.

North Mountain, which enters the northwestern corner of the Natural Bridge quadrangle, ends abruptly near Mill Creek southeast of Daggers Springs. Whereas the structure of most Appalachian ridges involves a single anticline or syncline, North Mountain includes several distinct folds that are parallel to the course of the mountain. The most conspicuous is an anticline which forms the larger part of the mountain, and has been unroofed at two places.

Limestone Hollow at the southern end of the mountain is a deep recess that has been etched from calcareous beds of Martinsburg (Trenton) age, along the axis of the fold. The hollow is drained by a creek which occupies a sharp notch through Silurian sandstones that completely encircle the blunt southwestern end of the mountain. (See Fig. 14.) A narrow syncline, floored by Silurian sandstones, extends along the northwestern slope of North mountain. Both folds, which continue to the northwest, are visible along State Highway 251 between Collierstown and Longdale Furnace.

The James River range is an irregular group of ridges that ~~extends between two~~ connect Camp Mountains and Purgatory Mountains, north of Buchanan. It includes a rugged, uncleared area, broken by short irregular mountains. It is crossed by a narrow country road from Mill Creek to Dunkard Church.

The structure of this range is more than usually complex. Purgatory Mountain consists of an unroofed anticline that exposes Martinsburg shale along its axis, and plunges southward below the overthrust block of the Pulaski fault. The eastern limb of the anticline is folded into a narrow broken syncline that plunges northeastward to merge with the Short Hills syncline. The western limb of the anticline extends northward to ~~from~~ Back Creek Mountain, near Cherry Orchard Gap, the structure becomes involved by the appearance of adjacent synclinal tracts that curve simuously to form Round, Mays, Gully, and Orebank mountains. One of these synclines, although partly crushed at the south, becomes more open between the two Camp Mountains which terminate the range at the north. With the exception of the anticline which forms Purgatory Mountain, the general structure of the James River range is largely synclinal.

The strike of the range is conspicuously at variance with that of the other local ridges. It is probable that the discordant ~~reverse~~ strike and complex structure of the range have resulted, in part, if not wholly, from the effects of movements along the Pulaski overthrust.

Bigge Mountain, southeast of North Mountain, is formed by a symmetrical anticline, 3 miles long and 1 mile wide. The mountain, which is capped by Cacapon sandstones, rises from an area of "Romney" shales. Its structure is closely analogous to that of Big Hill, north of Gala.

A long narrow ridge, which is parallel to North Mountain from west-central Rockbridge County to the head of Turkey Pen Hollow, includes Brushy, Panther, Wildcat, Prisehouse and Stamping ground mountains. The ridge is monoclinal and is formed by Silurian sandstones that are either vertical, or steeply inclined ~~at high angles~~ to the northwest. Its southwestern end, which is truncated by the Pulaski overthrust near Allen Creek, is complexly folded so as to form a connecting section, somewhat broken by local displacements, between the James River and Eagle Rock ranges.

Scurff and Sheets mountains, both of which are synclinal in structure, are prominent ridges that plunge southwestward in the area northeast of Eagle Rock. They form the northernmost members of the Eagle Rock Range, and are genetically related to the Stamping ground-Prisehouse mountain ridge. Their northern ends are truncated by the northernmost displacement of the Pulaski overthrust which separated them from the main mass of ~~the~~ Crawford and Rathole mountains. ~~ridge.~~

Crawford and Rathole mountains occur on opposite sides of the Eagle Rock water gap. At the southwest, Crawford Mountain (Pl.58) ends abruptly near Forest Grove School; Rathole Mountain (Pl.57) ends sharply at the northeast near Daggers Springs. Despite the apparent unity of the Crawford-Rathole ridge, its structure is unusually complex, for a branch of the Pulaski overthrust follows the crest of the ridge and finally separates it into two structural parts, a northwestern unit associated with the Craig Creek synclinal basin and a southeastern unit associated with the Salem block of the Pulaski overthrust. Although Rathole and Sheets mountains appear to be closely associated, the two are separated by a fault and have ~~different~~ no structures in common.

Poplar Hill, which rises abruptly between Little Patterson and Lapsley Creeks, is capped by Keefer sandstone; Helderberg formations and the Onondaga shale may be traced around its slopes. The hill, ~~which is~~ representing a nearly oval ~~in shape, is an~~ anticline that rises from black Devonian shales which surround it on three sides. The Salem block of the Pulaski overthrust formerly covered the structure, but has now been worn back by erosion so that "Romney" shales crop out between the fault line and the Helderberg outcrop. A small fault, presumably an off-shoot of the Pulaski overthrust, has obliterated the Helderberg and Keefer formations on the eastern side of the hill.

Switzer Mountain is a ~~long~~ narrow, sharp "hog-back", nearly ~~seven~~ 7 miles long. Its structure is that of a highly folded syncline which lies between the two parallel displacements of the Pulaski overthrust. Clinch, Cacapon, and Keefer sandstones form its knife-like summit. The heavily forested northwestern side of the ridge is flanked with Brallier shale; Upper Ordovician shales (Martinsburg and Athens) form the southeastern side which has been cleared and cultivated to the crest of the ridge.

The Silurian sandstones are truncated at both ends of the mountain by the Pulaski overthrust. Poorhouse Hollow, at the southwestern end, has been eroded in soft Cacapon shales between the more resistant Clinch and Keefer sandstones.

Eagle Rock Gap

Near Eagle Rock, James River has cut a deep, narrow gorge which serves as a pass through Crawford and Rathole mountains for the James River Division of the Chesapeake and Ohio Railway, State Highway 12, a country road, and James River. Although the structure of the Eagle Rock watergap is not so spectacular in appearance as the "Rainbow Arch" at Iron Gate, it is more interesting to the geologist because of its greater complexity.

On either side of the gorge, steep, almost vertical cliffs rise several hundred feet above water-level. From a vantage point on the eastern face of the gorge, the southwestern wall of the gap is clearly visible. (See Pl. 57.) At the extreme left (southeastern) end of Crawford Mountain, Clinch sandstones rise vertically in a single, towering wall. To the left of this wall are slopes of Martinsburg shale; to its right is a shallow ravine eroded in Cacapon shales. The right-hand (northwestern) side of the ravine is formed by massive Keefer sandstones that rise from the water's edge at an angle of 45° and, midway up the face of the gorge, bend sharply to a vertical position. (See Fig. 36.) Near the top of the gorge they are overturned to the right so as to form a large inverted U-shaped fold. The Keefer ledges give way at the right to a deep, wooded ravine that marks the outcrop of a

vertical displacement.

Still further to the right, another series of Keefer sandstones forms the highest point of Crawford Mountain, where it caps a wooded slope developed upon ~~the~~ Cacapon ~~formation~~ shales; below the latter is a massive ledge of Clinch sandstone. Between the Clinch sandstone and river level, there is a heavily wooded talus-slope that effectively conceals the bed rock. All of the formations to the right (northwest) of the deep ravine dip northwestward and may be traced below the Helderberg and "Romney" formations of Craig Creek valley. A somewhat similar but reversed view of the eastern wall (Pl. 58) may be obtained climbing the high ledge of vertical sandstone above the western end of the new bridge. (See Pl. 10, B, and Fig. 37.)

At first glance, the structure exposed in the gap appears to be that of a somewhat broken anticline; further study reveals that a much more complicated structure is present. Although it has the present form of an anticline, the great arch of Keefer sandstone at the southeastern end of the gorge is actually a synclinal fold which has been so completely overturned that its former southeastern limb has been bent beyond the vertical, up-turning the entire structure. As the succession of Helderberg, Tonoloway, Keefer, Cacapon, and Clinch formations at the northwestern end of the gorge is in normal sequence below the Devonian shales of Craig Creek valley, a vertical displacement must separate the two Silurian ~~sequences~~ series.

When the locality was first visited during the field seasons of 1929-1932, structural interpretations were complicated by a lack of adequate exposures. Subsequent construction of the new bridge and grading of State Highway 12 through the gap have ~~considerable assisted in revealing~~ revealed many ledges of bed rock that were previously concealed, and the structural relations, although not entirely clear, are now somewhat less obscured.

The key to the solution of the structure is to be found in a highly inclined displacement that may be traced from the crest of the mountain down to water-level. The plane of this displacement, if projected across the river, would extend parallel to the strike of Crawford and Nathrie mountains; it is inclined steeply to the northwest. Midway down the eastern face of the gap, the fault plane diverges to enclose 2 wedges, or horsts, of (1) Oscapon sandstone and (2) Tonoloway-Keyser formations. The horsts are also separated from each other by another displacement. In one block, Oscapon sandstone and shales occur in nearly horizontal position; they are wedged between vertical beds of red Oscapon sandstone and the tightly compressed syncline of Tonoloway limestone (P148,B) and Clifton Forge (Middle Keyser) sandstone which constitutes the other block. The overturned syncline of Silurian rocks occurs to the southeast of these horsts and the fault zone; northwest of the fault zone is a partially overturned monocline of Silurian rocks.

According to these data, the structure exposed in the gap is resolved into a thoroughly overturned syncline at the southeastern end that appears to have been (1) "rolled" along a fault margin, and (2) overthrust upon an equally disturbed Silurian sequence in the southeastern limb of Craig Creek syncline. Wedged securely between the two blocks are 2 small horsts of Oscapon, Tonoloway and Clifton Forge formations. It is clear that the two ends of the gap do not possess the same structure, and that more than one broken fold is involved.

Not the least confusing feature is the fact that the sections on opposite sides of the river are not wholly symmetrical, for differences in the slope of the valley walls and a linear convergence in the quarter-mile across the eroded gap prevent the structure of one wall from being the exact reverse of the structure of the opposite wall.

Possibly the most obscure item of structural interpretation is the nature of the displacement that occurs in the middle of the gorge. Contrary to the majority of Appalachian faults, its plane is clearly inclined to the northwest. It was the author's interpretation in 1932 that this fault zone was the main sole of the Pulaski overthrust. It was then thought that the Pulaski fault-plane, which emerges near Eagle Rock on the southeast side of Crawford and Rathole mountains, was highly arched so as to plunge downward below ground in the gap. Such an explanation was thought to account for the northwesterly inclination of the fault-plane, as well as for the "rolled" character of the Keefer sandstone at the southeastern end of the gap. At no point northwest of the Eagle Rock Range, however, was any outcrop found where the fault-plane again emerged at the surface.

The possibilities (1) that the fault might be a normal, or gravity, fault, or (2) that it was caused by pressure from the northwest, have both been considered but are discarded in view of the difficulties involved in either hypothesis. When traced laterally, the displacement merges into, or becomes, an overthrust of the usual Appalachian type; under such circumstances it could scarcely be a gravity fault in the gap. The evidence that the pressure which produced Appalachian structures came from the southeast is so overwhelming elsewhere in this region, that the likelihood of an overthrust from the northwest is almost negligible, and is contrary to all observed data.

It is suggested that the displacement was originally that of an overthrust from the southeast, either antedating the main movement of the Pulaski fault-block, or representing an early stage of Pulaski overthrusting. As it approached the surface, the plane of this fault originally sliced through the local rock series at a high angle. During the main epoch of Pulaski thrusting, folds

previously formed, together with the plane of the earlier displacement, were alike driven forward, and were overridden by a mass of the main Salem block. This movement had the effect of overturning and crushing the previous folds, as well as distorting the plane of the earlier displacement. After the erosion of the forward edge of the main fault block, the present disturbed structures were uncovered by James River.

Inasmuch as little conclusive evidence is available to verify any interpretation of the structure of this gap, no hypothesis should be discarded which will fit the known data into a logical pattern. The fortunate discovery of new exposures at one or more crucial points would do much to establish the mechanics of the complicated structure; present data suggest the interpretation stated immediately above.

It is disconcerting to the geologist to speculate that, but for the watergap through this range, the complex structure of the ridge would probably have escaped notice. Crawford and Rathole mountains are bounded on the northwest by Devonian shale, and on the southeast by Ordovician shale; their crests are of Silurian sandstone. Unless attention were specially drawn to the ridge, the geologist would describe it as a simple monocline. One can not help but wonder if other ridges, now considered of simple structure, might be revealed in a different light if they, too, were penetrated by a convenient watergap.

In view of the interesting structure, beautiful scenery, and rugged walls of Eagle Rock gap, the opportunity to develop the locality as a small State park might well be considered. In the event that all pollution of James River is terminated, the river can be restocked with fish, and restored to its original beauty. Properly cared for, and landscaped along the highway and railroad, the spot would make an excellent small State park or reservation of easy access. Inter-

esting geologic features, a fine stream for fishing and bathing, rugged cliffs for mountain-climbing, beautiful scenery, and excellent woodland would combine to form an ideal recreation spot, which could be developed at small initial cost and low maintenance. It is to be hoped that many small parks of this kind may eventually be established in Virginia by citizens interested in perpetuating some of the interesting natural features of the State. Natural Bridge, previously described, is an obvious location for a similar reservation.

MINOR GEOLOGIC STRUCTURES

Joints

Jointing is common to all rock formations of this area. A joint is a rock fracture along which no displacement has occurred; the fissure is normally vertical or but slightly inclined. As a general rule, local systems of joints parallel the larger rock structures and strike northeasterly. (See Pl. 31, B.) A less conspicuous joint system is parallel to the direction of pressure, and strikes northwesterly. Jointing is common in the resistant Silurian and Cambrian sandstones (Pl. 28, B), as well as in the crystalline rocks of the Blue Ridge.

Cleavage

Cleavage, which has developed during epochs of folding, shearing, and crushing, is conspicuous in the crystalline rocks of this area. Similar but less prominent cleavage has been developed in some Paleozoic rocks, especially Ordovician shales and the Cambrian and Silurian sandstones. Cleavage commonly results from mineral recrystallization, wherein, under pressure, the mineral grains become rearranged through considerable bodies of rock so that their flat surfaces are parallel. The rock will split, or cleave, along some of these mineral planes as freely as along the original bedding of the rock. In general, the cleavage of local rocks is parallel to the larger structures of the area; in most cases, it was formed contemporaneously with the larger folds and faults. The cleavage of many local sedimentary rocks, ~~can be identified by~~ possesses a lower angle of dip than that of the true bedding.

GEOLOGIC HISTORY

GENERAL FEATURES

Geologic history, like human history, is interpreted from available records and carefully drawn inferences. In the case of human history, the records are monuments, inscriptions, personal observations, and similar memoranda; the inferences come from legends, indications of popular sentiment, and analogous intangible sources. Geologic history is interpreted from rock formations and structures, mineral deposits, soils, features of the landscape, and similar concrete items of record; its inferences are largely derived by the application of inductive reasoning to the available data. In both types of historical study, the purpose is to reconstruct the past with the greatest degree of accuracy.

For the Natural Bridge area, many of the events of ancient geologic history are inscribed in the bedrock formations; scenic, or topographic, features indicate certain major events of later history; inductive reasoning may be used to fill in many of the details for which other data are inaccessible.

Geologic history is measured in incredibly long periods of time. Whereas human history is a matter of a few centuries, geologic history is a matter of millions of years. There is general agreement among geologists that the Paleozoic era, during which most of the local rocks were formed, began about 650,000,000 years ago, and came to a close 430,000,000 years later in an epoch of mountain-building known as the "Appalachian Revolution". The scenery and landscape of this region have been formed in the 220,000,000 years since the close of the Paleozoic era.

EARLY GEOGRAPHIC CONDITIONS

In early geologic time, a long narrow strait, or geosyncline, occupied the site of the present Appalachian Valley and the Blue Ridge, separating still more ancient lands. This strait, then lay east of a broad area of crystalline (pre-Cambrian) rocks which was, perhaps, the original nucleus of the continent of North America. The land surface was low and undulating, for it was repeatedly submerged by shallow bodies of marine water in which sedimentary rocks were slowly accumulating.

The Appalachian strait, or geosyncline, was bordered on the east by another ancient land-mass of crystalline rocks. This borderland, known as Appalachia, was long and narrow, separating the waters of the geosyncline from the open Atlantic Ocean. The topography of the borderland may have been rugged, for active erosion of its surface furnished immense quantities of rock debris to the rivers that flowed westward down its slopes into the nearby basin. No doubt, other rivers flowed eastward into the open ocean, but of their deposits there is no known trace below the broad surface of the present Atlantic Ocean.

The Appalachian geosyncline thus received coarse rock sediment from the eastern highland, and, with subsidence of the western mainland and opening of straits through the borderland, it was also repeatedly inundated by marine water. As a result, sedimentary rocks of many kinds--including coarse, clastic material from Appalachia, and marine, calcareous sediment with Arctic and Pacific faunas from the west--were laid down on its floor. The invading waters were replete with abundant and diverse animal and plant forms, whose remains constitute the fossils of local shales and limestones.

The filling of the sinking trough with these sediments, and the subsequent building of the ancestral Appalachian Mountains [redacted] constitute the Paleozoic history of eastern North America.

I have no objection if this section is rewritten in terms of Fuccion's views of the pre-Cambrian rocks. HMO.

PRE-CAMBRIAN TIME

So much time has elapsed since the beginning of the Cambrian period that nearly all trace of earlier events has been obliterated, and it is chiefly by inference that one can reconstruct portions of pre-Cambrian history. Erosion, weathering, and sedimentary deposition were active processes during much of that early time, and successions of sediments were built up both as sub-aerial, or terrestrial, deposits, and as muds and sandbanks in the shallow pre-Cambrian seas. Volcanic activity was probably extensive, for molten igneous rocks, such as granite and granodiorite~~s~~, penetrated, absorbed, and metamorphosed many of the sedimentary terranes ~~that~~ which they invaded from deep-seated sources.

Intrusion of the hypersthene granodiorite which forms the crest of the ~~local~~ Blue Ridge, and invasion of various types of the Marsball and other granites are examples of the igneous ~~acitviey~~ activity of the period. Folding, shearing, and compression of these rocks added to their already complicated structure, and, near the close of pre-Cambrian time, ~~they were~~ the region was elevated into a mountainous ~~tra~~ upland, ~~tract.~~ Later erosion, directed against the newly formed summits, soon lowered their elevations, and exposed a basement of broken and gnarled rock that was the floor and shore of the early Paleozoic seas.

How long an interval elapsed between the intrusion of the last granite and the deposition of the first Cambrian sediment can not now be determined. Probably it was a long interval even in geologic ~~time calculation.~~ chronology. To this interval must be assigned the peneplanation of the older crystalline rocks and the submergence that enabled the waters of the Appalachian geosyncline to collect where now stand the Blue Ridge and folded Appalachian mountains. Events following this interval are much more legibly recorded than those preceding it,

and the first recorded succession of events occurred in the Cambrian Period of the Paleozoic Era.

PALEOZOIC ERA
Cambrian Period

The Cambrian, earliest period of the Paleozoic Era, ushered in a long time of sedimentary deposition. At the beginning of the period, Appalachia formed a bold borderland east of the Appalachian geosyncline; but as the period progressed, the borderland gradually lost elevation a result of sinking and long-continued denudation.

The earliest Paleozoic event of the Natural Bridge region was the deposition of coarse clastic debris, accompanied by a mild renewal of vulcanism. Flows of rhyolitic and basaltic lavas were outpoured upon the old land surface and along the sea margins. The vulcanism was short-lived, for it was quickly followed by erosion that completely removed the flows in many places. Shortly thereafter, the rapidly encroaching early Cambrian seas covered the flows, reworked the volcanic material, and intermixed its debris with the arkosic sediments of the new sea-bottom.

Vast quantities of coarse sediment were poured into the Appalachian geosyncline. Gravels, sands, and muds accumulated in great volume to form the thick Chilhowie series (Unicoi, Hampton, and Erwin formations) that covered the shore and floor of the strait. The coarseness and cross-stratification of these deposits strongly suggest either that they came from a region of high relief, or that they were deposited in waters close to the source of the sediment.

Little by little, the upland of Appalachia was lowered while the geosyncline became wider, approaching the size and configuration of a great gulf. Its warm shallow waters afforded a rich opportunity for organic development, and new faunas of marine animals appeared. Limestones and calcareous shales (the Shady, Rome ("Watauga"), and Elbrook formations) were deposited in the expanded

seaway during the later stages of the Cambrian period; they rest upon the land-derived sediments of the Chilhowie group.

Ozarkian and Canadian Time

Favorable conditions for calcareous deposition continued long after the Cambrian period closed, for Ozarkian and Canadian time was distinguished by the production of massive dolomitic beds (Conococheague, Chepultepec, Stonehenge, Nittany and Bellefonte formations) during and epoch of crustal quiet. With the exception of a few sandy lenses within the Ozarkian system, all of the rocks were the result of marine ~~biochemical~~ precipitation, ~~It is probable that~~ in which sea-living ~~marine~~ plants and bacteria contributed actively to the formation of the ~~rocks~~ sediments. Although Ozarkian and Canadian seas were warm and suitable for evolutionary development, there were few groups of organisms that possessed hard parts capable of fossilization, and only a few rare shells of gastropods and cephalopods bear testimony to the ~~progress~~ development of life during this time.

Ordovician Period

At the beginning of the ~~During the Early~~ Ordovician period, clear seas were responsible for the thin pure limestones (Mosheim, Holston, Lenoir) that accumulated on top of the thick "Cambro-Ordovician" dolomites. During the middle ~~part~~ epochs of the period, the waters of the geosyncline were muddied by land-derived sediment that produced a thick series of shales and thin interbedded limestones. These shales (Athens) and mudrocks (Lowville) occur throughout the entire Appalachian region, and testify to changing conditions along the length of the Appalachian geosynline. Study of Ordovician faunas suggests that local barriers may have prevented migration of faunas between different parts of the geosyncline.

A remarkable episode of mid-Ordovician time was the wide distribution of volcanic ash, which is now consolidated into metabentonite. The location of the vents that furnished this ash is unknown, but the debris was blown by the winds from Ontario to Alabama and as far west as Iowa and Minnesota. The rarity of Ordovician volcanism in North America is in strong contrast to the vigorous activity of western European volcanoes. Possibly the latter were sources of the local volcanic deposits, although it is difficult to explain the transportation of ash from Europe to North America, unless the winds of the time were the reverse of those prevailing today. Possibly nearby vents, now concealed in the igneous terranes of the Blue Ridge, were responsible for the material.

Swarms of invertebrates, chiefly graptolites, brachiopods, and trilobites, lived in the waters of middle and late Ordovician time. Uplift of Appalachia and a corresponding shoaling of the sea, caused more rapid accumulation of sediment during the closing epochs of the Ordovician period, when muds and sands of Martinsburg and Juniata age buried countless shells of marine invertebrates. The advancing edge of these later deposits crowded the marine population into more

and more limited space, where severe competitive conditions induced great changes in life. Conspicuous faunal differences distinguish Ordovician and Silurian formations. Inasmuch as several early Paleozoic formations, (Nolichucky, Axeman, Ottosee) elsewhere present in the Appalachian area do not occur in the Natural Bridge region, there must have been several intervals of erosion, or non-deposition, between late Cambrian (Elbrook) and early Silurian (Clinch) times.

Silurian Period

Sharply contrasting conditions mark the close of the Ordovician and the beginning of the Silurian period. The Silurian system begins with a thick series of coarse sandstones that indicates a time of shallow-water deposition and rising lands. Appalachia was again undergoing uplift attended by rapid erosion that duplicated conditions of the early Cambrian. The Silurian sandstones (Clinch, Cacapon, and Keefer) were distributed far and wide throughout the Appalachian region where they now form a convenient and distinctive formational unit. Their sands are the relics of an old wave-beaten beach, spread out by transient currents along the ancient Silurian coastal plain. That they are again entering circulation by erosion and weathering after millions of years of burial, testifies to the external cycle of geologic processes.

During the deposition of the Cacapon sandstone, a quantity of ferruginous material--possibly iron carbonate--was deposited in portions of the geosyncline, and with its subsequent alteration to iron oxide, beds of "Clinton" hematite were formed. Early Silurian erosion so lowered the elevation of bordering lands that little clastic material clouded the waters of the Appalachian gulf in late Silurian time. The latest Silurian rocks are thin limestones with scattered lenses of sand that

contain few traces of the life of Silurian seas. Sand-boring worms left tubes and tracks in the basal sandstone; fragments of corals, brachiopods, and trilobites occur in later Silurian rocks.

Devonian Period

As there was no pronounced change from the close of the Silurian to the beginning of the Devonian, early Devonian (Helderberg) sediments are very much like those upon which they were deposited. The thin sandy limestones, which comprise the first Devonian rocks, were later covered by a thin sheet of wave-spread sand (Oriskany). Black muds, now the "Romney" black shales, gradually covered a wide area of sedimentation during Middle and early Late Devonian. The presence of abundant Helderberg, Oriskany, and "Romney" fossils indicated profuse marine Devonian life, and fragmentary stems and fronds of plants suggest that Devonian lands were acquiring vegetation.

During Late Devonian time, a thick body of gravel, sand, and mud sank into the rapidly shallowing geosyncline to form the present Brallier, Chemung, and Catskill formations. They constitute the waste of Appalachia which had suffered long erosion during the period. Great deltas, built by the turbid flood-waters of large streams, merged in these deposits, where the interbedding of sands, sandy clays, and muds, together with cross-bedding, ripple-marks, and sun-cracks, afford abundant evidence of shifting deposition, irregular currents, and wide expanses of tidal flats. Gradually the geosynclinal sea shaloed until waves became effective in reworking and distributing the great volume of material furnished from the borderland.

Mississippian Period

Inundation of the broad Devonian plain in the early Mississippian period brought waves that swept new sands and pebbles to form the ~~earliest~~ first Mississippian deposits (Price formation) of the region. Gravels near the base of the Price indicate either that the land to the east was reelevated, or that an increased rainfall brought vigor

to Mississippian streams. Swamps and coastal lagoons were lush with plants whose accumulated remains formed beds of peat that now enrich the Price formation with thin seams of coal. Local Mississippian rocks comprise the edge of a vast sub-aerial delta, or alluvial plain, that was built outward from the southeast and interfingered with thin marine beds toward the west. Only the lower part of the Price formation crops out in this area; other Mississippian and late Paleozoic rocks, if ever present, are now removed by erosion.

Post-Mississippian Time

The marine water which first inundated the Appalachian geosyncline at the beginning of the Cambrian period largely withdrew during the Mississippian, ~~Period,~~ possibly because the basin had been completely silted up. There is no evidence that these waters ever returned to the local region for any length of time, and the Price formation is the youngest, or latest, of the bedrock formations. Although they can not be found within the limits of this area, it is possible that Pennsylvanian and even Permian sediments were deposited in west-central Virginia, but it is unlikely that they ever covered much of the Natural Bridge area.

Throughout the entire Paleozoic era, subsidence and sedimentary deposition characterized the Appalachian geosynclinal region. A vast volume of earth material shifted positions as a result of these processes during an era in which epigene, or destructive, agencies were active. Inasmuch as the removal or transfer of huge quantities of rock debris from one segment of the earth's surface to another invariably disturbs the equilibrium of the ~~earth's~~ rock crust, it was with increasing surface instability that the Paleozoic Era drew to a close, and the constructive forces of uplift and mountain-formation began to assert their influence.

At some time, probably well toward the close of the Pennsylvanian period, a progressive uplift of the entire Appalachian region began, initiating a succession of earth disturbances that produced the ancestral Appalachian Mountains. This sequence of crustal movements is called the Appalachian revolution. Its origin may be traced to the overloading of the old geosyncline, and, although it ~~had been~~ was ~~initiated~~ begun well toward the middle of the era, it culminated in the closing periods of the Paleozoic with a maximum of disturbance in the late Pennsylvanian and Permian. Thus it extended over tens of millions of years.

Besides a direct uplift that brought the area of the Appalachian geosyncline high above sealevel, there was a persistant lateral movement of the earth's surface. The effects of this thrusting ~~were~~ was to produce a series of folds, warps, and faults in rocks that had been recently deposited. Paleozoic sediments were crumpled, crushed, and driven from an original horizontal to an inclined position. Although the results of these movements are displayed on a grand scale, it is probable that they transpired very slowly and quietly. The total uplift of the land was less than 10,000 feet. If only 10,000,000 years were involved--scarcely one-fifth of the Pennsylvanian period--the increase in elevation during any one year would have been so imperceptable, that not even the most astute modern observer could have detected ~~a~~ any minute change in his ~~own~~ environment. Nevertheless, changes of marked import were in progress. No doubt, even before the upfolds or anticlines were completely formed, they were attacked by weathering and erosion; probably at no time were the folds of the ancient Appalachian Mountains complete or uneroded.

The geologic record of west-central Virginia indicates that the folds and faults were not simultaneously or even continuously formed. They are clearly the result of a continuous process that operated during a long period, yet produced active results only at intervals,— i. e., a continuous effort with discontinuous effects.

Several disturbances in various parts of the Appalachian region preceded the main Appalachian revolution, but little is known about them. The exact relations of the uplifts and warpings which produced unconformable relations between many Paleozoic formations are also rather vague. Possibly they, too, were harbingers of the greater revolution which was to follow.

The earliest structures caused by the Appalachian revolution were the great open folds, of which Rich Patch anticline is a typical example. These folds were part of a system of wave-like flexures involving the entire eastern Appalachian region. The folding, initiated in the ancient crystalline land-mass of Appalachia, progressively involved rocks farther to the northwest, until its effects disappeared in the plateau country of West Virginia, Ohio, and Kentucky. The ~~effects~~ results of this folding were ~~[illegible]~~ intense in the shales immediately above the competent "Cambro-Ordovician" limestones. Buttressed on all sides by resistant formations, the relatively weak shales were contorted into a intricate series of minor wrinkles and faults.

Following the first epoch of folding, or occurring late in its cycle, was a stage of faulting or dislocation of masses of the crumpled rock. Compressed and folded beyond the breaking point, vast rock slices, ~~segments or slices~~ or nappes, were thrust bodily several miles toward the northwest, over-riding and burying rock bodies that would normally overlie them. The Kerrs Creek, Pulaski, and Blue Ridge overthrusts exhibit excellent examples of these gigantic ~~displacements~~ fractures, and involve horizontal displacements of many miles. The lateral shortening of

the earth's crust which was accomplished by such folds and overthrusts, tended to relieve the pressure that caused them. Little by little, the need for compression disappeared; folding and faulting ceased; and the region returned to a crustal stability.

It is difficult to assign an exact date to the various stages of folding and disturbance in this area. The local structures involve rocks as late as Early Mississippian; elsewhere in the Appalachain region, undisturbed Triassic rocks overlie the folded Paleozoics. Probably the major deformative movements occurred between these time limits. In Pennsylvania, rocks of late Pennsylvanian and possibly Permian age were folded during the Appalachian revolution. It seems highly probable, therefore, (1) that the main crustal movements began near the end of the Pennsylvanian Period and continued at intervals into the Permian Period, and (2) that they had largely ceased before the early part of the Mesozoic Era began.

MESOZOIC ERA

The events which followed the Appalachian revolution during the Mesozoic and Cenozoic eras are not recorded in the bedrock, but may be interpreted from the character of the topography. The early geologic history of post-Paleozoic time was characterized by gentle uplift and active denudation. The newly formed Appalachian Mountains were gradually worn down by erosion, and the debris was swept eastward into the Atlantic Ocean. Possibly land animals of the Mesozoic, such as dinosaurs, wandered into this general region, but there is no local record of them.

Throughout the early Mesozoic era (Triassic and Jurassic periods), the entire Appalachian area was involved in a cycle of erosion which terminated the long Paleozoic era of continuous sedimentation. Although the details of this erosion are not known for the early Mesozoic, it appears that no sedimentary deposits were locally laid down after the Appalachian revolution, and that the forces of weathering and erosion had ample time to reduce all elevations to a comparative monotony of surface expression. This long-continued denudation produced an erosion surface that was nearly level and must have been developed somewhere near the baselevel of the streams. The surface is now called the Upland peneplane and may have come to completion during the late Cretaceous period.

Although it is not definitely known that the Upland peneplane was the first distinct erosion level to be produced over this region, it is the earliest level of which definite remnants have been preserved. There is reason to suspect, however, that earlier (and higher) levels may have been produced and destroyed before the formation of the Upland surface. The cycle of erosion which produced this surface took place during such a long era of crustal stability that streams traversing it had opportunity to reach full maturity and to develop meandering courses.

A recent, but not wholly convincing, suggestion[1] has been made that the peneplane surface was covered with coastal-plain deposits which sloped gently toward the Atlantic Ocean. According to this theory, the extended coastal plain obliterated all trace of previous drainage and supported a new series of southeastward-flowing streams upon the soft rock of its sloping surface. Renewed uplift of the land allowed these streams to cut through the coastal plain and entrench themselves into the older rocks of the buried upland surface. This theory differs from the common interpretation of Appalachian drainage in that it calls for the superposition of streams

---

1. Johnson, Douglas, A theory of Appalachian geomorphic evolution, Jour. Geology, Vol. 39, 1931, pp. 497-508.

from a later cycle of drainage upon the Upland peneplane; whereas it is generally thought that the peneplane inherited its meandering master streams from an earlier cycle. An important objection to the coastal-plain theory is the fact that the deposits which must have been produced during peneplanation are required to cover the very region from which they were derived. It seems extremely difficult for erosion thickly to spread fluvial deposits upon the exact surface which furnishes the debris.

It is a more common hypothesis that the main streams on the Upland surface developed their meandering courses in the normal process of peneplanation, and that a series of uplifts followed which renewed stream erosion in all parts of the area. This uplift was the last local event of the Mesozoic era, or the first event of Tertiary time.

CENOZOIC ERA

As recorded in the topography of the Natural Bridge region, there is little or no evident break between the Cretaceous period, last of the Mesozoic divisions, and the Tertiary period, first division of the Cenozoic Era. The uplifts which terminated the Upland cycle involved a warping of the older peneplane as well as any actual elevation of the surface amounting to nearly 3,000 feet; active rejuvenation of the entire drainage of the Appalachians ensued. Belts of weak rock became profoundly eroded to form the deep, narrow valleys of the Valley and Ridge region, while the more resistant rock belts formed ridges that preserved isolated remnants of the older Upland surface. Following the epoch of uplift came a period of stability that was sufficiently long for the widening of valley floors and the development of the Valley-floor peneplanes. These lower erosion surfaces, produced along belts of weak rock, were separated from one another by ridges of harder strata that resisted the attack of erosion. In those areas where belts of soft rock were wide, such as the Fincastle valley (Pl. 7), the Valley-floor peneplanes

attained broad development. That the uplift which ended the Upland cycle was discontinuous is evinced by the presence of intermediate erosion levels which stand between the Upland and Valley-floor surfaces.

The production of the Valley-floor peneplanes came to a close with another stage of uplift and warping which again rejuvenated the drainage and increased the gradients of the streams. In consequence, the present streams were able to cut deep trenches into their former valley floors, with the attendant production of many minor drainage adjustments, some of which are visible in the present valleys. Stream capture and diversion were common, and not exceptional, features.

The uplift of the Valley-floor peneplanes brought streams to their present positions and largely completed the production of present surface features. During very recent geologic time, some of the soluble limestones were partially dissolved by the circulation of ground water along bedding-planes and other crevices. In many places, the sub-surface drainage has enlarged the original channels to form caves and caverns, whose partial collapse has produced sinks, depressions, and Natural Bridge. Long-continued weathering has disintegrated and decomposed the upper surface of the bedrock into a thick mantle of residual soil that largely covers the entire area. Enrichment of residual metallic ores accompanied the production of some of the lower erosion levels.

The region has passed through at least two great cycles of erosion and at present is in a third cycle. The area has been more or less constantly in movement from Mississippian time to the present, during the late Paleozoic era, and large-scale warping with vigorous stages of uplift from the Cretaceous to the present. The uplifts are recorded (in part) by the depths of the valleys; intervening periods of crustal quiet have produced the erosion terraces and peneplanes.

MINERAL RESOURCES

GENERAL STATEMENT

The Natural Bridge region contains a limited number of minerals that are of commercial value under present economic conditions. Few of them are being mined at present, and satisfactory conditions for further mineral development can not be anticipated for the immediate future. Limestone is the chief natural product now being exported; local supplies of clays and cement materials deserve more attention than they have yet received; ores of iron and manganese, although not exhausted, have dropped from the active mining field; and coal, oil, gold, and silver are wholly absent in workable quantities.

For purposes of description, the local mineral resources may be classified as (1) metallic ores, and (2) non-metallic materials.

Figure 38 shows the location of the most important mines, prospect, quarries and furnaces in the Natural Bridge region.

METALLIC ORES

Iron and Manganese

General Statement

As early as the beginning of the 19th century, a few scattered charcoal furnaces were utilizing ores from small iron prospects in the Natural Bridge region. Although most of the workings were abandoned during the period from 1845 to 1860, a number of furnaces were rebuilt and put into Confederate use during the War between the States. Immediately after the war, both mines and furnaces were idle during two decades when some prospecting, but very little serious mining, was attempted. About 1880, the introduction of coke furnaces and an increased demand for iron and steel gave a strong impetus to metal mining in this part of Virginia, and during the period from 1880 to 1905, many new mines were opened and new furnaces were blown in.

Before the rapid development of Lake Superior iron ores in 1892-1893, the Virginia iron workings were flourishing and had every prospect of continued profitable operation. However, the Lake ores became so quickly established as a cheaper and more accessible source of iron, that the Virginia companies were unable to meet the strong competition; and, the larger companies one by one, began to abandon their Virginia operations.

With the beginning of the World War in 1914, the price of pig iron advanced, while freight rates remained relatively low. Those Virginia companies that were still in operation were able to work full blast, thereby earning profits that began to offset the lean years of the two preceding decades. With the close of the war, however, pig iron dropped in value, freight transportation became relatively more costly, and active iron operations came to a halt in this part of Virginia.

During the period from 1916 to 1920, the search for American supplies of manganese stimulated local prospecting and some mining, but since 1920, the demand for this material has been insufficient to warrant further operations. The final close came in 1924, when most of the operating companies ceased active work. At the present time, with high assessments, idle and decaying equipment, and no outlet for medium-grade ore, the iron properties of the State are losing investments for nearly all private holders.

It was impossible to foresee this sequence of events when the first surveys and descriptions of iron properties were made in 1880-1890. Hence the ores were often described with more optimism than discretion, and the accounts of some of the old surveys were written with a lavish hand. Many of the analyses here included are those which accompanied early reports. Some of them probably exaggerate the actual average iron content, for they may have been made from selected samples and not from the run of the mine.

Iron and manganese deposits of the Natural Bridge region may be classified as follows:

A. Red hematite
   a. Blue Ridge hematite (of Cambrian age)
   b. Clinton hematite (of Silurian age)

B. Brown iron and manganese
   a. Blue Ridge brown ores (of Early Paleozoic age)
   b. Oriskany brown ores (of Devonian age)

Blue Ridge Hematite

Description

A thin bed of Blue Ridge hematite occurs midway between two ridge-making quartzites near the middle of the Unicoi formation. The ore is known as "mountain specular ore", for it occurs high upon the flanks of the Blue Ridge foot-hills; it has little or no resemblance, however, to true "specular" hematite. It is highly siliceous and of medium grade, having an average content of from 35 to 40 per cent of iron, and from 20 to 35 per cent of silica. The combined amounts of phosphorus, sulphur, and manganese seldom exceed 1 per cent.

Blue Ridge iron ore is a bedded deposit of quartz sandstone which is partly replaced and cemented by hematite. The ore, which is dense and hard, commonly breaks with a blocky fracture. Where long exposed, it alters to soft limonite, and becomes brown on weathered surfaces; where freshly broken, it is dark purple-red. The siliceous character results from the presence of sand grains and quartz pebbles that are locally abundant along bedding-planes. The ore is contained between sandstones and shales of the middle Unicoi formation and exhibits the same strike and dip as the adjacent rocks. As the entire formation has been considerably deformed, the ore generally stands at high angles. Only one ore bed occurs throughout the Natural Bridge; two other thinner zones are locally present.

Blue Ridge hematite crops out in streams that cross the belt of Unicoi sandstones. It is well exposed along the road leading from Laurel Run across the Blue Ridge, 4 miles south of Buchanan, where it has a thickness of about 50 inches. Several outcrops of the ore may be seen in the gorge of Bearwallow Creek where exposures are duplicated by folding. The thickness of the ore

along Bearwallow Creek is about 32 inches. Blue Ridge hematite has been prospected at the junction of Jennings and North ~~Jennings~~ creeks, where the ore bed is 38 inches thick. It is also exposed along Sprouts Run, and in Arnold Valley near Glenwood Furnace.

During the heyday of Virginia iron mining, many prospects and some mines were opened in this area. Nevertheless, as the ore does not compare favorably with the more abundant and accessible Lake Superior ores, it is unlikely that the local deposits will again have economic importance until better-grade ores are largely exhausted.

Bearwallow Hollow Prospects. Blue Ridge hematite was prospected at several places in Bearwallow Hollow immediately south of Buchanan. An abandoned working occurs on the east side of the gorge at the head of an old wagon road which led to the mine. Openings were made on a spur of Cove Mountain 1/8 mile north of the southern edge of the Natural Bridge topographic quadrangle. Several shallow trenches also occur on the west side of the gorge, and an abandoned cutting is located at the point where the main road crosses the crest of the Blue Ridge. From the latter working, where it is 32 inches thick, the ore may be traced northeastward to a point near Glenwood furnace in Arnold Valley. In all of these prospects, the ore bed stands at high angles with a prevailing dip to the southeast. Commonly it is overlain by quartzite and has a footwall of shale. No extensive operations were attempted, although it is reported that 20,000 tons of iron ore were mined from Bearwallow Creek properties between 1880 and 1882.[1]

Analyses of one from these prospects are given in Table 3.

1. This report and many statements of similar kind occur in the interesting volumes of "The Virginias", published during 1880-1885 by Major Jed Hotchkiss. Many of the items appear as notes of the iron trade, as promotional advertisements, or as sheer rumor. How much credence may be given to them is not now determinable, but they are here reproduced for the sake of completeness.

TABLE 3.— Analyses of Blue Ridge hematite, ~~from~~ Bearwallow Creek, Botetourt County, Virginia

	A	B	C	D
Metallic iron.....	44.90	49.95	55.80	44.00
Sulphur.....	.....	0.06	tr.	.....
Phosphorus.....	0.48	0.40	0.22	0.465
Silica.....	26.80	19.69	.....	29.90
Metallic manganese.....	.....	tr.	.....	.....
Al_2O_3.....	.....	.....	.....	2.73

(A. A. S. McCreath, analyst
B. T. Egleston, analyst
C. F. W. Taylor, analyst
D. Lerch Brothers, analysts.)

A, B, C. Averages of various analyses of Blue Ridge hematite.[1]
D. Siliceous specular hematite, Arcadia mine, near Buchanan,[2]

---

1. Beckwith, L. C., The Arcadia iron property: The Virginias, vol. 1, p. 111, 1880.
2. Harder, E. C., The iron ores of the Appalachian region in Virginia: U. S. Geol. Survey Bull. 380, p. 222, 1909.

Jennings Creek Prospect.--An abandoned shallow trench, 30 feet long, occurs immediately north and east of the intersection of North and Jennings creeks. The cut follows an outcrop of Blue Ridge hematite which is 38 inches thick, and strikes ~~North 55~~ N.55°E.; ~~east~~, the dip is 70 degrees to the southeast. The ore, which may be traced along the flanks of the hills on both sides of the creek, ~~and it~~ is reported to become thicker along its strike. No other prospects were found nearby, although early reports suggest the presence of at least one other ore bed. The following analysis of [illegible] from this locality is reported by Beckwith.[1]

Analysis of Blue Ridge hematite,
Jennings Creek, Botetourt County, Virginia
(A. S. McCreath, analyst)

Metallic iron	43.30
Phosphorus	0.47
Silica	28.30

1. Beckwith, L. C., op. cit., p. 111.

Glenwood Prospects.--Glenwood furnace is located ~~one-fourth~~ 1/4 mile east of Elk Creek in Arnold Valley. (See Pl. 59, A.) It is reported [1] that the

1. See footnote, page 296. This report seems unlikely, for it is not known that Blue Ridge hematite was ever used in any of the early charcoal furnaces.

furnace was used to smelt Blue Ridge hematite from property adjoining the furnace. No show of ore was observed although dumps near the furnace contain fragments of hematite. A red hematitic sandstone was found in the hill immediately west of the furnace and may have been mined as lean ore. Campbell[1] has reported the following analyses for ore from the Glenwood property.

Analyses of Blue Ridge hematite, Glenwood property, Rockbridge County, Virginia

(Analyst, J. L. Campbell)

	A	B
Metallic iron	44.55	50.00
Sulphur	tr.	tr.
Phosphorus	0.030	0.023
Silica	21.50	20.88

---

1. Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia: p. 56, New York, 1882.

Pico Mine.--The Pico iron mine, formerly operated by the Pulaski Iron Company, is located along the northwest face of the main Blue Ridge, about 2 miles south of Garts Store. A bed of Blue Ridge hematite, which is exposed along the face of the mountain, has been followed underground for some distance in several operations. The ore is about 50 inches thick and strikes ~~North 40° East~~ N. 40° E.; it is nearly vertical. A narrow-gauge railway connects the mine with a washer and camp which are located along the valley of Laurel Run on the edge of the Natural Bridge quadrangle. The camp was connected with the Shenandoah Division of the Norfolk and Western Railway by a broad-gauge track. The mines were closed in 1920, and the equipment and buildings are rapidly deteriorating.

Clinton Hematite
General Statement

Thin, discontinuous beds of red hematite are associated with Clinton horizons from New York State to Alabama. Clinton ore occurs locally (1) along the southeastern face of Rich Patch Mountain, (2) on Horse Mountain, and (3) in the gap at Iron Gate. When fresh, the hematite is a hard, massive bed from 16 to 20 inches thick. It weathers readily to soft ore whose stain exaggerates the actual thickness of the bed. The ore occurs near the top of the Cacapon formation, not far below the basal Keefer sandstones.

The ore is of good grade, but is limited in occurrence and variable in thickness; it is reported to contain about 47 per cent of metallic iron, 0.5 per cent of phosphorus, and from 7 to 12 per cent of silica.

Mines and Prospects

Roaring Run Hematite Prospect.--A thin seam of Clinton hematite was formerly prospected near the old Roaring Run Furnace, 4 miles north of Horton. (See Pl. 60, A.) The ore bed, which occurs on the southeast flank of Rich Patch Mountain not far below the crest of the ridge, is crossed by the road that ascends the gorge of Roaring Run. It is less than 12 inches thick, and was used with brown Oriskany ore in the Roaring Run furnace at the foot of the mountain. It is reported to contain 47.16 per cent of metallic iron, and 0.98 per cent of phosphorus.[1]

---

1. Hotchkiss, Jed., The Virginias, vol. 5, p. 198, 1884.

Horse Mountain Mine.--An iron mine is located on the southeast slope of Horse Mountain, north of the Lowmoor Oriskany mines. The mine was opened in 1905, and produced 15,000 tons of ore in 1907. The ore bed, which is exposed near the summit of the ridge, dips northwestward at an angle of 15°. It contains a hard layer of red hematite, that is slightly less than two feet thick, and has a blocky fracture; the ore grades into soft brown ocherous clay. A 30-foot bed of white sandstone overlies 2 feet of dark shale that from a cap over the ore.

Analyses of ore from the Horse Mountain mine are given in Table 1.

TABLE 4--Analyses of ore, Horse Mountain mine,

Alleghany County, Virginia

	1	2	3
Metallic iron	44.82	56.70	41.71
Phosphorus	.....	0.428	0.444
Silica	15.51	6.83	.....
CaO	.....	0.12	.....

---

1. Holden, R. J., in Watson, T. L., Mineral resources of Virginia: p. 442, Virginia-Jamestown Exposition Commission, Lynchburg, Virginia, 1907.

2. Harder, E. C., Iron ores of the Appalachian region in Virginia: U. S. Geol. Survey Bull. 380, p. 272, 1909.

3. Harder, E. C., op. cit., p. 232.

Other Prospects.-- It is reported that Clinton hematite was also mined near Lowmoor and Rich Patch. The ore bed is 16 inches thick on Callaghan Creek, near Lowmoor.

A thin zone of red hematite occurs at the crest of North Mountain between Longdale Furnace and Collierstown, and a prospect of Clinton ore is reported on Purgatory Mountain 3/4 miles north of Buchanan.

Blue Ridge Brown Iron and Manganese

General Statement

Deposits of brown iron and manganese ore occur at many localities along the west foot of the Blue Ridge and in residual soils of the Valley lowland. The deposits are small and represent surface concentrations of metals that were derived from the underlying rocks. The deposits commonly occur at more or less definite physiographic levels, generally upon one of the Valley floor peneplains.

Blue Ridge brown ores consist of nodular or mamilary masses of limonite and manganese oxides. The iron oxides range from limonite to goethite and contain from 35 to 45 per cent of metallic iron. The manganese oxides are chiefly psilomelane, manganite, and wad.

Mines and Prospects

James River Iron Prospects.--Blue Ridge brown ore is reported at several localities along the foot of the Blue Ridge between Bearwallow Hollow and Arnold Valley, but no deposits of workable character were observed. It is reported that this ore was used in the old Arcadia furnace which was in blast during the War between the States. The following analysis of ore from Arcadia was made by Campbell[1] in 1882:

Analysis of Limonite,
Arcadia, Botetourt County, Virginia

(J. L. Campbell, analyst)

Metallic iron	48.83
Phosphorus	0.62

1. Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia: pp. 56-57, New York, 1882

Glenwood furnace, located in Arnold Valley, is reported to have used limonite from nearby deposits. (See Pl. 59,A.) An analysis of this ore was made by Campbell[2] in 1882:

Analyses of Limonite,
Glenwood, Rockbridge County, Virginia

(Analyst, J. L. Campbell)

	A	B
Metallic iron	51.58	55.60
Sulphur	0.01	tr.
Phosphorus	0.22	0.55
Silica	9.96	3.98

2. ~~Campbell, J. L.,~~ Op. cit., p. 56.

Bearwallow Manganese Prospects.--An undeveloped tract containing brown manganese ore is located immediately southwest of Bearwallow Creek, about 1 mile southeast of Buchanan.[1]

---

1. Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 118, 1919.

It lies between Boyd Mountain and the main Blue Ridge in a synclinal valley that is floored with Shady dolomite and is deeply covered with residual soil and quartzitic debris. A small quantity of manganese ore crops out along the road for a distance of about 800 feet, ~~one-~~ 1/4 ~~quarter~~ mile south of C. G. Layman's house. The ore consists of nodules of hard, compact steel-blue psilomelane which contain considerable quantities of chert and quartz sand ~~and chert~~ that have been partly replaced by manganese oxide. Similar ore is reported from yellow-ocher pits at the east foot of Boyd Mountain. Despite the poor showing of ore, it was recommended in 1919 that exploratory drilling be attempted. Under present economic conditions, ~~such advice is not justifiable.~~ further exploration is probably unwise.

Oriskany Brown Iron and Manganese

General Statement

Brown ores of iron and manganese which are associated with Oriskany and Helderberg rocks are commonly called "Oriskany ores"; they were responsible for a flurry of iron-mining in west-central Virginia between 1885 and 1915. The ores consist of irregular masses of limonite and other hydrated iron oxides associated with varying amounts of sand, chert, and clay; analogous manganiferous oxides are occasionally present. Although the ore-bodies are somewhat irregular in occurrence, they are commonly tabular and conform in attitude to the bed rock. Where free from impurities, the ore is generally concretionary or botryoidal in structure. Pockets or stringers of clay, sand, and limestone are common in the ore-bodies; veinlets of pure ore run through the containing rocks.

The ores commonly occur (1) at the base of the Onondaga or "Romney" shale, (2) within the Oriskany sandstone, or (3) in (on) the upper formations of Helderberg. Although it has been common practice to assign all ore-bearing sandstones to the Oriskany, it is probable that various Cayugan and Helderberg horizons have been mistaken for the Oriskany sandstone.

The brown ores, which are commonly inclined at high angles, crop out along the lower slopes of Appalachian ridges between 200 and 500 feet above present streams. The richer ore-bodies are definitely associated with benches, or terraces, along the mountain flanks, (See Fig. 39.) where they were concentrated during production of the benches. Metallic elements--chiefly iron and manganese--which were leached from higher levels by descending surface water, were deposited near the water table on the benches, or local erosion surfaces. Subsequent uplift and stream incision has left the deposits some distance above present water-level. Probably the ores have been additionally enriched since their initial formation.

As the overlying Devonian black shales carry from 4 to 5 per cent of iron, it is thought that they were the source of the metallic elements. An alternate suggestion that the Oriskany sandstone was the source of the metals is commonly rejected, for many of the ore bodies are much thicker than the Oriskany.

The iron content of Oriskany brown ores varies considerably, as the ores grade into sandstones and limestones. Workable beds, however, contain between 35 and 50 per cent of metallic iron, from 0.06 to 0.5 per cent of phosphorus, from 10 to 20 per cent of silica, and as much as 40 per cent of manganese. Commonly less than 5 per cent of manganese is present. Early Oriskany mines were open cuts that followed the strike of the ore-bodies; later operations involved extensive underground workings.

Mines and Prospects

Lowmoor Mines.--The Lowmoor mines are located in the valley of Carne Creek between Rich Patch and Horse mountains, about 2 miles south of Lowmoor. The Lowmoor Iron Company, organized in 1873, began mining in 1895[7], and its furnace at Lowmoor was blown in during 1880. The mines, which were worked steadily until 1905, produced more than 1,000,000 tons of ore, and were finally closed in 1924.

The ore was mined from a series of small folds on both sides of the synclinal basin of the creek. It is conformable to the adjacent rocks, and is of good quality but varies considerably in thickness. Both "soft" earthy ore and "solid" rock-ore were mined. A broad-gauge railway formerly connected the mine and the furnace at Lowmoor; the furnace was demolished in 1930. The first prospects were mined by stripping the ore outcrop; later ~~mining~~ operations utilized underground drifts.

Table 5 shows various analyses of ore from the Lowmoor mines.

TABLE 5.-Analyses of Oriskany ore, ~~from the~~ Lowmoor mines, Alleghany County, Virginia

	A	B	C	D	E	F
Metallic Iron	46.52	43.84	51.68	53.13	50.58	48.09
Insoluble residue	17.60	.....	.....	.....	.....	.....
Silica	.....	22.87	.....	.....	.....	.....
Phosphorus	.....	0.636	0.19	0.53	0.29	0.48

A. [illegible] 2.
B. F. A. Gooch, analyst. 3.
C, and D, Otto Wuth, analyst. 4.
E, and F, C. E. Dwight, analyst.

---

1. Holden, R. J., op. cit., p. 440.

2. Harder, E. C., op. cit., p. 249.

3. Hotchkiss, Jed., The Virginias, vol. 1, p. 150, 1880.

4. Pechin, E. C., The iron development and ore resources of Virginia: Amer. Inst. Min. Eng. Trans., vol. [illegible], p. 1021, 1891.

Rich Patch Mine.--The Rich Patch iron property is located between Rich Patch and Horse mountains, in the valley of Carne Creek, 6 miles southeast of Covington; it is a short distance southwest of the Lowmoor mine. The mine, which was opened in 1895 by the Lowmoor Iron Company, was a large producer, furnishing 90,000 tons of ore in 1902. The ore, which was mined from a synclinal structure, crops out on both sides of the valley between fossiliferous Becraft chert and granular Oriskany sandstone. Onondaga and "Romney" shales overlie the sandstone. The ore bed was reported to be 30 feet in thickness at the south end of the area where it consists of a solid mass of laminated and jointed limonite. It contains much sand near the hanging wall (Oriskany) and much chert near the foot wall (Helderberg). The former is a rusty sandstone; and the foot wall consists of irregularly bedded chert, 35 feet thick. The main operations were underground; later workings were opened by steam-shovels. A standard-gauge railway formerly connected the mine with the company's furnace at Lowmoor. The following analyses show the siliceous character of Rich Patch ore:

Analyses of Oriskany ore, ~~from the~~ Rich Patch mine, Alleghany County, Virginia

	1	2
Metallic iron	42.90	53.75
Silica	25.60	10.31
Phosphorus	0.33	0.191
Manganese	0.78	0.57
Water	.....	10.48

---

1. Holden, R. J., op. cit., p. 440.

2. Harder, E. C., op. cit., p. 222.

Big Hill Mines.--The Big Hill mines are located along the eastern side of Big Hill, 3 miles south of Glen Wilton. Exploration was begun in 1880, on the site of a small earlier prospect. Regular mining was begun the following winter when a horizontal shaft was driven into the base of the hill through "Romney" shales that dip eastward at high angles. A fair show of ore was encountered, and several thousand tons of ore were shipped. A second shaft was sunk, and open pits were worked along the Onondaga-Becraft contact. A narrow-gauge railway was constructed to connect the mine with the Chesapeake and Ohio Railway at Gala, 2 miles to the south. The mines were operated by the Longdale Iron Company from 1900 to 1905, when the ore was shipped to the Longdale furnaces at Longdale. Shortly after 1905, mining operations were discontinued, and the prospects were abandoned. The mine buildings have been razed, the tracks are removed, and the shafts and openings are now caved in. Figure 10 shows the present location of the workings with reference to State Highway 12.

Limonitic ore at Big Hill is associated with Oriskany sandstone and upper Becraft limestone ~~directly~~ immediately below the ~~base of the~~ Onondaga and "Romney" shales. It is nodular and occurs both in irregular masses and as replacements of the limestone. Analyses of the ore are given in Table 9.

TABLE 9.-- Analyses of ore, Big Hill mines, Botetourt County, Virginia

	A	B	C	D	E
Metallic iron	55.28	44.08	56.67	44.89	56.77
Silica	4.63	23.60	3.91	.....	4.96
Alumina	3.14	2.17	0.63	.....	.....
Lime	1.26	1.15	0.09	.....	.....
Phosphorus	0.726	0.404	0.795	0.342	0.504

A. Dark "rock-ore"; Otto Wuth, analyst.
B. Brown ore; Otto Wuth, analyst.[1]
C. Brown hematite; J. Blodgett Britton, analyst.[2]
D. H. Froeling, analyst.[3]
E. H. Froeling, analyst.[4]

1. Hotchkiss, Jed., The Virginias, vol. ~~III~~ 3, p. 39, 1882
2. Hotchkiss, Jed., The Virginias, vol. ~~II~~ 2, p. 109, 1881

3. Hotchkiss, Jed., The Virginias, vol. V, p. 52, 1884

4. Froehling and Robertson, A handbook of the minerals and mineral resources of Virginia: p. 62, Richmond, Virginia, 1904

The mines are not now operated, and the observed ore reserves are small.

Roaring Run Oriskany Mines.--These mines are located on the southeast slope of Rich Patch Mountain, 4 miles north of Horton, Botetourt County; adjacent manganese workings are known as the Horton prospect. The openings, which are on a mountain spur about 1,600 feet above sealevel, were commercially opened about 1880, although the Roaring Run furnace (Pl. 60, A) had been erected in 1832, and the mines were operated on a small scale during the War between the States. The deposits occur in shaly sandstone at the top of the Helderberg group. The rocks are steeply inclined to the southeast, and the ore zones occur in narrow belts. The observed workings are surface cuts with several shallow shafts sunk along the strike of the outcrop. The manganese ore consists of lumps and nodules of hard psilomelane embedded in a fine yellowish clay. This ore is mammilary or botryoidal, and some lumps reach 100 pounds in weight. Nearby iron ores consist of brown limonite intermixed with much sand. An analysis of the ore by Froehling and Robertson[1] is as follows:

Analysis of Oriskany ore, Roaring Run mine, Botetourt County, Virginia

Metallic iron	51.28
Phosphorus	0.616
Silica	11.09

---

1. Froehling and Robertson, Op. cit., p. 62

It is reported that the Oriskany ores were mixed with local Clinton ore for use in the old Roaring Run furnace.

Oriskany and Adjacent Mines.--The Oriskany and adjacent mines lie in the foot-hills of Rich Patch Mountain, 14 miles due west of Eagle Rock; the main workings are immediately west of the Eagle Rock topographic quadrangle. A mining camp, Lignite, (Pl. 12, A) now largely deserted, and the chief mine buildings are located on the western edge of the quadrangle. A sketch map, Figure 41, shows the location of the workings.

The Oriskany mines were opened about 1897 and were operated by the Alleghany Ore and Iron Company until they were closed in 1924. The ore was sent to the company's furnace at Buena Vista, which was taken out of blast in December 1924. In 1925 the mine was reopened, and about 20,000 tons of ore were put on the stock-pile; from 1926 to 1930, however it was idle. In 1930, a crew of 30 men was shipping ore from the stock-pile, and during the summer of 1930, the company shipped daily about 120 tons (two cars) of ore to their furnace at Pulaski. Mining operations were abandoned as a result of increased freight rates, and at present (1932) the equipment is rapidly deteriorating.

The largest workings are about 1.5 miles due west of Lignite, and are connected with the camp and washer by a narrow-gauge railway, which meets Craig Valley Branch of the Chesapeake and Ohio Railway at Oriskany, where the ore was transferred to the standard-gauge railroad by a steam conveyor. (See Pl. 61, B.) Several acres have been excavated by steam shovels. The ore consists of limonite which replaces sandstone, together with both iron and manganese oxides in loose botryoidal and mammilary masses. The prevailing dip is about 30° to the southeast; the hanging wall is Oriskany sandstone, and the footwall is cherty Becraft limestone.

There are several shallow cave-like openings, and a deep inclined tunnel which was sunk at an angle of 33° for a distance of 730 feet along the dip of the ore zone. Several side drifts were made from the tunnel, and different levels were opened at the bottom of the tunnel. Although it is now impossible to examine the walls of the tunnel, it is said that the ore held its iron content to the bottom of the tunnel.

A large surface working, known as the Farrow bank (Pl. 61, A), was opened ½ one-half mile north of Lignite in fairly rich ore highly stained with manganese. The ore replaces Oriskany sandstone and dips gently away from Rich Patch Mountain. The footwall is cherty limestone; the hanging wall is red clay.

The Oriskany mines occur on both sides of the narrow synclinal valley that separates Rich Patch and Little mountains. Although the main workings are located on the northern side of the valley, a few prospects occur on the southern side. Little Mountain, which is a narrow anticline, is encircled by the Oriskany outcrop. The latter has also been prospected along Craig Valley Branch of the Chesapeake and Ohio Railway in the southeastern side of the hill.

The Oriskany and associated mines (including the Fenwick mine in Craig County) have been the greatest iron-producing group in the State; since 1907, they have produced more than 1,000,000 tons of ore. The average annual production from 1912 to 1924 was 56,830 tons; the maximum yearly production was in 1917, when 80,791 tons were mined.[1] In 1907, d'Invilliers reported to the company that there were more than 6,000,000 tons of available ore; in 1924 Mr. L. G. Lackey estimated a reserve of 3,500,000 tons of ore "in sight."[1] Although it is probable that both estimates are optimistic, it is undoubtedly true that a large body of ore is readily available whenever conditions are suitable for profitable operation. The

1. Information furnished by Mr. F. F. Musgrove, treasurer, Alleghany Ore and Iron Company.

Oriskany and associated mines represent one of the most promising Virginia reserves of limonite.

Average ore from the Oriskany mine contains between 37 and 45 per cent of metallic iron. The total present production is distributed to manufacturers of soap, lard, &c. The town of Lignite, established as a camp for the miners, has been abandoned since 1924.

About two miles west of the Oriskany mine occurs the Fenwick mine, formerly operated by the Lowmoor Iron Company; it utilizes the same ore zone that supplied the Oriskany mines. A standard-gauge track connects the mine with Craig Valley Branch of the Chesapeake and Ohio Railway at Oriskany. The narrow-gauge train of the Oriskany mine and the broad-gauge track of the Fenwick mine are only a mile apart at the mines. Geologic conditions are entirely similar at the Fenwick and Oriskany mines. Both are located along the same outcrop of ore near the "Romney" shale outcrop. Several of the Fenwick shafts penetrate the black shales, with side drifts extending horizontally into ore horizons below the shales. The ore rests upon buff-colored, fossiliferous Becraft chert which is commonly decomposed to a soft, white, siliceous mass containing plastic clay. Some of the more recent operations have been cut by steam shovels; several deep shafts formerly permitted underground mining.

Grace Ellen mine, now (1932) owned by the Tredicate Company of Richmond, is located one mile northeast of Lignite along the belt of Oriskany sandstone on the southeastern side of a narrow shale valley. Although the original openings were small, considerable reserve ore is reported. The workings are near the site of Grace furnace, first opened in 1849 and abandoned in 1890. The Reid, or Peanut, mine, now abandoned, is located a short distance southeast of the Grace Ellen mine.

Various analyses of ore from the Oriskany workings are given in Table 7.

TABLE 7.--Analyses of ore, from the Oriskany mines, Botetourt and Craig counties, Virginia

	A	B	C	D	E
Metallic iron	44.60	40.37	45.88	52.26	47.15
Insoluble residue	.....	21.81	16.29	.....	15.20
Silica	22.30	.....	.....	8.93	.....
Phosphorus	.....	0.45	0.12	0.12	0.11
Manganese	.....	0.69	2.18	.....	1.98

A. Ore from Fenwick mine.[1.]
B. Ore from Reid mine.[2.]
C. Ore from Oriskany mine.[2.]
D. Ore from "Craigs Creek" mine.[3.]
E. Ore from Oriskany mine.[4.]

---

1. Holden, R. J., op. cit., p. 446.

2. Holden, R. J., op. cit., p. 443.

3. Froehling and Robertson, op. cit., p. 62.

4. Furnished by the Alleghany Ore and Iron Company.

Callie and Adjacent Mines.--A small group of mines occurs on the eastern slope of Rich Patch Mountain near the Alleghany-Botetourt county-line. Among them are the Callie and Wilton mines which are located near Callie furnace. The mines are situated well up the flanks of the mountain at elevations of about 1,600 feet above sealevel. The local rocks are nearly vertical, and, at some points, are overturned. The ore zone thus appears to rest upon "Romney" shale with Oriskany and Helderberg rocks overlying it. Whereas the normal directions of dip is southeasterly, it may exceed 60° to the west in the overturned belts. Much loose lump ore occurs on the Oriskany outcrop, and the exposed ore zone reaches local thicknesses of from 30 to 50 feet.

The analyses in Table 8 show the reported character of ore from the Callie and adjacent mines.

TABLE 8.--Analysis of Oriskany ore, from the Callie and Wilton mines, Botetourt County, Virginia

	A	B	C	D	E	F	G
Metallic Iron	46.17	45.62	56.77	51.57	59.41	60.05	51.60
Silica	.....	.....	.....	13.46	.....	1.96	9.20
Phosphorus	0.07	0.67	0.50	0.05	0.28	0.29	0.29

A. Ore from Callie mine; Froehling and Robertson, analysts.[2.]
B. Ore from Callie mine; F. A. Gooch, analyst.[3.]
C. Ore from Wilton mine; H. Froehling, analyst.[4.]
D. Ore from Wilton mine; J. B. Britton, analyst.[5.]
E. Ore from Wilton mine; J. B. Britton, analyst.[5.]
F. Ore from Wilton mine; J. B. Britton, analyst.[6.]
G. Ore from Wilton mine; H. Froehling, analyst.[1.]

---

1. Froehling and Robertson, op. cit., p. 62.
2. Holden, R. J., op. cit., p. 442.
3. Harder, E. C., op. cit., p. 249.
4. Hotchkiss, Jed., The Virginias, vol. V, p. 52, 1884.
5. Hotchkiss, Jed., The Virginias, vol. III, p. 23, 1882.
6. Hotchkiss, Jed., The Virginias, vol. III, p. 78, 1882.

Retreat and Adjacent Mines.--The Retreat mine is located in a sag along the crest of Mays Mountain near its junction with ~~the point where Mays~~ and Back Creek Mountains, 9½m. The ore occurs in rounded lumps and masses upon Helderberg and Oriskany outcrops where it was mined in open cuts and pits over an area of nearly an acre. The workings are now entirely abandoned, and the cuts and trenches have largely fallen in; small piles of loose ore remain near the workings. Tables 9 and 10 show the reported content of Retreat ores.

TABLE 9.--Analyses of Oriskany ore, Retreat mines, ~~Purgatory Mountain~~, Botetourt County, Virginia

	A	B
Metallic iron	54.85	47.60
Phosphorus	0.085	0.489
Silica		13.66
Sulphur	tr	

(A. J. L. Campbell, analyst [1.]
B. H. L. Froehling, analyst [2.])

1. Campbell, J. L., The "Purgatory" iron property, Botetourt Co., Virginia; The Virginias, vol. 1, p. 157, 1880.
2. Froehling and Robertson, A handbook of the minerals and mineral resources of Virginia: p. 62, Richmond, Virginia, 1904

TABLE 10.--Analyses of Oriskany ore near Retreat Furnace, Botetourt County, Virginia [1.]

(W. B. Rogers, analyst)

	A	B
Peroxide of iron	21.20 grains	24.06 grains
Silica	5.20	2.45
Alumina	0.73	0.50
Water	2.73	2.74
Loss	0.14	0.27
	30.00 grains	30.00 grains

1. Rogers, W. B., Geology of the Virginias, pp. 14-15, New York, D. Appleton and Co., 1884. (A reprint of annual reports and other papers on the)

Ores from this mine and adjacent prospects were smelted in Retreat (See Pl. 59, B.) furnace, formerly located near the head of Purgatory Creek. A narrow-gauge railway also connected the workings with Etna furnace on Purgatory Creek.

Mays prospect is located on the west slope of Mays Mountain, north of its junction with Green Spur; it is about 2½ miles due west of Saltpetre Cave. Karnes prospect is located on the west slope of Back Creek Mountain, one mile west of Karnes Spring. Neither prospect was ever commercially developed. Analyses of ores from Purgatory Mountain are given in Table 11.

TABLE 11.-Analyses of Oriskany ore
Purgatory Mountain, Botetourt County, Virginia

	A	B	C
Metallic iron	41.800	56.55	56.35
Phosphorus	0.094	0.112	0.112
Sulphur	tr.	tr.	
Silica			6.47
Metallic manganese			0.23

(A and B; J. L. Campbell, analyst
C; H. L. Froehling, analyst)

A. Limonite from Mays bank) 1.
B. Limonite from Karnes bank)
C. "Lump ore," Purgatory Mountain 2.

---

1. Campbell, J. L., op. cit., p. 157.
2. Froehling and Robertson, op. cit., p. 62.

Salisbury prospect is situated in Hickory Hollow, 3½ miles northeast of Saltpetre Cave; it is a short distance north of, and above, Hickory Hollow Branch. Ore from this locality is said to have been smelted at Salisbury furnace, located near the junction of James River and Catawba Creek.

Other workings along Purgatory Mountain include the following prospects: (1) McCarty prospect, located near the southwest end of Purgatory Mountain, about one-fourth (1/4) mile north of James River; (2) Holmes prospect, located along the western flank of Purgatory Mountain, about 2½ miles northeast of Springwood; (3) Lee prospect,

located on the eastern flank of Purgatory Mountain, about one mile northwest of Buchanan; and (4) Bald prospect, located near the crest of Purgatory Mountain, about one-half mile southeast of Cartmell Gap. None of these prospects, however, is of present importance.

Sand Bank Iron Mine.--The Sand Bank iron mine[1] is located along the northeastern slope of North Mountain about 2 miles east of Daggers Springs, where it was opened in brown Oriskany limonite

---

1. Holden, R. J., op. cit., p. 442.

---

that was concentrated in the upper beds of the Helderberg group. It is reported that the ore had a local thickness of 40 feet, and it was mined by open cuts for several hundred feet along its strike. Some attempt was made to follow the ore below ground, but the openings are now entirely inaccessible. The rocks dip northwestward at an angle that is but slightly greater than the slope of the mountain. A long steep incline connected the mines with a washer and crusher that were located along a tributary of Mill Creek about 1 mile east of Daggers Spring. A broad-gauge railway formerly connected the camp with the Chesapeake and Ohio Railway at Gala. At present (1932), the character, thickness, and structure of the ore bed are largely concealed, as the operations are thickly grown over with oak scrub and have slumped in.

Cook or Ruhl Manganese Mine.--The Cook or Ruhl mine[1] is located

1. Stose, G. W., and Miser, H. D., Manganese deposits of Western Virginia; Virginia Geol. Survey Bull. 23, pp. 109-111, 1922.

about 2 miles east of Daggers Springs, on the southeast slope of the south end of North Mountain, at an elevation of about 1,700 feet above sealevel. The mine was worked in 1911, when it is reported to have produced 120 tons of manganese ore that contained about 54 per cent of manganese. At the present time (1932), the workings and tunnel are caved in and it is difficult to determine the structural relations of the ore body. The manganese apparently occupied a tabular area several feet thick in residual clay above upper Helderberg limestone. The rocks dip southeastward, and the soil and ore contain abundant nodules of fossiliferous Becraft chert. The ore, which consists of psilomelane and associated iron oxides, also occurs in lumps or masses irregularly distributed through the clay. There are some indications of this ore for several miles along its strike, but at no point was enough workable ore observed to warrant present operation.

Burman Manganese Prospect.--The Burman prospect[1] is located

1. Stose, G. W., and Miser, H. D., op. cit., p. 111.

about 4 miles east of Deggers Springs, along Sloan Branch (Pl. 10, B) which drains the southern end of Heartsblood and joins Mill Creek near the ruins of Jane furnace. The prospect is 2 miles east of the Cook mine, at the southwestern end of Panther Mountain at an elevation of about 1,900 feet above sealevel. A surface cut 20 feet long was made in 1910 in residual clay above Helderberg (Becraft) limestone that dips to the southeast at an angle of 60°. The ore consists of slabby manganite which replaces the clay and limestone. It is free from iron and silica and is of good quality. Its limited occurrence removes the possibility of commercial development.

Sheets Mine.--An abandoned iron mine occurs on Hathole Mountain, 1½ miles northeast of Eagle Rock. The workings, which are about 500 feet above the floodplain of James River, formerly supplied a small quantity of ore which was hauled by wagon to Gala. An analysis of the ore is reported by Froehling and Robertson[1] as follows:

Analysis of Oriskany ore, Peake's property, North Mountain, Botetourt County, Virginia

Metallic iron	59.64
Phosphorus	0.462
Silica	2.46

1. Froehling and Robertson; op. cit., p. 62.

Iron Furnaces

Several ruins of old blast furnaces attest the former activity of the iron industry in this region. All of the early furnaces were charcoal furnaces that were supplied with fuel from nearby forests. Later furnaces were either built for coke use, or were adapted for coke-burning from earlier charcoal furnaces.

Etna furnace, now demolished, was located on the east bank of Purgatory Creek, 3 miles north-northeast of Buchanan and ~~one-quarter~~ ¼ mile west of Lee Highway. It was first erected in 1792 but was soon abandoned. It was rebuilt in 1848, and is reported to have been in blast during 1861-1865; it has long been in ruins. The Etna was a charcoal furnace that smelted ore from nearby mines on Purgatory, Orebank, and Mays mountains. A narrow-gauge tramline originally connected it with the mine workings.

Retreat furnace (Pl. 59, B) is located near the head of Purgatory Creek, 1½ miles north-northeast of Dunkard Church. It was built in 1827 and was in operation for 22 years before it was abandoned in 1849. The furnace, which was located in a pleasant glade near Orebank Mountain, was supplied with brown iron ore from nearby mines.

Rebecca furnace was located along Mill Creek near the intersection of the small creek that drains Limestone Hollow. It was built in 1830 and was in operation for 29 years. Jane furnace, now in ruins, was located near the southern end of Biggs Mountain in a stream flat along Mill Creek. It was erected in 1835 and abandoned in 1850.

The ruins of Salisbury furnace are visible at the junction of Catawba Creek and James River. The furnace, which was built in 1827, had one stack 32 by 10 feet. It was abandoned in 1849, but was rebuilt 20 years later to a capacity of 4,000 tons. It was in operation from 1881-1884 but has since been abandoned. Ore

smelted at this furnace was furnished by Salisbury mine located a few miles east of the furnace.

Arcadia furnace (also known as Boyd furnace) is located along Jennings Creek about ~~one-quarter~~ 1/4 mile south of the Norfolk and Western Railway near the road leading to Solitude. It was built in 1862 and was run by the Confederate Government from 1862-1865; after the war it was taken out of blast. Like other furnaces of the area, it was constructed of stone and is 36 feet high by 9 feet square. Its blast was supplied from a wheel driven by Jennings Creek.

Glenwood furnace (Pl.59,A) was originally built in 1849. In 1874 it was rebuilt and was run with occasional interruptions until 1884. It is located on the flat floor of Arnold Valley, about ~~one-quarter~~ 1/4 mile east of Elk Creek and immediately east of the main road in the valley. It is 2 miles due south of Natural Bridge station. It had one open stack 35 by 8½ feet, and its blast was supplied by water power. It had an estimated annual capacity in 1884 of 2,000 tons and smelted ores from the immediate vicinity.

Catawba furnace (Pl.60,B), located on Catawba Creek, 11 miles west of Fincastle was built in 1830. It was abandoned in 1849, although it saw service between 1861 and 1865. Roaring Run furnace (Pl.60,A), which is situated ~~seven~~ 7 miles northwest of Eagle Rock, was built in 1832. It was rebuilt in 1854, but was again abandoned; it was put into temporary use during the War between the States. Grace furnace, located near Craig Creek, 14 miles west of Eagle Rock, was built as a charcoal furnace in 1849. It was burned in 1864, and was rebuilt in 1874 as a coke furnace with a capacity of 1,600 tons. It has been abandoned since 1890. Callie furnace is situated on the southeast slope of Rich Patch Mountain, 2 miles north of Glen Wilton. It was built for charcoal in 1873 and later enlarged for coke; its capacity was about 4,000 tons. Princess furnace at Glen Wilton was erected in 1884 with a capacity of 10,000 tons. None of these furnaces has been in recent blast.

Other nearby furnaces include the Lucy Salina, Longdale, Lowmoor, Iron Gate, Cloverdale, Covington, Dolly Ann, Australia, and Rumsey furnaces.

The last furnace to be in blast in the Natural Bridge region was the Iron Gate furnace, owned and operated by the Alleghany Ore and Iron Company. It was closed in 1923, During the summer of 1930, the old Lowmoor furnace was dismantled, and its usable parts were shipped out of the State.

Future Development of Iron and Manganese

Although there is a considerable showing of iron ore in the Natural Bridge region, it is clear that the present economic possibilities are far from promising. There is no doubt that a large quantity of ore of fair grade is accessible to transportation facilities and available for relatively easy mining. At present, however, its moderate quality and distance from steel-producing centers remove it from practical competition with cheaper and better ores already on the market. With the inevitable exhaustion of higher-grade iron ores and a probable increased demand for steel, the time should ultimately come when operations may profitably begin again.

The manganese ores are even less promising and it is unlikely that they can successfully compete with ores from other localities unless their operation is stimulated by more abnormal conditions than are to be reasonably expected.

At the present time, bodies of these ores beneath the lands of west-central Virginia add little to property values. In a few generations, however, the ore-bearing lands may command a more profitable premium.

NON-METALLIC MATERIALS

Limes and Cements

General Statement

The Natural Bridge region is abundantly supplied with calcareous rocks of many kinds. Stone for rough construction, crushed limestone for road metal, ground lime for agricultural and chemical use, and miscellaneous cement materials are all available within the area.

As theoretically pure limestone is merely a massive form of the mineral calcite, its chemical composition should consist entirely of calcium carbonate, represented by the chemical formula $CaCO_3$. Such a rock, however, is extremely rare, and two impurities normally reduce the lime content: (1) magnesia, which replaces some of the calcium, and (2) silica, iron, or clay. Thus, relatively pure limestones grade in one direction through magnesian limestones into true dolomites, and in another direction from argillaceous limestones into limy shales.

In the production of lime, a stone free from all impurities is desired; for the manufacture of cement, a certain amount of argillaceous material is important. An ideal limestone for lime production should contain about 95 per cent. of calcium carbonate and less than 1 per cent. of silica, or insoluble material; an ideal stone for cement manufacture should carry about 75 per cent. of calcium carbonate, and 20 per cent. of clayey materials. Fortunately, however, it has been found practical to use rock in the lime industry whose calcium-carbonate content is as low as 86 or 87 per cent., and the required composition of cement materials can be met by combining pure limestones with sufficient argillaceous rock to produce the desired proportions.

Lime

General Features

The Holston limestone, which is the most important source of lime, is a coarsely crystalline blue-gray limestone that varies from 4 to 40 feet in thickness. It has an average content of more than 85 per cent, of calcium carbonate, and is reasonably free from undesirable impurities. Many beds which contain more than 95 per cent, calcium carbonate occur within the formation and are sufficiently pure for high-grade chemical lime. The Holston has several outcrops that are adjacent to rail transportation, and it has been quarried extensively at Eagle Rock, Rocky Point, and Indianrock.

Although the Lenoir and Mosheim formations are also highly calcareous, they have been utilized at only two localities. Other beds, including the Elbrook, Conococheague, and Chepultepec formations, contain individual members that can be burned in local kilns for agricultural lime. They do not, however, contain rock of commercial value. The Shady dolomite has been quarried at Buchanan (Pl. 62) as flux for the manufacture of iron.

Analyses of limestones from the Natural Bridge region are given in Tables 12, 13, and 14.

Local Developments

The Liberty Limestone Corporation, with offices at Rocky Point, operates two large quarries on either side of Roaring Run, ~~one~~ 1 mile north of Rocky Point Station. The limestones strike ~~North 50° East~~ N. 50° E., and dip 40° southeastward. Although the Mosheim, Lenoir, and Holston limestones are all quarried, most of the production is from the Hoston and Lenoir formations which supply respectively "white" and "black" limestone. The Rocky Point quarries are large open cuts from which rock is extracted with steam shovel and by hand. A narrow-gauge electric tramway connects them with a crusher near James River. The first cuts were made in 1920, and the quarries have been run continuously since that time. The plant has a present (1932) capacity of about 1,500 tons per day. The rock is crushed and pulverized to any required size between 8-inch stone and a 200-mesh powder; most of the black stone (Lenoir) is used for railroad ballast and road material. The light stone(Holston) is shipped to North Carolina and eastern Virginia for agricultural and chemical purposes; other shipments are made for filler and for use in dusting coal mines; a large quantity of Holston limestone is used for concrete.

TABLE 12.--Analyses of Ordovician limestones, Natural Bridge Region, Virginia

	A	B	C	D	E	F	G
$CaCO_3$	94.88	89.03	82.06	——	96.71	97.98	97.28
CaO	53.13	——	——	53.71	58.18	——	——
$MgCO_3$	1.03	3.20	1.66		0.90	0.84	0.55
MgO	0.49	——	——	0.83	0.42	——	——
SiO_2	2.54	5.20	12.68	0.73	1.62	——	1.64
Al_2O_3) + Fe_2O_3)	1.24	2.01	——	0.79	0.72	0.60	0.52

A. Massive dove limestone, Mosheim formation, Murat Post-Office; W. M. Thornton, analyst.[1].

B. Dark-blue Lenoir limestone, Murat P. O.; Wm. M. Thornton, analyst.[1].

C. "Dark limestone," Lenoir formation, Rocky Point quarries; Froehling and Robertson, analysts.[2].

D. Pure gray Holston limestone, Lexington; C. Catlett, analyst.[3]

E. Compact white Holston limestone, Reservoir Hill, Lexington; J. H. Gibboney, analyst.[3].

F. Coarse crystalline white Holston limestone, Murat P. O.; Wm. M. Thornton, analyst.[1].

G. "Gray limestone," Holston, Rocky Point quarries; Froehling and Robertson, analysts.[2].

---

1. Bassler, R. S., The cement resources of Virginia, west of the Blue Ridge: Virginia Geol. Survey Bull. 2A, p. 130, 1909.
2. Furnished by the Liberty Limestone Corporation, Rocky Point, Virginia.
3. Bassler, R. S., op cit., pp. 127-28.

The Dillon quarries, operated by E. Dillon's Sons, are located ~~one~~ 1 mile due north of Indianrock and ~~one~~ 1 mile west of the Rocky Point quarries. Several open cuts, which have been opened in Ordovician limestones, are connected by a narrow-gauge railway with kilns along James River at Indianrock. The Dillon quarries utilize the same limestones that occur at Rocky Point. Both Mosheim and Holston limestones are burned for lime; the intervening Lenoir limestone

is discarded. The beds dip southeastward at a uniform angle of 45 degrees. Only one small working was in operation when the locality was visited in 1931-32.

Two quarries in the Holston limestone are located on the west bank of James River at Eagle Rock; they supply the main industry for the village. (See Pl. 63, A.) The Moore Lime Company, of Richmond, started operations at Eagle Rock in 1883 with a few small surface cuts that were augmented in 1912 by underground mines. As the crusher and kilns were located on the east bank of the river, stone was transported across the river by a suspension cable. In 1934, the quarries and equipment were taken over by the Virginia Lime Products Company which has a daily capacity of about 75 tons of lime and 600 tons of crushed stone. The Eagle Rock Lime Company, of Eagle Rock, has been in operation for about 30 years. Its quarries are located on the north side of State Highway 12 about ½ ~~one-half~~ mile west of James River; its kilns are situated along the river near the western end of the old bridge. The Eagle Rock Lime Company uses the Holston limestone for lime only.

The Holston attains a thickness of about 40 feet at Eagle Rock where it is crushed and folded along the margin of the Salem block of the Pulaski overthrust along which a wedge of Nittany dolomite has been thrust upon the Ordovician limestones. In the quarries of the Eagle Rock Lime Company, the overthrust dolomite has been eroded away to expose the broken limestone below the fault plane. (See pp. 244-246.) At the underground mines formerly operated by the Moore Lime Company, the overthrust wedge of dolomite is the hanging wall in openings that extend for some distance into the western bank of James River. (See Pls. 55, 56, and 64, B.)

The pure character of the Holston limestone at Eagle Rock is evinced by the following analyses:[1]

Analyses of Holston limestone, Moore Lime Company quarries, Eagle Rock, Virginia

(Froehling and Robertson, analysts)

	A	B
$CaCO_3$	99.91	94.20
SiO_2	0.04	0.48
Fe_2O_3, Al_2O_3	0.06	0.36
$MgCO_3$	trace	4.95
total	100.01	99.93

1. Furnished by the Moore Lime Company, Eagle Rock, 1929.

Burned lime from A and B (above)
(Analysis by Warner Laboratory, Cresson, Pa.)

Loss on ignition	0.66
Insoluble material	0.29
Fe_2O_3 and Al_2O_3	0.32
CaO	98.59
MgO	0.10
	99.96

Hydrated lime from burned lime (above)
(Froehling and Robertson, analysts)

Silica	0.54
Fe_2O_3 and Al_2O_3	0.24
Hydrated lime	94.57
$CaCO_3$	3.76
Hydrated magnesium	0.86
	99.97

TABLE 13--Analyses of Holston limestone, Eagle Rock, Virginia

	A	B	C
$CaCO_3$	98.46	96.78	97.32
$MgCO_3$	0.43	0.64	0.15
Al_2O_3, Fe_2O_3	0.306	1.44	0.22
	99.20	98.86	97.69

A. Lime from Moore quarry, Eagle Rock.[1.]
B. Lime from Peak's quarry, Eagle Rock.[1.]
C. Analysis of "Murat" (Holston) limestone, Eagle Rock[2.] J. H. Gibboney analyst.

---

1. Froehling and Robertson, A handbook of the mineral and mineral resources of Virginia, p. 68, Richmond, Virginia, 1904.

2. Bassler, R. S., op. cit., p.133.

Although several smaller quarries have been opened in the Holston outcrop east of James River at Eagle Rock, none has furnished any valuable stone.

The Natural Bridge Lime Company of Glascow formerly operated a quarry in Shady dolomite at Sherwood, ~~one-half~~ 1/2 mile southwest of Natural Bridge Station, where lime was burned for agricultural purposes. The quarry and kilns are now abandoned.

The Shady dolomite ~~was~~ was formerly prized as a source of stone for flux in the smelting of irom. The Virginia Iron, Coal, and Coke company owns an extensive quarry along the Norfolk and Western Railway near the mouth of Bearwallow Creek, ~~one-half~~ 1/2 mile east of Buchanan. (See Pls. 62 and 63, B.) This quarry formerly supplied stone for furnace use at Roanoke. It has not been operated for many years and the equipment is rapidly deteriorating. Table 14 shows the reported chemical character of the Shady dolomite.

TABLE 14.--Analyses of Shady dolomite, Buchanan, Virginia

	A	B	C
$CaCO_3$	53.34	——	38.33
CaO	——	29.54	——
CO_2	——	34.17	——
$MgCO_3$	46.02	——	16.30
MgO	——	13.05	——
SiO_2	6.45	17.30	36.60
Al_2O_3	1.05	6.18	6.33
Fe_2O_3	——	1.62	
P	0.01	——	——
S	0.14	——	——

A. Limestone from quarry southeast of Buchanan; P. Salom, analyst.[1.]
B. Average analysis of natural cement rock; Balcony Falls.[2.]
C. Hydralic lime, Rockbridge County; W. B. Rogers, analyst.[3.]

1. Hotchkiss, Jed., The Virginias, vol. 6, p. 62. 1885
2. Watson, T. L., Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, p. 161, 1907
3. Rogers, W. B., Geology of the Virginias, p. 138, New York, D. Appleton and Co., 1884

Cement Materials

~~General Statement~~

Although pure limestone is required for the manufacture of cement, it is not the sole requisite and a body of clayey, or argillaceous, material is also necessary. In a few rocks (known as natural cements) the original composition of the stone supplies both lime and clay in the proper proportions; normally, however, it is necessary to mix relatively pure limestones with less pure, argillaceous, stone to provide the desired composition, and either limy shales or shaly limestones may be used in such a mixture.

Several local formations contain stone suitable for admixture with pure limestone for cement purposes. Among them are the Lenoir, Athens, Chambersburg, lower and Martinsburg (Trenton) formations, all of which crop out near the Holston limestone. Primarily to qualify for cement use, shaly beds must be physically free from sand, chert, and flint and chemically free from magnesia and excess silica. Most of the rock in the Ordovician shaly limestones meets this requirement, and beds of almost any desired composition can probably be found in the Natural Bridge region. As the composition of the argillaceous material needed depends upon the grade of pure limestone used, it is not possible to specify which shaly beds are most usable. Nevertheless, ~~since~~ as all grades of stone from pure limestone (Holston) to shale (Athens) are present, there should be no trouble in finding material for the necessary mixture.

The cement industry has no present development in the Natural Bridge region. A cement plant was formerly located in the gorge of James River below Balcony Falls and is reported to have used natural cement derived from the Shady dolomite near the junction of James and North rivers. The plant, operated by the James River Cement Company,[1] was in operation from about 1860 to 1910.

---

1. Bassler, R. S., op. cit., p. 292.

Summary of Limes and Cements

Materials for lime and cement manufacture constitute an important mineral reserve for the Natural Bridge region. Excellent transportation facilities are accessible to belts of Holston outcrop from which high-grade limestone is already being obtained; and quantities of argillaceous rock for cement mixture are equally available. It is not unreasonable to expect that a local cement plant could be developed to supply the industrial area of Roanoke. Probably the best location for such a plant would be near one of the three operating lime quarries. There are no geological factors to prevent a considerable increase in the production of lime for agricultural and other purposes. Inasmuch as quarrying of limestone is the chief mineral indutry in the region, it is highly desirable to increase it as far as economic factors will permit, and the geologic factors for a considerably increased development are entirely favorable.

Clays and Shales

The manufacture of brick and other ceramic products demands an adequate supply of clay or clay shale. Local materials of possible use in the clay industry are of two types; (1) true sedimentary clays or shales, and (2) residual clays from the decomposition of bed-rock.

True Sedimentary Clays or Shales

Various bedrock formations furnish clay shales suitable for brick of tile. The most important are the Rome ("Watauga") formation, Elbrook limestone, Athens shale, and the "Romney" and Brallier shales.

The Rome ("Watauga") formation contains stiff shales near Lithia, 6 miles southwest of Buchanan, that assume a fair plasticity when ground and mixed with 18 per cent of water. Although its air shrinkage and tensile strength are low, the material can be molded without much difficulty. Ries and Somers[1] report that this clay can be used for

---

1. Ries, Heinrich, and Somers, R. A., The clays and shales of Virginia, west of the Blue Ridge: Virginia Geol. Survey Bull. 20, pp. 29-30, 1920.

---

common brick and probably for hollow brick. Similar shales crop out in the same belt from Lithia northeastward through Buchanan, Indianrock, Gilmore Mills, and Glasgow. Red and purple shales of Rome ("Watauga") age are used at Glasgow with residual shady clay in the manufacture of common brick.

Although the Elbrook formation is largely calcareous, a few beds of gray shale occur which, if mixed with residual clay from nearby limestones, might be used for brick. Shales of this character occur southwest of Springwood, and between Buchanan and Botetourt.

The Athens outcrop north of Fincastle contains a shale that is dark-colored when fresh, but turns gray-yellow upon weathering and disintegrates into a smooth residual clay. Although the fresh shale is poorly plastic when ground, it can be mixed with nearby residual clay to form a satisfactory base for clay-brick. Abundant outcrops of Athens shale occur between Catawba Creek and Cedar Ridge.

Shaly beds within the "Romney" and Brallier formations approach the character of clay-shales. Most of the beds, however, are too hard or stiff for commercial use, or fail to be sufficiently plastic when ground. Devonian shales of fair quality are exposed along Craig Valley Branch of the Chesapeake and Ohio Railway northwest of Eagle Rock.

Residual Clays from Decomposition of Bedrock

Residual clays produced by long-continued weathering are widely scattered in the Natural Bridge region. Although they differ in character with variations in the bedrock, many of them are satisfactory for ceramic use.

The Shady dolomite produces a thick reddish clay-soil that is of potential value where free from transported impurities. It has been examined near Nace[1] (Lithia) and at Buena Vista where it occurs in

---

1. Ries, Heinrich, and Somers, R. A., op. cit., p. 45.

---

workable quantities. It is utilized at Glasgow in a large brick yard, operated by the Glasgow Clay Products Corporation, ~~is located~~. Both residual shady soil and bedrock of Rome ("Watauga") age are used at Glasgow to form a mixture that produces a good brick.

Redidual clay from the Elbrook limestone is abundant west of James River between Buchanan and Springwood. It is unctuous and fairly plastic, although the fresh limestone is of no value for clay products.

Similar clay occurs one mile northeast of Springwood.

The wide area which is underlain by Ozarkian and Canadian dolomites, contains a thick mantle of residual soil. Most of the calcareous material has been leached out during weathering and the clays are soft, smooth, and plastic. Many of them can be used locally for brick and tile, although they vary considerably in shrinkage and absorption after firing.

Athens, Chambersburg, and Martinsburg formations crop out in the northeastern part of the area between Natural Bridge, Oakdale, and Lexington. Samples of their clay were examined by Ries and Somers[1] who report a deposit of good plastic clay 2 miles east of Lexington.

---

1. Op. cit., p. 44.

Residual clays from Devonian shales are common near the Oriskany and Fenwick iron mines. The basal Devonian shale near Oriskany weathers into a whitish clay that reaches a thickness of from 5 to 10 feet. It can be traced for several thousand feet along its strike, and has been followed in the direction of dip for more than 300 feet below ground. The overburden consists of a red or yellow clay that is covered with mixed dirt and sandstone gravel. A drill-hole near Flatwoods, northeast of the main Oriskany mine, indicated 20 feet of white clay covered by 10 feet of yellow clay.

The white clay is dense and is not distinctly stratified. It works up with 36 per cent. of water to a mass of good plasticity that has 6.1 per cent. air shrinkage. Although it burns to a buff color, the clay was gray at Cone 9; it was steel hard at Cone 05.[1] It was practically non-absorbent from Cone 03 to Cone 5, at which point its absorption increased slightly. As it is plastic and dense-burning, it could be used for face brick or for ordinary stoneware pottery. An analysis of this clay is reported by Ries and Somers[2] as follows:

---

1. Data supplied by the Alleghany Ore and Iron Company. See also description by R. J. Holden, Virginia Polytechnic Institute Engineering Institute Division Bull., no. 14, pp. 1-12, 1928.

Analysis of white clay from Lignite, Virginia

SiO_2	59.17
Al_2O_3	24.26
Fe_2O_3	4.62
CaO	none
MgO	1.06
K_2O	4.94
Na_2O	0.27
H_2O	5.72
	100.04

---

2. ~~Ries, Heinrich, and Somers, H. M.,~~ Op. cit., p. 85.

The red clay which overlies the white clay, has entirely different properties. Its fire shrinkage is altogether too high to permit it to be used alone, but it probably can be satisfactorily mixed with the white material. An attempt ~~was made~~ in 1924, to utilize the latter near the Oriskany mine, ~~which~~ was abandoned when iron mining ceased in December 1924.

Summary of Clays and Shales

In the absence of a strong demand for clay products in the Natural Bridge region, none of the local supplies of ceramic materials has been commercially exploited, save at Glasgow, which is outside the area of this report. Under suitable conditions of demand, transportation, and experienced management, it is possible that some of the clays can be successfully developed. Sufficient material is at hand to supply brick and tile for all local use.

Coal and Oil

A small coal prospect was investigated during the War between the States as a possible source of fuel for the Catawba iron furnace located nearby. The prospect occurs on Stone Coal Run, 7 miles due west of Fincastle, and ½ mile south of the southwestern corner of the Eagle Rock quadrangle. It is located in the outcrop of Price sandstone on the southeastern slope of Caldwell Mountain near the middle of Stone Coal Gap. Another prospect was found in Lees Gap. It was reported[1.]

1. Hotchkiss, Jed., The Virginias, vol. 4, p. 159, 1883.

in 1883 that two benches of coal, separated by 18 inches of hard shale were exposed along the creek, a short distance below the road in Stone Coal Gap. The benches were reported to reach a total of 10 feet in thickness, and were opened by a tunnel driven for 80 feet into the seam.

In 1914, R. W. Howell[2.] examined two caved openings that may

2. Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, p. 278, 1925.

have represented the original workings. Dump piles near the abandoned pits were composed of shale and bony coal. Howell also observed several old prospect pits ¼ mile southwest of the gap, where a seam of coal 5 to 6 feet thick was exposed. The bed, which was shaly, was much crushed and sheared. A short distance stratigraphically above this seam were two beds of carbonaceous shale that contained small flakes of coal.

With Doctor Ladd, the writer examined these workings in 1929 but found no additional data. The dumps were badly weathered, and the scattered lumps of coal were thoroughly decomposed. The local rocks strike N.40° E., and dip south at an angle of about 35 degrees. The small show of coal does not justify any attempt at development.

Misguided attempts to dig coal out of the black "Romney" shales of Craig Creek and James River valleys should be discouraged, for no coal-bearing rocks occur in that vicinity. Indeed, no workable coal seams occur in the Natural Bridge region, nor in its immediate vicinity.

There are no geologic indications that the search for petroleum will be successful. To discourage the search for oil in this region is a sound recommendation.

Miscellaneous Non-metallic Materials

Ocher

Ordinarily, commercial ocher is hematite or limonite in earthy form, more or less admixed with clay. Natural ochers are commonly red or yellow, depending upon their iron content and the amount of clay present. Most ochers are developed in residual clays underlying or adjacent to beds rich in iron. Although ocherous clays are associated with the deposits of limonite in this area, no commercially valuable ocher was observed. It is reported that yellow ocher was once dug from pits along the east base of Boyd Mountain, south of Buchanan. It also occurs on the outcrop of Shady dolomite near the junction of James and North rivers, and at Paint Bank, in Craig County.

Travertine

Streams that flow over calcareous rocks tend to become loaded with lime carbonate that may be deposited in frothy masses of travertine along their channels. Such deposits attract local attention as possible sources of lime, and are locally known as "marl". Travertine is common in streams west of Buchanan and Springwood. A fine display also occurs in the channel of Cascade Creek near Natural Bridge, and in the channel of Lapsley Run, 4 miles south of Eagle Rock. The deposits are extremely local and are of no economic value. An analysis of local travertine is reported by Ellett and Eskridge as follows:

Analysis of travertine,
Rockbridge County,
Virginia

CaO	47.87
MgO	3.24
K_2O	0.31
P_2O_2	0.80
Insoluble residue	4.34

1. [illegible] Virginia marls: Virginia Agr. Exper. Station, Bull. 6, (n. ser.), pp. 65-70, 1897.

Construction Materials

Ample supplies of sand and gravel can be readily obtained from streams and flood plains to meet all local needs. The area also contains an abundance of stone that is available for all types of rough construction work. The massive "Cambro-Ordovician" limestones and resistant Silurian sandstones afford excellent material for local use in foundations, rough masonry, and for road metal.

One mile east of Fincastle, a small quarry was formerly opened in Nittany dolomite to supply black limestone, or "marble", for interior decoration. Although the stone is of good quality and takes a fine polish, it can not be quarried in blocks sufficiently large for commercial use, for the rock is highly seamed and fractured. Some beds of the Nittany or

Conococheague formations contain stone that could be trimmed for local building purposes.

Extensive underground mines have been worked in Helderberg limestones, midway between the Rich Patch and Lowmoor mining camps on Carne Creek. (See Pl. 64, A.) The stone was mined for use as flux in the Lowmoor Furnace. Although the quarries were closed in 1924, a considerable supply of stone suitable for furnace use is still available. The quarries were developed near stream level in the lower Becraft limestone; upper Becraft beds form the hanging wall. The rock dips gently to the northwest, and was followed for some distance down dip.

A number of small quarries for road metal have been in temporary operation in the Valley lowlands. The rocks quarried are the Elbrook, Conococheague, and Nittany formations, which have supplied much of the stone for local roads. The more permanent quarries at Rocky Point, Indianrock, and Eagle Rock also supply stone (Holston and Lenoir limestone) for road surfacing. A large quarry, formerly operated by E. Dillon is located on the north bank of James River, 1 mile downstream from the mouth of Bearwallow Creek. The quarry furnished Shady dolomite for road metal and for iron flux. A small quarry in Shady dolomite was formerly operated along Laurel Run, one-quarter mile north of the Pico mining camp. (See Pl. 63, B.) It has been abandoned since 1923.

It is possible that certain of the pre-Cambrian granitoid rocks might be utilized for building purposes. Some of these, especially the red varieties of the Marshall granite, are even-textured, massive, and free from abundant joints. Except for the factor of inaccessibility, the pre-Cambrian crystalline rocks represent a good supply of stone that could be polished and used as a trim for local buildings. The pinker phases of the Holston limestone might be used as a marble for decorative purposes.

Although several slate quarries have been opened near the base of the Unicoi formation a short distance east of Snowden on James River, No slate deposits are known to occur within the area of this report.

Minor Economic Products

Saltpetre was formerly dug from a small opening at Saltpetre Cave near James River, and, it is reported, was used in the manufacture of gunpowder. Small amounts of onyx have been extracted from the same cave, but neither material occurs in sufficient quantity to attract commercial attention. A small cave along Cedar Creek near Natural Bridge also furnished local supplies of saltpetre. Barite, or barium sulphate, has been reported from several farms in this area. Barite is a very heavy, glistening white mineral containing the element barium, which is used in sugar refining and in paint manufacture. Elsewhere in Virginia, it occurs in deposits of economic importance, but no important occurrences are known in this area. It is reported to be present 2 miles north of Buchanan, near Buffalo Mills, and near Lexington.

SUMMARY OF MINERAL RESOURCES

Although deposits of iron and manganese ore occur within this area, they are of such character that profitable extraction is impossible at the present time. As they may offer opportunity for future mining operations, they may be considered a valuable mineral reserve. Non-metallic materials, chiefly lime and clay, are present in abundance, and lime quarrying is the most important mineral industry of the region. Additional development of lime and clay resources might well be attempted, but no other minerals of economic importance are known to occur in workable quantities.

It is probable that future mining and quarrying operations will be largely concerned with the mineral resources described in this report. It is possible, of course, that additional minerals may be found, or that new uses may create a demand for materials of little present value. It is to be hoped that opportunity for further development will be provided by improvements in methods of mineral proparation, through extension of transportation facilities, and by the normal increase in market demands, so that more of the local deposits may be brought into the field of practical operation.

WATER RESOURCES

SURFACE WATER

The average annual rainfall of the Natural Bridge region, which is about 40 inches, is usually so uniformly distributed that surface water is available for all needs, including potable or domestic water, water for stock, and water for industrial establishments that require larger quantities for steam and other uses.

James River is the largest stream in the area. Its chief local tributaries are Craig, Catawba, Looney (Mill), Purgatory, Cedar, and Jennings creeks. It enters the area at an elevation of about 990 feet above tide, and leaves the area at an elevation of about 740 feet. Its total fall is 250 feet in a distance of about 40 miles, or an average fall of $5\frac{3}{4}$ feet per mile. It is not available for navigation, although before the coming of the railroad, it was opened to Buchanan which was then the head of river navigation. Locks, now in ruins, give evidence of considerable effort to improve the navigation of the river. One occurs $\frac{1}{2}$ mile below Indianrock, another about 2 miles east of (below) Rocky Point. Heavy masonry near Lyle Tunnel and at Compton (All P.O.) was formerly part of the improvement of river navigation.

The following analysis of water from James River is the average of 36 separate analyses, taken tri-monthly between April 1, 1929 and March 31, 1930 at Buchanan.[1] Five analyses were made by S. K. Love; thirty-one were made by K. T. Williams.

Analysis of water from James River at Buchanan, Virginia

	Parts per million
Suspended matter	36
Total dissolved solids	145
SiO_2	7.9
Fe	0.10
Ca	28.0
Mg	6.1
Na	5.7
K	1.3
HCO_3	96.0
SO_4	22.0
Cl	4.4
NO_3	0.13
$CaCO_3$	95.0
Oxygen consumed	
Unfiltered	20
Filtered	18
Color [a]	45

a. United States Geological Survey standard measurement of turbitidy and color.

1. Collins, W. D., and others, Chemical character of surface waters of Virginia, preliminary report: Virginia State Division of Water Resources and Power, Bull. 2, table 7, p. 22, 1930.

Tri-monthly analyses of water from Craig Creek were taken during the same period at Parr.[1] The average of 36 analyses is as follows:

Analysis of water from Craig Creek at Parr, Virginia
(T. Judson, E. W. Lohr, and others, analysts)

	Parts per million
Suspended matter	7.0
Total dissolved solids	53.0
SiO_2	7.4
Fe	0.07
Ca	12.0
Mg	2.8
Na	1.5
K	0.9
HCO_3	45.0
SO_4	5.7
Cl	0.9
NO_3	0.18
$CaCO_3$	41.0
Oxygen consumed	
Unfiltered	1.1
Filtered	1.1
Color [a]	8

a. United States Geological Survey standard measurement of turbidity and color.

1. Collins, W. D., and others, op. cit., pp. 28-9.

For the year ending September 30, 1933, the mean monthly discharge of James River was 2,030 second-feet at Lick Run and 3,080 second-feet at Buchanan.[2] The run-off for that period was 20.13 inches at Buchanan,

2. Grover, N. C., and others, Surface water supply of the United States, 1933, part 2, South Atlantic slope: U. S. Geol. Survey Water-supply Paper 742, pp. 13-14, 1935.

computed on the basis of a drainage area of 2,080 square miles. Prior to September 30, 1927, the mean monthly discharge of the river at Buchanan reached a maximum of 3,800 second-feet during the twelve months from October, 1900, to September, 1901, when it averaged 1.83 second-feet per mile of drainage basin, with 24.81 inches of run-off. The mean monthly discharge reached a minimum of 1,600 second-feet during the twelve months from October, 1924, to September, 1925, when it averaged 0.769 second-feet per square mile of drainage basin, with 10.43 inches of run-off.[1]

1. Virzulaitis, J. J., and Stevens, G. C., Water resources of Virginia: Virginia Geol. Survey Bull. 31, pp. 145-175, 1927.

For the year ending September 30, 1933, the mean monthly discharge of Craig Creek was 466 second-feet at Parr, 7 miles northwest of Eagle Rock. The run-off for that period was 19.12 inches computed for a drainage basin of 331 square miles. During the year ending September 30, 1927, the maximum discharge of the creek was 9,090 second-feet on December 26; the minimum discharge for the same period was 48 second-feet. The mean discharge of Catawba Creek at Fincastle for the year ending September 30, 1933, was 141 second-feet, computed for its drainage basin of 104 square miles.[1]

1. Grover, N. C., and others, op. cit., pp. 26-29.

After a long period of steady rains, many of the creeks rise rapidly, overflowing their banks. Floods of Looney Creek occasionally obstruct traffic along United States Highway 11. Two such floods, in August, 1928, in August 1931, occured during the field work of this report. James River occasionally rises to the level of the bridge at Buchanan and, in 1901, 1913, 1933, and 1936, seriously flooded the village of Buchanan.

Relatively slight use has been made of surface water in this region. The water of James River has been polluted with waste material from pulp mills near Covington, which has rendered it totally unfit for any domestic use. It is regrettable that pollution of so important a stream as James River was ever permitted.

A small reservoir has been impounded along the headwater of Moore Creek to supply water for the city of Lexington. A short earth dam was built across the creek opposite the north end of Brushy Mountain and almost exactly upon the northern edge of the Natural Bridge topographic quadrangle. A reservoir several acres in area was formed at an elevation of about 1,800 feet above sealevel; its water is transported to Lexington by pipe-line. A small power dam is located on Cedar Creek, 1 mile below Natural Bridge. (See Pl.65,A.)

A small dam, to impound water for power, could be placed across Cedar Creek at the point where it breaks through the Silurian sandstones at the rim of Short Hills. The creek gorge is extremely narrow, and massive sandstone ledges jut almost across it. It would be possible to impound a small body of water with a fall of considerable height. Such a project would be suitable for the development of electricity for local use and could be undertaken at comparatively small expense.

GROUND WATER

In any region of wide limestone outcrop, underground drainage plays an important part in distributing the rainfall. Sinks and caves (Pl.65,B) in this area give proof of abundant underground drainage that finds its way through crevices and fissures in limestones and dolomites and represents surface water that has percolated downward through soluble rocks. Many springs emerge within the area, especially along the floor and margins of the Valley lowland; the majority of them emerge from "Cambro-Ordovician limestones.

The chemical character of spring water varies according to the character of the rock through which it has traveled. All local spring water is lightly mineralized but is comparatively free from suspended matter. It is generally clear and has an average surface temperature of 52°F. It contains abundant carbonate, but has little iron and only

slight quantities of sulphate and chloride. The following analysis is an average of 25 separate analyses of water from local springs.

Average analyses of spring water in the Natural Bridge area.

(Margaret D. Foster, analyst)

Temperature. . . . . 52.6°F.

Proximate analysis . . . . . .(Parts per million)

Dissolved solids.	170
Fe.	. .
Ca.	46
Na.	8
HCO_3.	164
SO_4	6
Cl.	0.8
NO_3	3.7
$CaCO_3$	146

---

1. Collins, W. D., and others; op. cit., pp. 33-5, 40-41.

Karnes spring is located near the Holston-Lenoir contact, about 6½ miles north of Buchanan. It emerges from a low bank, and its flow is carried by Purgatory Creek. Two large springs are located along South Fork of Buffalo Creek near Rapps Mill, where they emerge from an outcrop of Canadian dolomite. Black spring is located about 1.2 miles northeast of Rapps Mill; Ayers spring is located about 4 miles northeast of Rapps Mill. Three large springs which emerge in Arnold Valley and empty into Elk Creek, flow from the Shady dolomite. A large spring occurs near the base of a small hill 1½ miles west of Murat. The spring emerges from Athens shale, and its water is used to nourish a large patch of watercress. Blue spring, located at the southwestern end of Rich Patch valley, is a large spring that emerges from Lowville limestone at the head of Blue Spring Creek. Fridley spring, which is located ~~one-quarter~~ 1/4 mile above Hooks Mill, is the source of Roaring Run.

Table 15 shows the discharge, temperature, and chemical character of water from important local springs.

Daggers mineral springs (formerly called Dibbrells Spring) are located in the valley of Mill Creek 4 miles northeast of Eagle Rock and 3 miles east of Gala. The springs emerge in "Romney" shale near its contact with the Brallier. The temperature of the water is variable, ranging from 50 to 80 degrees. The water, which is strongly sulphurated, was formerly bottled for commercial distribution, and the locality was once advertised as a health resort. Its chemical composition was reported by Rogers[1] in 1884 as follows:

Analysis of water from Daggers Spring (Parts per 100)

	1.
Sodium carbonate	2.486 grains
Sodium sulphate	0.914
Sodium chloride	4.115
Potassium chloride	trace
Calcium carbonate	3.485
Magnesium carbonate	0.875
Iron peroxide	0.430
Silica	0.570
Organic matter	2.000
Ammonium carbonate	trace

1. Rogers, W. B., Geology of the Virginias, p. 561, New York, D. Appleton and Co., 1884.

A small sulphur spring occurs on the northwest flank of Price Mountain, along the road from Fincastle to Craig Creek Post Office; another emerges from Athens shales, 1 mile northeast of Fincastle. It is reported that J. D. Campbell discovered several small mineral springs near Smith Flats.

Good supplies of drinking water for domestic and farm use are ordinarily obtainable from wells commonly less than 50 feet in depth. It is probable that greater quantities of water can be obtained from deeper wells drilled near, or along, fracture zones within the valley limestones. The water supply of Buchanan is derived from springs and surface drainage in Bearwallow Creek immediately south of the town. Eagle Rock is supplied with water from a spring at the foot of Rathole Mountain.

GEOLOGY AND MINERAL RESOURCES OF THE NATURAL BRIDGE REGION, VIRGINIA

(Eagle Rock and Natural Bridge Quadrangles)

by

Herbert P. Woodward

Plates and Figures

Tables

1936
Newark, New Jersey

VIRGINIA DIVISION OF MINERAL RESOURCES LIBRARY

ILLUSTRATIONS

PLATE		Near manuscript page
1.	Geologic map of the Natural Bridge region	In pocket
2.	Geologic structure sections of the Natural Bridge region	In pocket
3.	Natural Bridge, viewed from the south	Frontispiece
4.		
5.	A, Village of Buchanan, viewed from the flank of Purgatory Mountain; B, Village of Eagle Rock, viewed from the eastern pinnacle of Crawford Mountain	19
6.	A, The blunt southwestern end of Short Hills; B, Short Hills, viewed southward from the crest of North Mountain	20
7.	Pinnacle and the Pinnacle Valley. View looking north	20
8.	A, Apple Orchard Mountain; B, The crest and summit of Rich Patch Mountain	21
9.	A, Subsoil pinnacles of Nittany dolomite produced by unequal decomposition and exposed by removal of residual soil; B, Gullied outcrop of Conococheague limestone near Midway School	25
10.	A, Irregular foothills of Rich Patch Mountain; B, Headwaters of Sloan Branch in the heart of the James River range east of Eagle Rock	28
11.	A, Floodplain of James River, south of Purgatory Mountain; B, Floodplain of James River, north of Eagle Rock	29
12.	A, Mining camp of Lignite; B, View of Bethole Mountain looking northeast along new concrete bridge over James River	29
13.	A, Symmetrical cone-like end of Purgatory Mountain; B, Montgomery Knob	33
14.	A, Gorge of James River through the Blue Ridge above Balcony Falls; B, Entrance of James River into its gorge above Balcony Falls	35
15.	Panoramic view looking northeastward up James River valley	38
16.	A, Upland peneplane on Rich Patch Mountain; B, Level crest of Pine Mountain southeast of Indianrock	39
17.	A, Rolling Valley-floor peneplane west of Buchanan; B, Level surface of the Valley-floor peneplane near Bessemer	42
18.	A, The Knob, north of Buchanan; B, Northern end of Short Hills	45
19.	A, Lace Falls of Cedar Creek, above Natural Bridge; B, Cedar Creek, viewed southward from the arch of Natural Bridge	51
20.	Arch of Natural Bridge, viewed from the north	52
21.	A, Entrance to "Lost River", in the gorge of Cedar Creek, above Natural Bridge; B, Cascade Creek, near its discordant junction with Cedar Creek, immediately below Natural Bridge	59
22.	August view of Natural Bridge, looking northward from Pine Ladon	62
23.	April view of Natural Bridge, looking northward from Pine Ladon	62
24.	A, Watergap of James River at Eagle Rock; B, Rocky face of Bethole Mountain and the Eagle Rock Gap of James River	68
25.	A, "The Gorge"; B, View of the Gorge looking northwestward	73
26.	A, Confluence of James River and Craig Creek floodplains; B, Fertile James River floodplain above Eagle Rock	77
27.	A, Coarse conglomerate at the base of the Unicoi formation; B, Contact of the Hampton shale and the Unicoi sandstones	85

(Page)

28. A, Contact of Erwin quartzite and Hampton shale; B, Prominent jointing in the Erwin quartzite ——— 96
29. A, Folded members of the Erwin quartzite; B, Massive Shady dolomite near the Pico camp ——— 99
30. A, Sharp-crested Blue Ridge foothills of Erwin quartzite east of Glasgow; B, Rounded hills on the Rome ("Watauga") outcrop southwest of Buchanan ——— 102
31. A, Sharp hogback ledges of Rome ("Watauga") shale east of Buchanan; B, Knobby Elbrook limestone along Lee Highway — 104
32. A, Contact of dolomite and limestone in the Conococheague formation; B, Irregular calcite veins in the Conocoocheague formation ——— 109
33. A, Cryptozoa in the Conococheague formation northeast of Buchanan; B, Sandstone lense in the Conococheague formation ——— 111
34. A, Canadian (Nittany) dolomite along Lee Highway; B, Lower Stones River limestone in Rich Patch valley ——— 114
35. A, Chert on exposure of the Lower Stones River limestone, Rich Patch valley; B, Residual chert in weathered soil of the Nittany dolomite, Rich Patch valley ——— 121
36. A, Horizontal surface of Lenoir limestone showing laminated character and structural unconformity; B, Gently folded shaly limestone at base of Athens shale near Dunkard Church 125
37. A, Jointed black Athens limestone; B, Pebbly conglomerate in Athens shale ——— 135
38. A, Knobby phase of Chambersburg limestone south of Collierstown; B, Reticulated surface of Chambersburg limestone north of Oakdale ——— 141
39. A, Green Hill; B, House Mountains, west of Lexington ——— 142
40. A, Shaly phase of the Martinsburg formation in Rich Patch valley; B, Towers of lichen-covered Clinch sandstone on Bathole Mountain ——— 144
41. A, Heartsblood, between Panther and Camp mountains; B, Gorge of Back Creek through Rich Hill ——— 154
42. A, Purplish shale and shaly sandstone of the Juniata formation in Hays Gap; B, Massive red Oscapon sandstone near Hooks Mill ——— 155
43. A, Ledges of Keefer sandstone along Roaring Run; B, Massive beds of Keefer sandstone in the Eagle Rock Gap ——— 158
44. A, High quarry face of Tonoloway limestone at Prices Bluff; B, Contact of Healing Springs sandstone and Coeymans limestone at Prices Bluff ——— 160
45. A, Oriskany sandstone at Prices Bluff; B, Mural cliff of Brallier shale along Potts Creek ——— 172
46. A, Stratified high-level gravels of James River above Buchanan; B, Contact between peridiotite stock and Ordovician limestone southwest of Oakdale ——— 187
47. A, Quaternary deposits of travertine along Lapsley Run; B, Solution channels and cave deposits along Cedar Creek below Red Mills ——— 188

(Page)

48. A, Gentle folds in Unicoi sandstones near Snowden; B, Closely contorted Tonoloway limestone, Eagle Rock Gap — 227
49. A, Gentle folds in Chambersburg limestones west of Collierstown; B, Anticlinal fold in the Shady dolomite below Buchanan — 228
50. A, Symmetrical anticline of Brallier shale along Craig Creek valley; B, The "Rainbow Arch" at Iron Gate — 231
51. Panoramic view of Rich Patch Mountain and its eastern line of foothills — 231
52. A, Sharp northern elbow of the Rainbow Arch at Iron Gate; B, Small folds in Brallier shale along Little Patterson Creek — 234
53. A, Remarkable folds within the Unicoi formation on Cove Mountain; B, Small vertical fault in the Conococheague formation northeast of Buchanan — 241
54. A, Quarry face along Lee Highway near Highbridge Church showing Elbrook limestone overthrust upon crumpled Athens shale; B, Small block of Elbrook limestone overthrust upon "Romney" shales — 244
55. A, Underground limestone mine at Eagle Rock, formerly operated by the Moore Lime Company; B, Knife-edge contact of Nittany dolomite above, and Holston limestone below, the plane of the Pulaski overthrust in the quarry shown above — 245
56. A, Face of cliff along James River opposite Eagle Rock showing the entrance to the underground limestone mine, or quarry; B, View within quarry figured above — 246
57. Panoramic view of the northeastern face of the Eagle Rock Gap; Bathole Mountain in foreground — 263
58. Panoramic view of the southwestern face of the Eagle Rock Gap; Crawford Mountain in foreground — 264
59. A, Abandoned stack of Glenwood furnace; B, Ruins of Retreat furnace — 304
60. A, Abandoned stack of the Roaring Run charcoal furnace; B, Ruins of the Catawba charcoal furnace — 305
61. A, Narrow Bank of the Alleghany Ore and Iron Company; B, "Big cut" at the Oriskany iron mine — 313
62. A, Virginia Iron, Coal, and Coke Company's quarry in Shady dolomite near Buchanan; B, Shady dolomite in above quarry — 331
63. A, Limestone quarry operations at Eagle Rock; B, Quarry operations southwest of Buchanan — 329
64. A, Inactive underground mine in the Becraft limestone west of Lowmoor; B, Inactive limestone mine in Holston limestone near Eagle Rock — 341
65. A, Small power dam on Cedar Creek below Natural Bridge; B, Large sink in Chambersburg limestone northeast of Collierstown — 348

FIGURE		Near manuscript page
1.	Index map showing the location of the Natural Bridge region, Virginia	5
2.	Generalized block diagram of the Natural Bridge region	19
3.	Ideal profile section across the Natural Bridge region showing erosion levels	38
4.	Sketch map of the Eagle Rock and Natural Bridge topographic quadrangles showing the distribution of various erosional surfaces	38
5.	Topographic map of the vicinity of Natural Bridge	48
6.	Sketch map of Cedar Creek	51
7.	Outcrop map of the vicinity of Natural Bridge	52
8.	Map showing present drainage near Natural Bridge	59
9.	Sketch map suggesting the course of drainage before the development of Natural Bridge	60
10.	Map showing topography near Natural Bridge and present relations of Cedar Creek, Cascade Creek, Broad Run, and Poague Run	62
11.	Progressive diagrams showing the development of a natural bridge or tunnel	64
12.	Progressive diagrams to suggest the production of a watergap by stream erosion upon a rising land	70
13.	Sketch illustrating the imminent capture by Rocky Run of the headwaters of Purgatory Creek	72
14.	Sketch showing the drainage changes at the southeastern end of North Mountain	73
15.	Sketch illustrating the diversion of North Fork of Buffalo Creek southeast of Oakdale	73
16.	Sketch indicating the imminent capture of Back Creek by tributaries of Milk Creek in Arnold Valley	73
17.	Diagrams to indicate the possible erosion of Sallings Mountain windgap by James River	74
18.	Sketch map showing Slash School marsh, 2½ miles southeast of Norton	77
19.	Generalized outcrop map of the Natural Bridge region	80
20.	Outcrop map of pre-Cambrian rocks	81
21.	Outcrop map of Cambrian rocks	83
22.	Outcrop map of Ozarkian and Canadian rocks	108
23.	Outcrop map of Ordovician rocks	120
24.	Outcrop map of Silurian rocks	152
25.	Outcrop map of Devonian rocks	162
26.	Outcrop map of Mississippian rocks	185
27.	Areal geologic map of the northern portion of the High Patch anticline and the region between Covington and Clifton Forge	231
28.	Cross section along James River at Iron Gate	234
29.	Cross section through Big Hill	236
30.	Cross section along railway cut at Prices Bluff	236
31.	Cross section through the Spreading Spring anticline	237
32.	Areal geologic map of the region near Pincastle	238
33.	West-east section through the abandoned Moore Lime Company quarry at Eagle Rock	244
34.	North-south section through the abandoned Moore Lime Company quarry at Eagle Rock	246
35.	Areal geologic map of the region between Collierstown, Lexington, and Buffalo Mills, Virginia	256

FIGURE		Near manuscript page
36.	Cross section of the southwestern wall of the Eagle Rock Gap	264
37.	Cross section of the northeastern wall of the Eagle Rock Gap	264
38.	Map showing location of the most important mines, quarries, prospects, and furnaces in the Natural Bridge area	291
39.	Generalized cross section showing the location of Oriskany brown iron-ore deposits	306
40.	Sketch map of the Big Hill iron mines	310
41.	Sketch map of the Oriskany and other mines adjacent to Lignite, Virginia	312

TABLES

		Near manuscript page
1.	Sedimentary bedrock formations of the Natural Bridge region	82
2.	Thickness and distribution of Paleozoic formations in the Natural Bridge region	82
3.	Analyses of Blue Ridge hematite, Bearwallow Creek, Botetourt County, Virginia	297 *
4.	Analyses of ore, Horse Mountain mine, Alleghany County, Virginia	302 *
5.	Analyses of Oriskany ore, Lowmoor mines, Alleghany County, Virginia	308 *
6.	Analyses of ore, Big Hill mines, Botetourt County, Virginia	310 *
7.	Analyses of ore, Oriskany mines, Botetourt and Craig counties, Virginia	315 *
8.	Analyses of Oriskany ore, Callie and Wilton mines, Botetourt County, Virginia	316 *
9.	Analyses of Oriskany ore, Retreat mines, Botetourt County, Virginia	317 *
10.	Analyses of Oriskany ore near Retreat Furnace, Botetourt County, Virginia	317 *
11.	Analyses of Oriskany ore, Purgatory Mountain, Botetourt County, Virginia	318 *
12.	Analyses of Ordovician limestones, Natural Bridge region, Virginia	328 *
13.	Analyses of Holston limestone, Eagle Rock, Virginia	330 *
14.	Analyses of Shady dolomite, Buchanan, Virginia	331 *
15.	Discharge, temperature, and analysis of spring water, Natural Bridge region	349

(* already typed in manuscript)

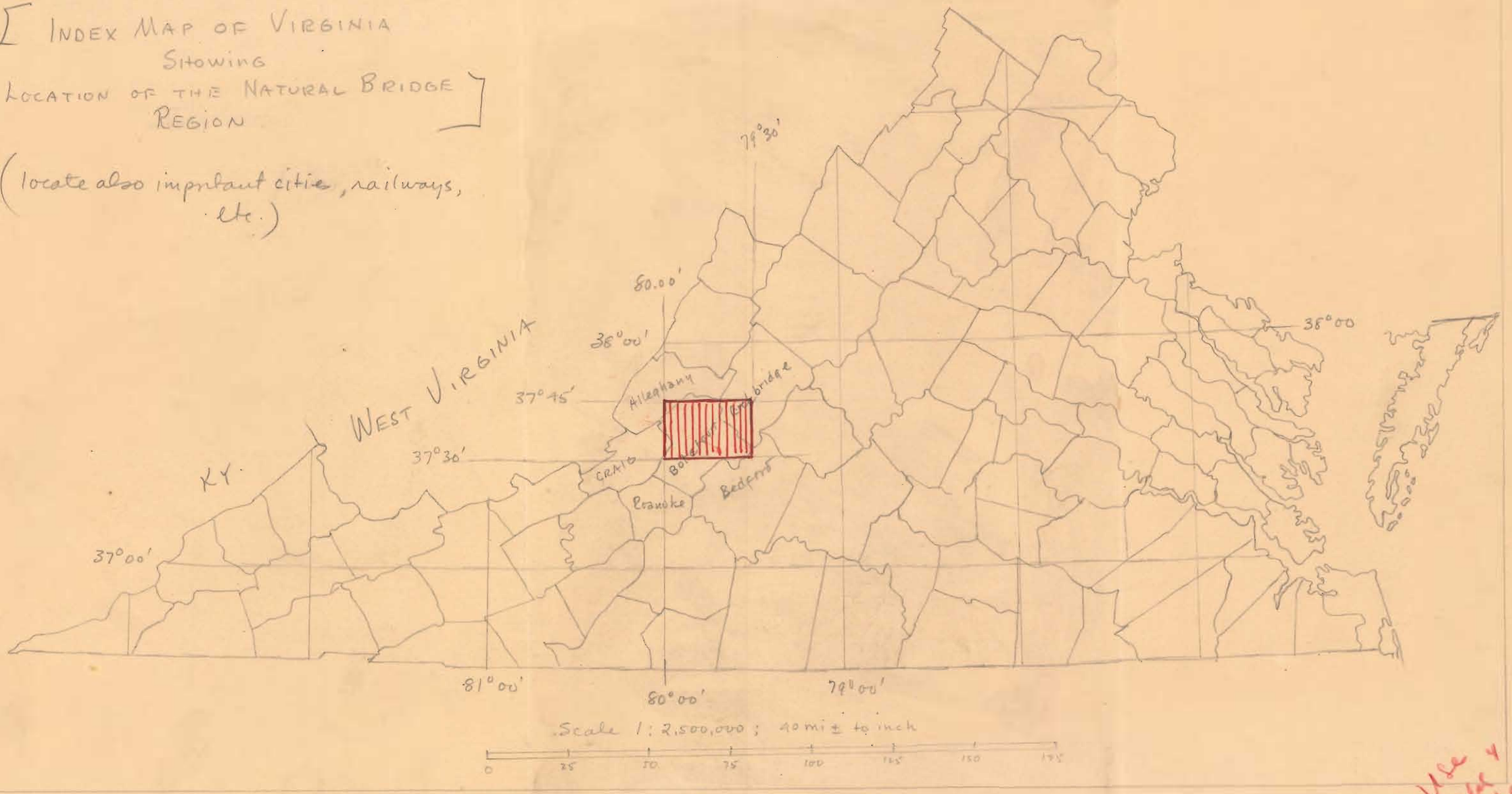


Figure 1. Index map showing the location of the Natural Bridge region.

(near mss. p. 5)

Use "Regular" index base map

Figure 2

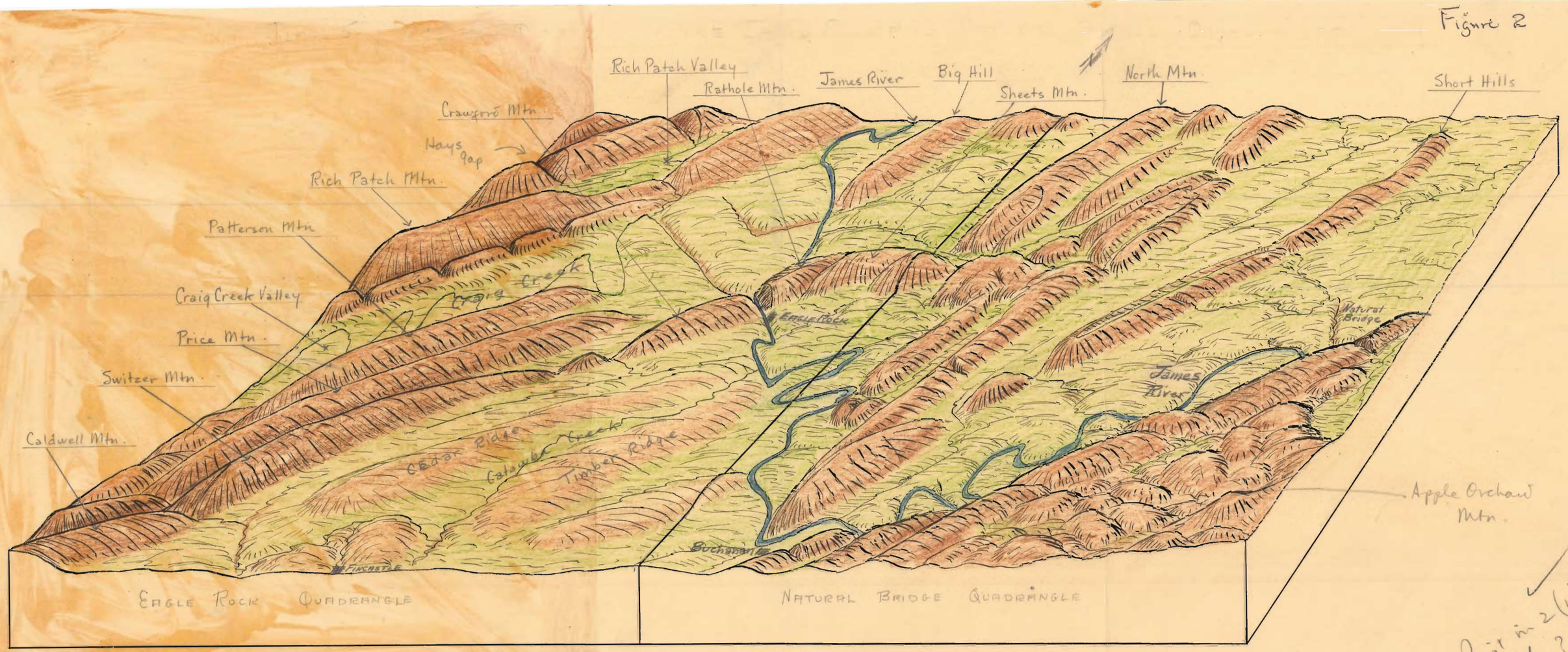


Figure 2. Generalized block diagram of the Natural Bridge region. (near mss page 19)

Print in 2(1) Colors?

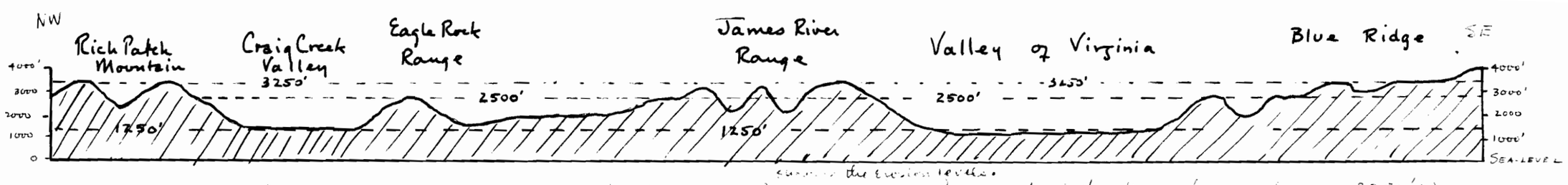


Figure 3. Ideal profile across the Natural Bridge region. Remnants of the Upland peneplane (3,250'±) are found on the crests of the Blue Ridge, James River range, and Rich Patch Mountain. The Valley-floor peneplane is preserved in the Valley of Virginia and in Craig Creek valley at elevations of [illegible] = 1,250'. The presence of intermediate levels (2,500') is suggested [illegible]

[illegible] p. 38.)

N
1300
1200
1100
1000
900
800
JAMES RIVER
MILES
0
1/4
1/2
SKETCH MAP OF THE
NATURAL BRIDGE AREA, VIRGINIA
CONTOUR INTERVAL - 20 FEET
Scale.
one mile

Figure 5.

Topographic map of the vicinity of Natural Bridge, redrawn from the U.S. Geological Survey topographic map. Contour interval 20 feet; scale 4 inches to the mile. (See pp. 48-53.)

(near mss p. 48)

Why use?

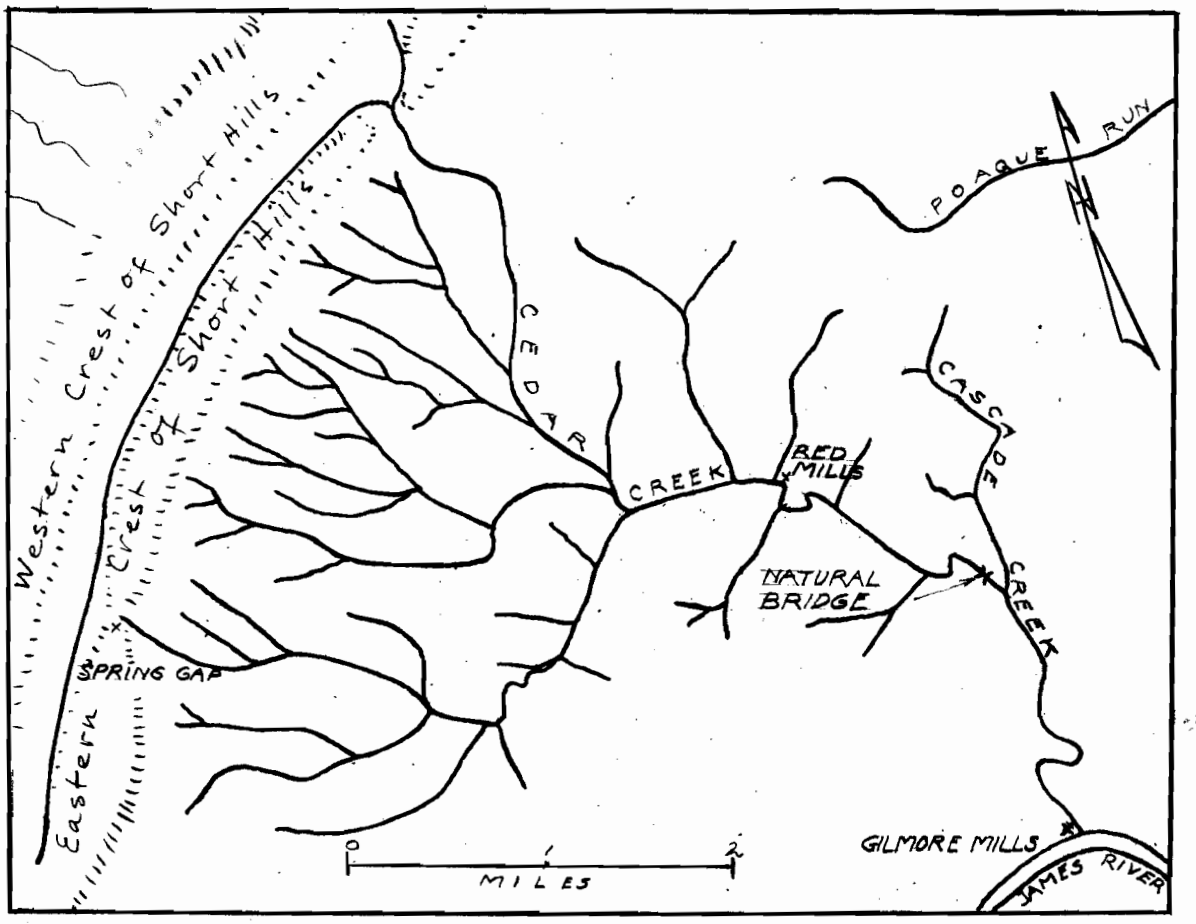


Figure 6. Sketch map of Cedar Creek showing location of Red Mills, Natural Bridge, and Gilmore Mills.

(near mss. p. 51)

?

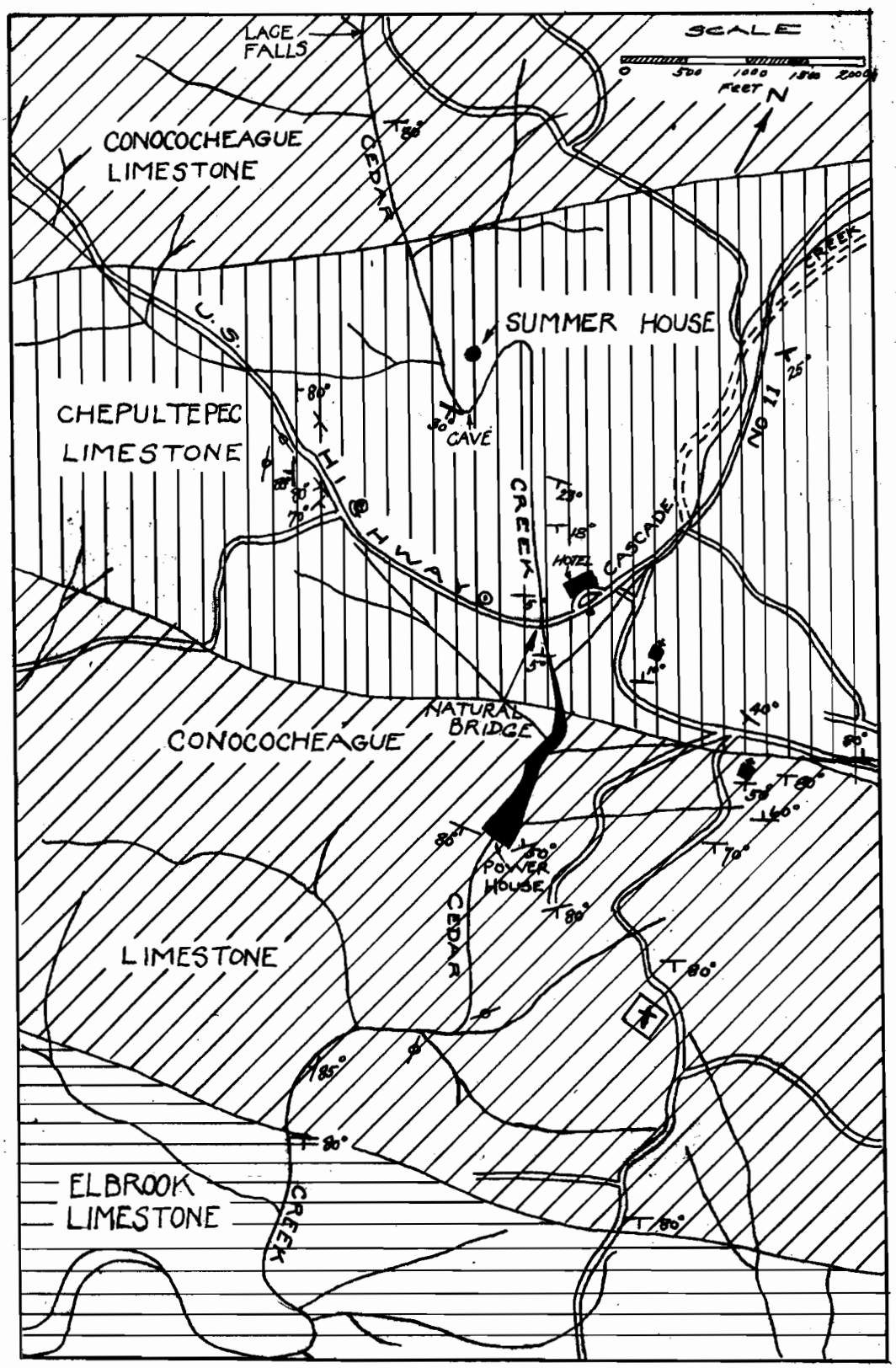

LACE FALLS
SCALE
0 500 1000 1500 2000
FEET
N
CONOCOCHEAGUE LIMESTONE
CEDAR CREEK
SUMMER HOUSE
U. S.
CHEPULTEPEC LIMESTONE
CAVE
HIGHWAY 11
CREEK
HOTEL
CASCADE
No 11
CREEK
NATURAL BRIDGE
CONOCOCHEAGUE
POWER HOUSE
CEDAR
LIMESTONE
ELBROOK LIMESTONE
CREEK

Figure 7.

Outcrop map of the vicinity of Natural Bridge. (See p. 52; compare with figure 5.)

(See map, p. 52.)

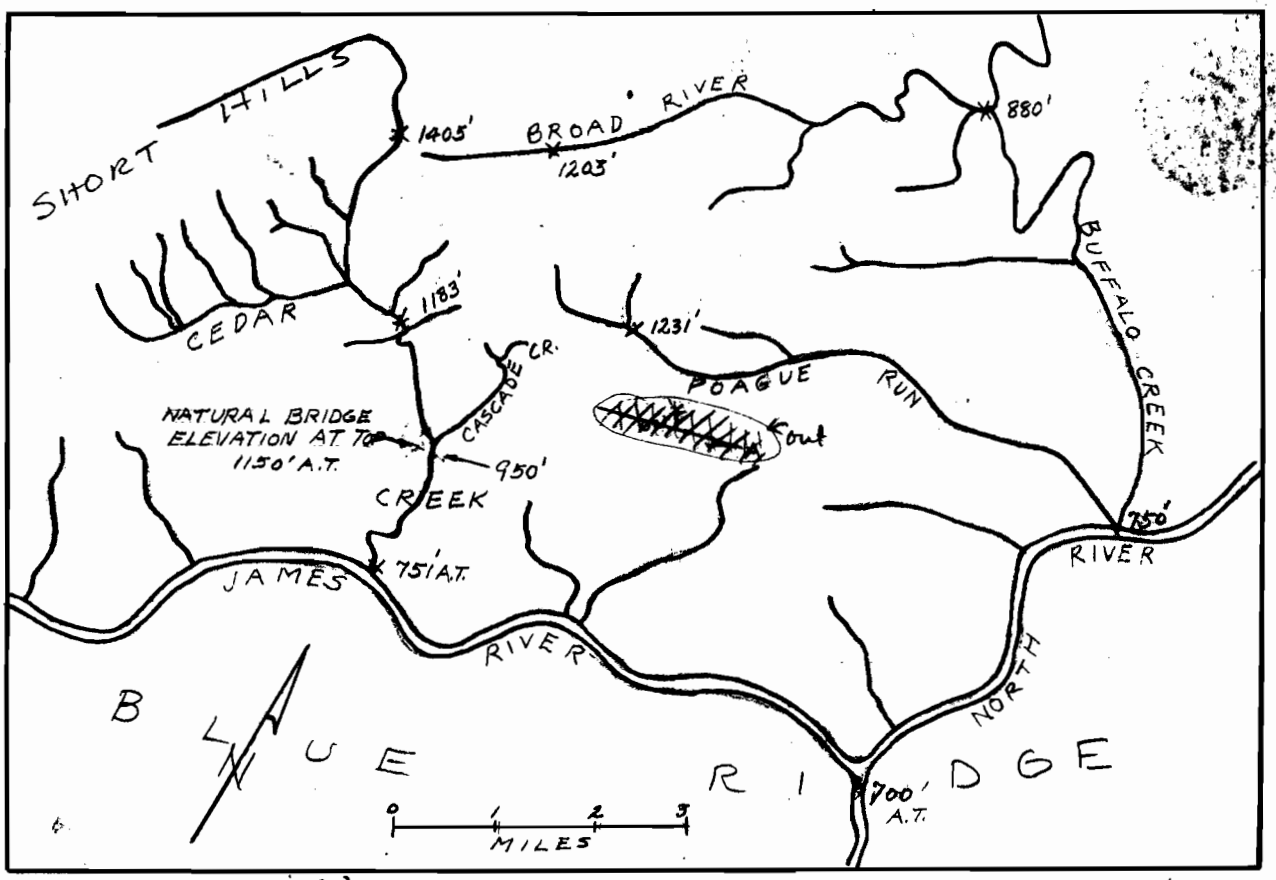


Figure 8 Map showing present drainage near Natural Bridge. (See p. 58-66; compare with figure 9.).

(near mss p. 59)

(near mss. p. 60)

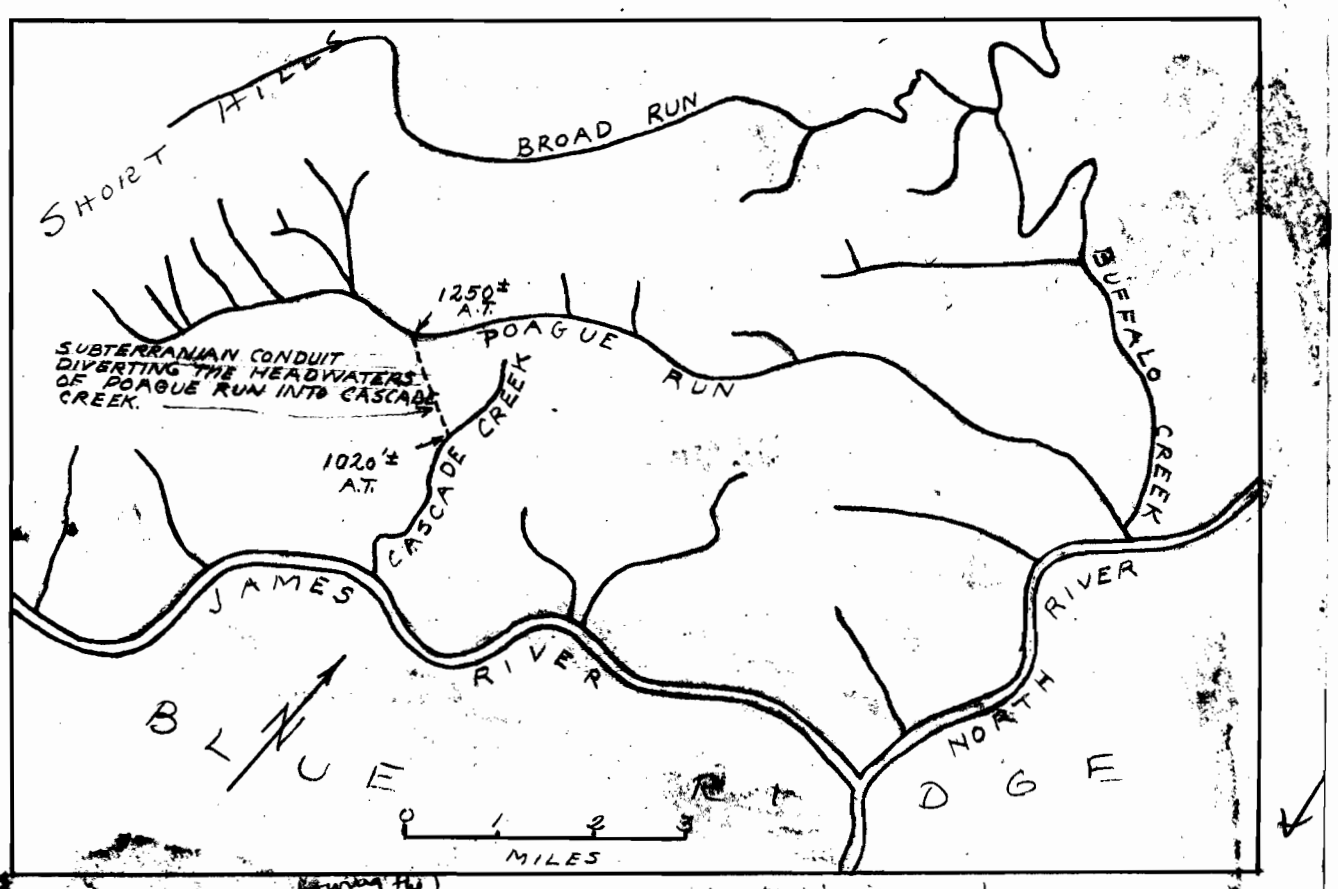
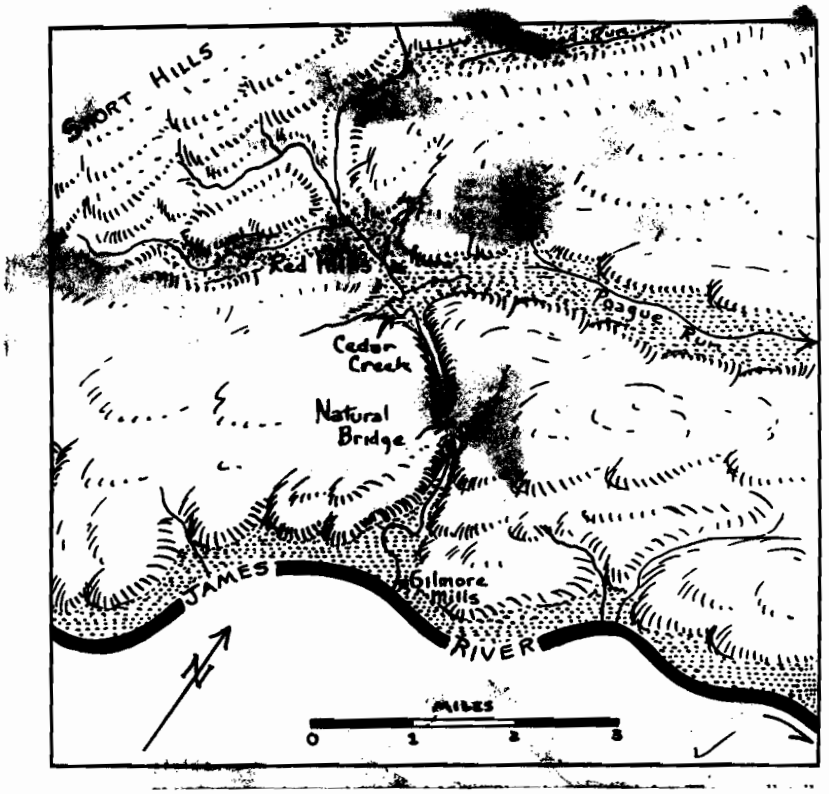
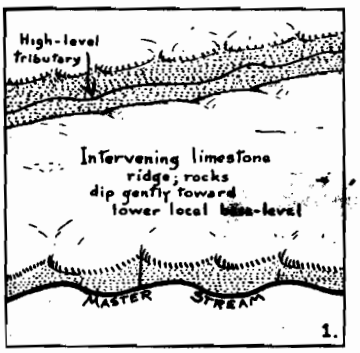
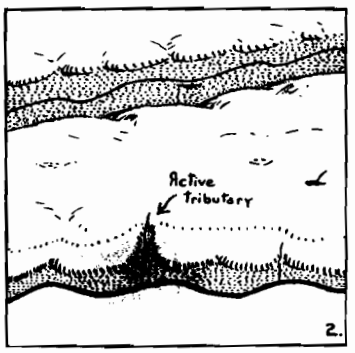
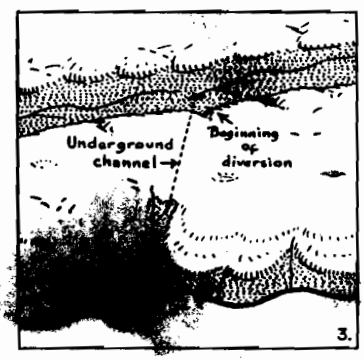


Figure 9. Map showing the suggested course of drainage before development of Natural Bridge. (Compare with figure 8.)


SHORT HILLS
Red Hills
Cedar Creek
Natural Bridge
Gilmore Mills
JAMES
RIVER
MILES
0 1 2 3


High-level tributary
Intervening limestone ridge; rocks dip gently toward lower local base-level
MASTER STREAM
1.


Active tributary
2.


Underground channel
Beginning of diversion
3.

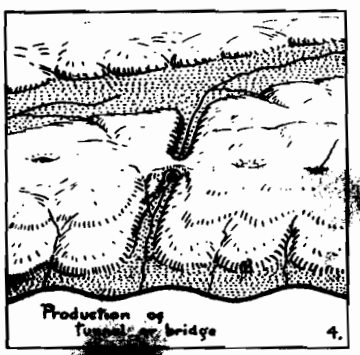
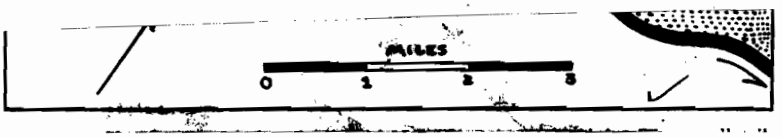

Production of tunnel or bridge
4.

Figure 10. (Redraw?) Cut out

Map showing topography near Natural Bridge and present relation between Cedar Creek, Cascade Creek, Broad Run, and Pogue Run. Cascade Creek joins Cedar Creek immediately below Natural Bridge. (near miss. p. 62.)



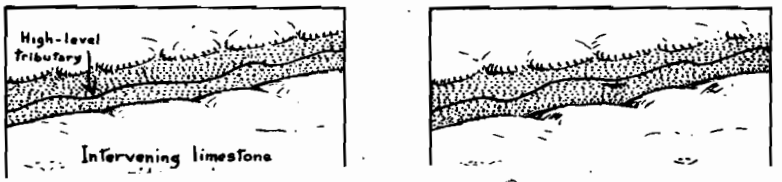
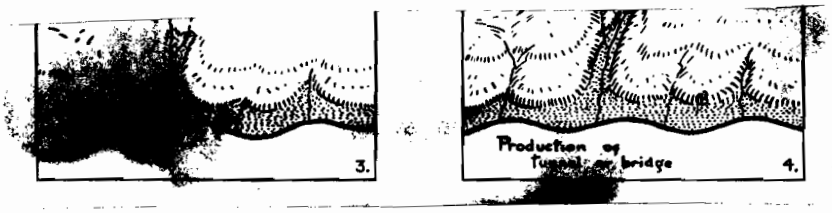
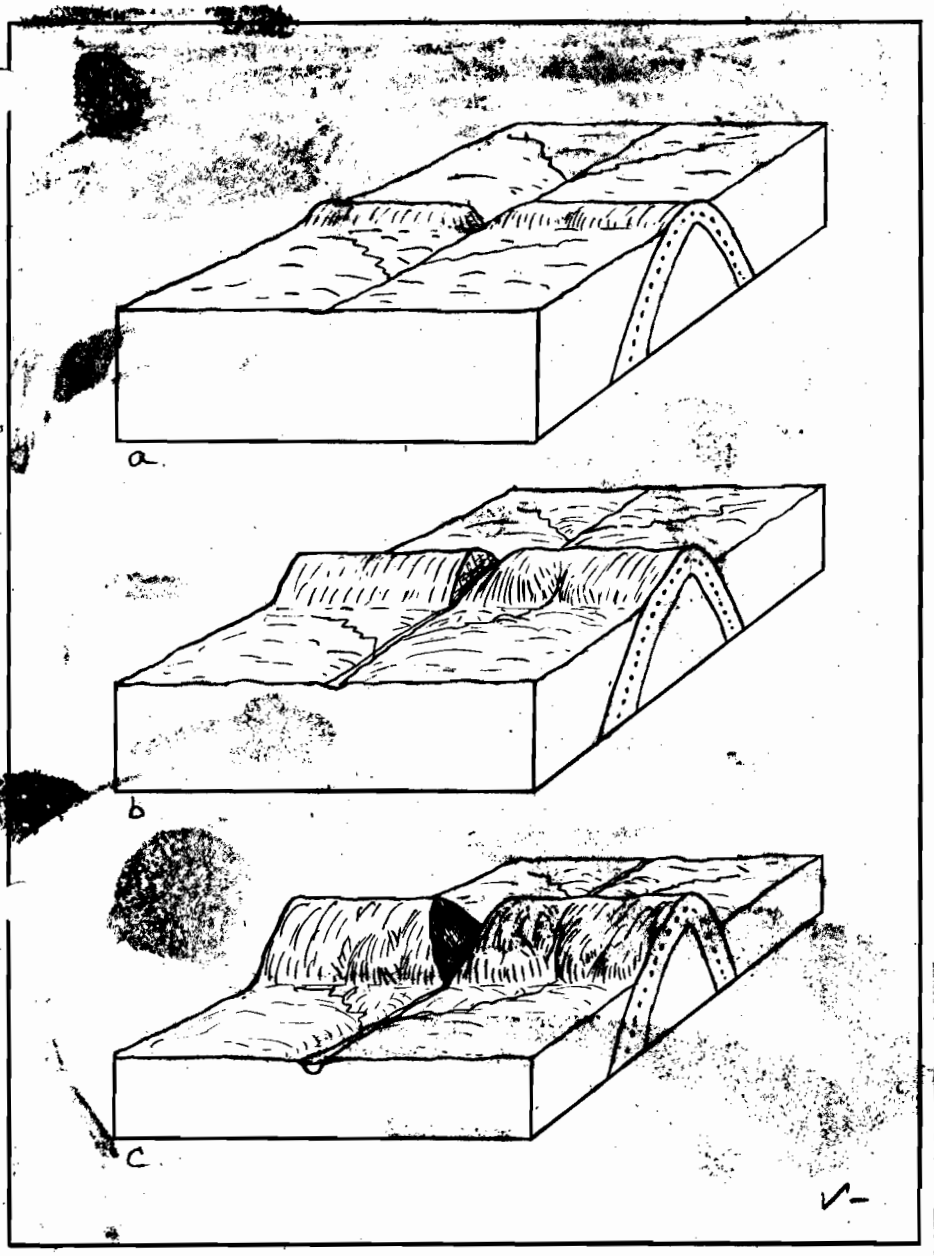


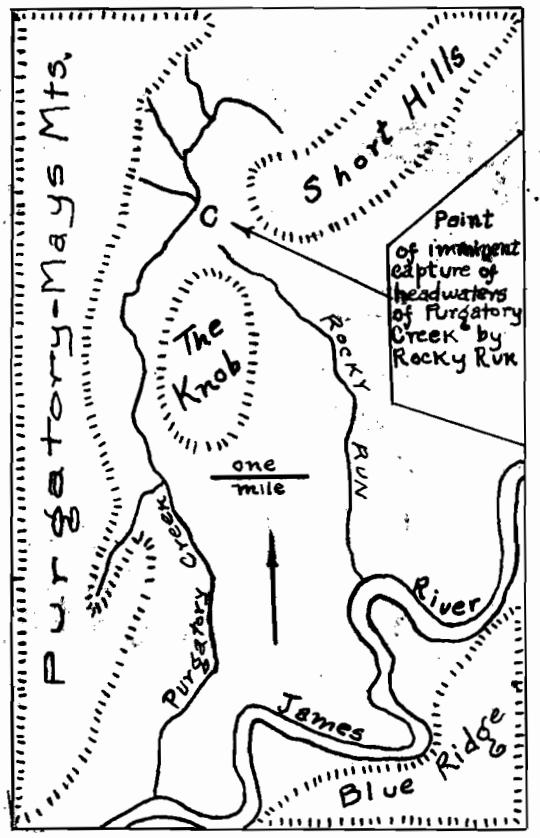
Figure 11 Redraw? Cut out

Progressive diagrams showing the development of a natural bridge or tunnel. (See p. 64.)

(near miss p. 64.)




a
b
c


Purgatory-Mays Mts.
Short Hills
C
Point of imminent capture of headwaters of Purgatory Creek by Rocky Run
The Knob
Rocky Run
one mile
Purgatory Creek
River
James
Blue Ridge

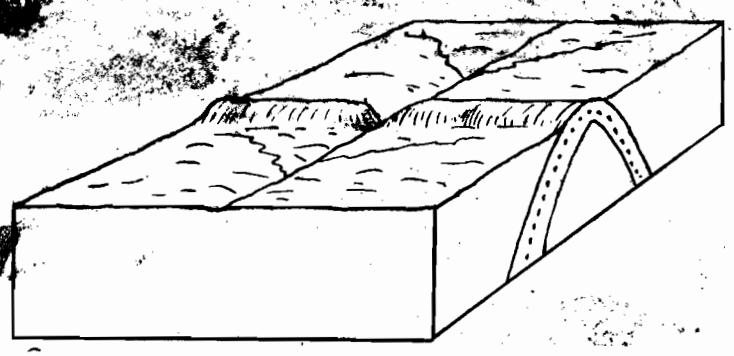
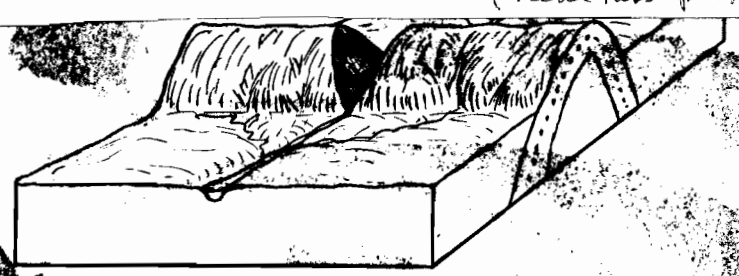


Figure 12.

Progressive diagrams to suggest the production of a water gap by stream erosion upon a rising land. Stages a, b, and c represent successive steps in the history of such a water gap as that of James River at Eagle Rock. At Eagle Rock, however, the rock structure is more complicated than represented in this diagram. (See pp. 69-70.)

(near mss p. 70.)



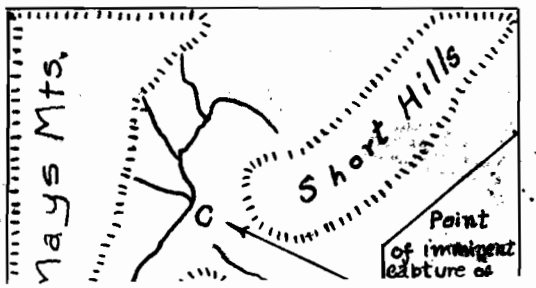
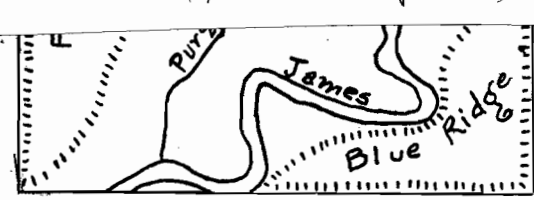


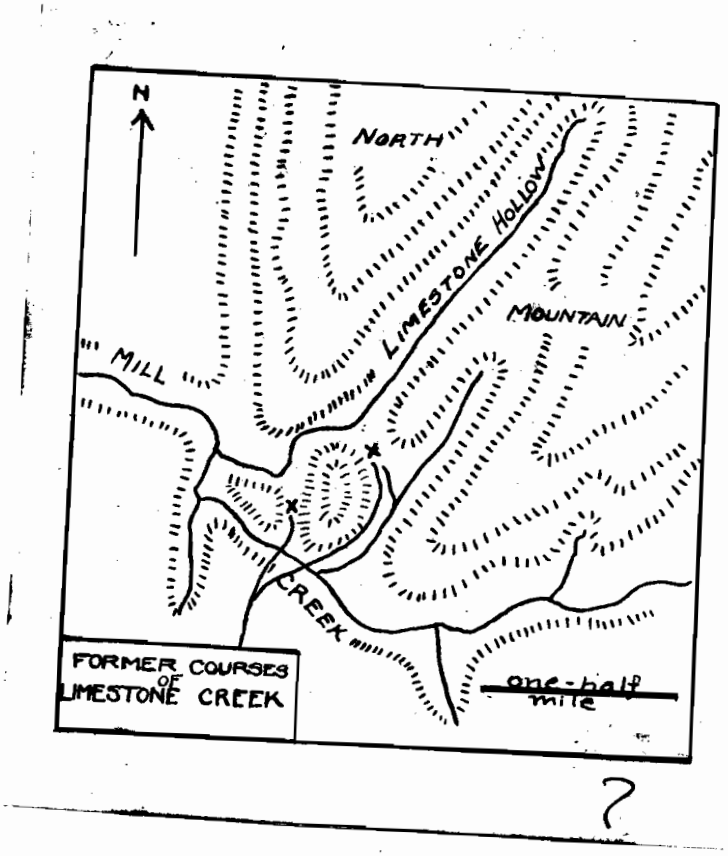
Figure 13.

Sketch illustrating the imminent capture by Rocky Run of the headwaters of Purgatory Creek. (See p. 72)

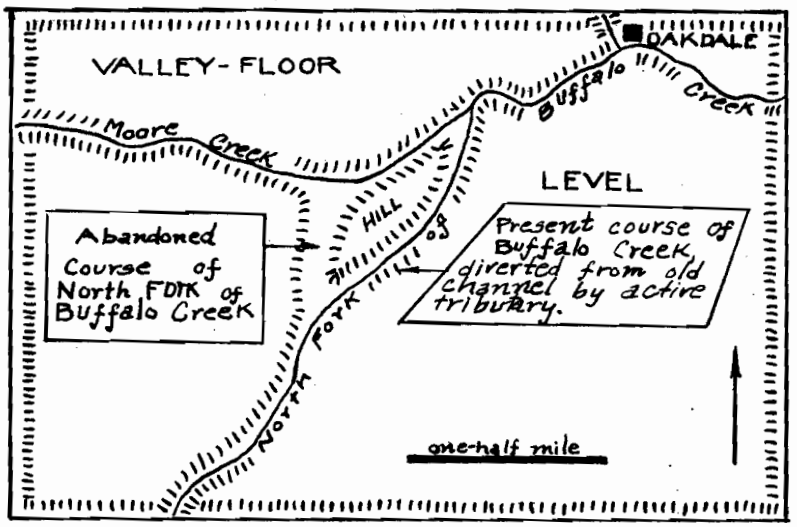
(near mss. p. 72)

Add illustration




N
NORTH
LIMESTONE HOLLOW
MOUNTAIN
MILL
CREEK
FORMER COURSES OF LIMESTONE CREEK
one-half mile

?


VALLEY-FLOOR
OAKDALE
Buffalo Creek
Moore Creek
LEVEL
HILL
Abandoned Course of North FORK of Buffalo Creek
Present course of Buffalo Creek, diverted from old channel by active tributary.
NORTH FORK
one-half mile

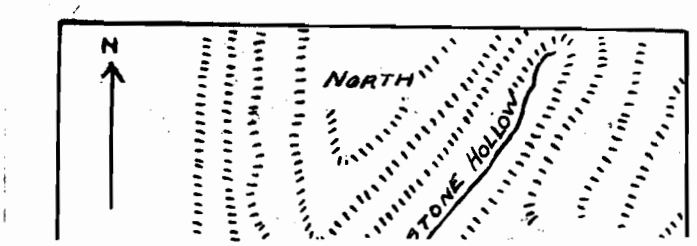
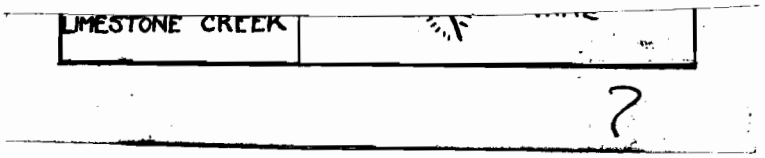


Figure 14. showing the drainage changes

Sketch at the southeastern end of North Mountain. At least two wind gaps, formed by the creek draining Limestone Hollow, are visible. (See p. 73.)

(near mss. p. 73.)



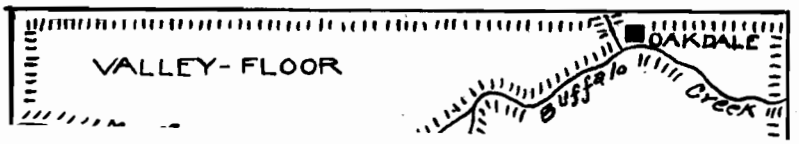
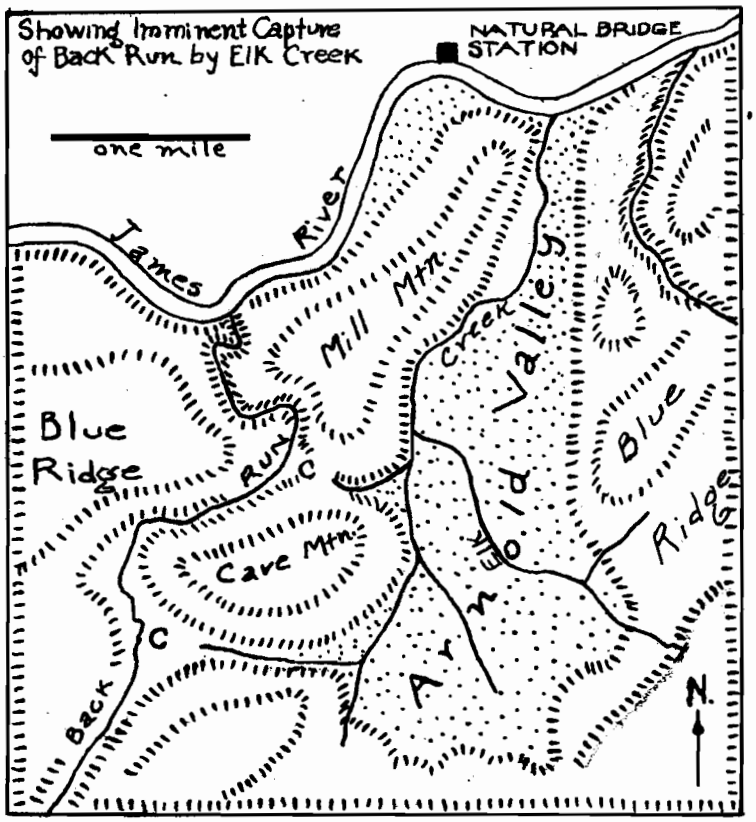


Figure 15:

Sketch illustrating the diversion of North Fork of Buffalo Creek southeast of Oakdale. (See p. 73.)

(near mss. p. 73



? Chose 1 diagram of Rocky Run

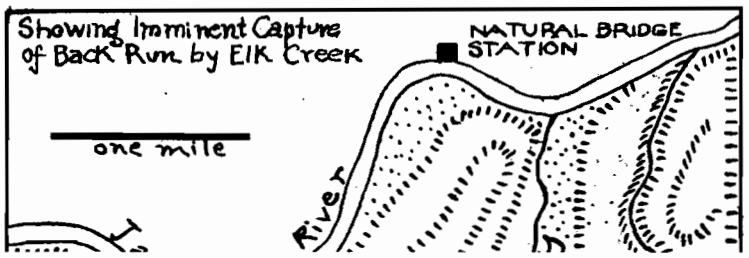
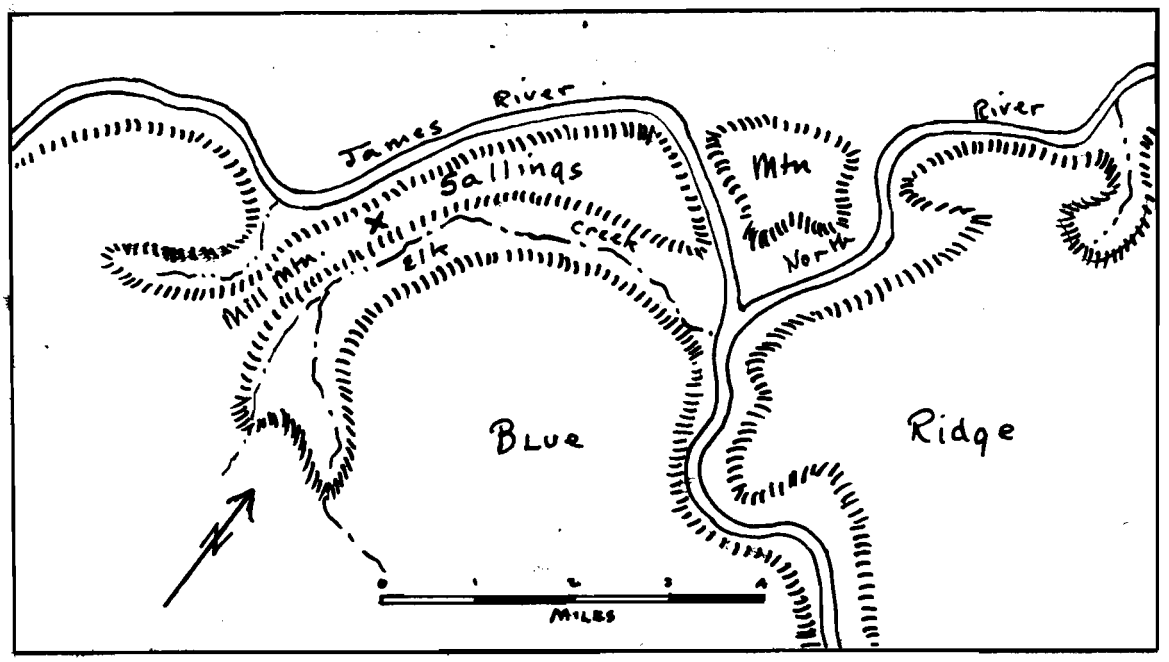


Figure 16

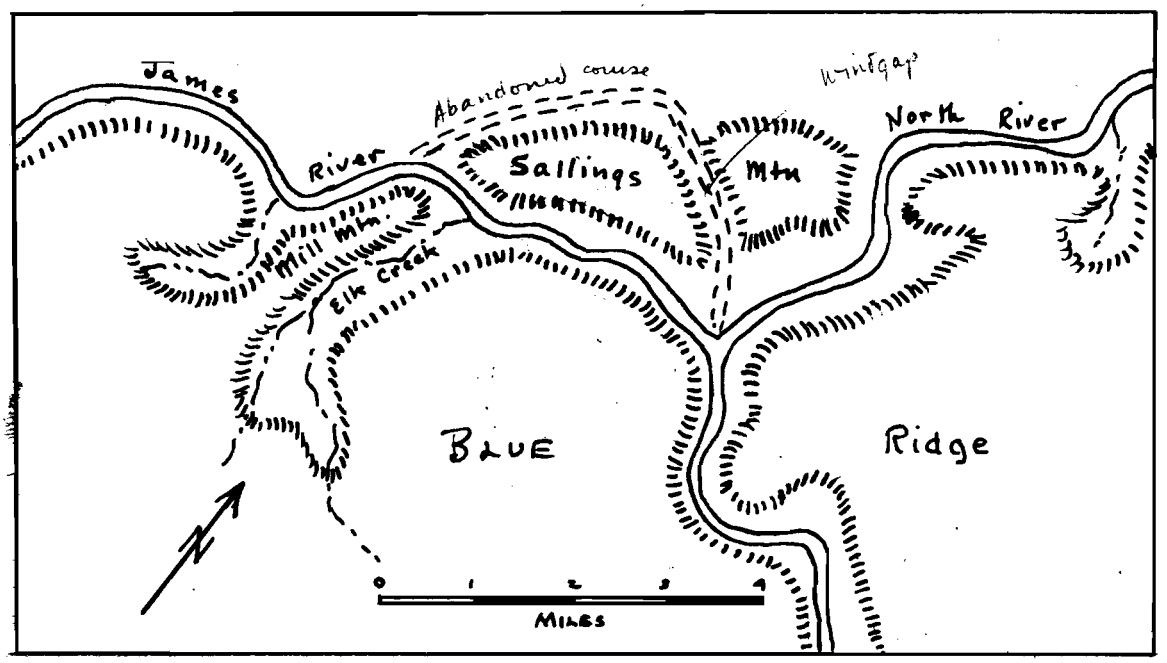
Sketch ~~map~~ indicating the imminent capture of Back Creek by tributaries of Elk Creek in Arnold Valley. The capture will occur at one of the cols marked "C". (See p 73.)

(near mss. p. 73

? Chose 1 diagram of Rocky Run



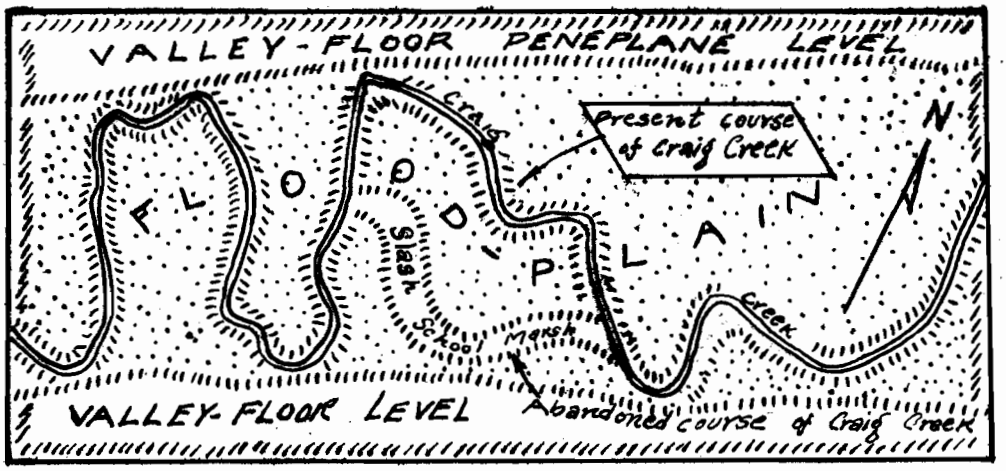
a.

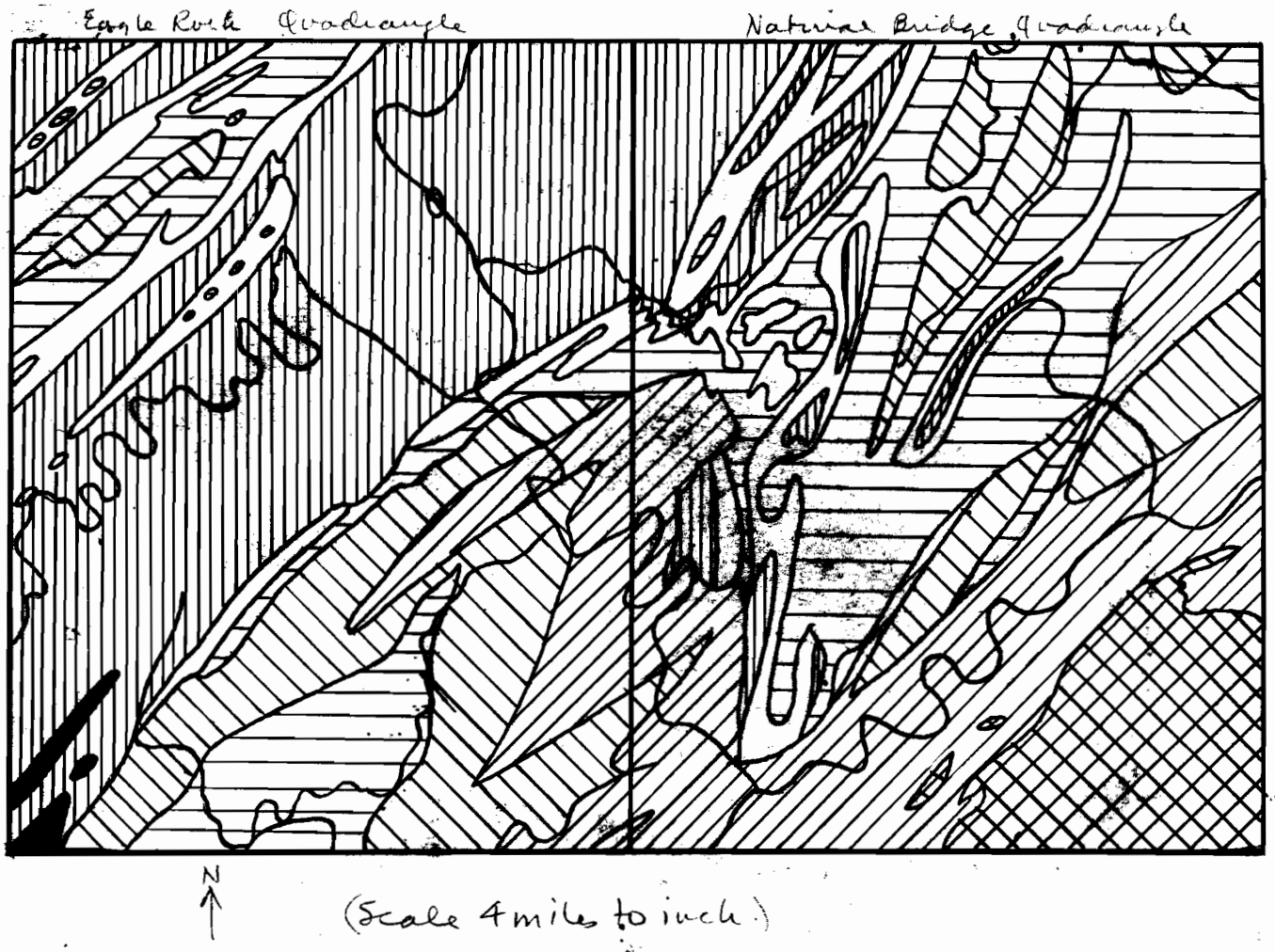


b.

Figure 17. Diagrams to indicate the possible erosion of Sallings Mountain windgap by James River. (See pages 74-76.) Stage a shows the hypothetical position of the James through the windgap. By intercision at X the river became diverted into the lower Elk Creek valley which it now occupies (stage b).

near miss p. 74


VALLEY-FLOOR PENEPLANE LEVEL
Craig
present course of Craig Creek
N
FLOODPLAIN
Slash
Marsh
Creek
VALLEY-FLOOR LEVEL
Abandoned course of Craig Creek


Eagle Rock Quadrangle
Natural Bridge Quadrangle
N
(Scale 4 miles to inch)

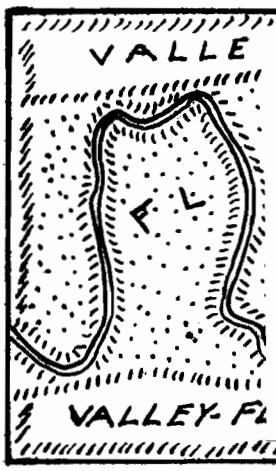


Figure 18.
Sketch map showing Slade School marsh, 2½ miles southeast of Horton, an abandoned cut-off of Craig Creek. (See p. 77.)

(near miss. p. 77)

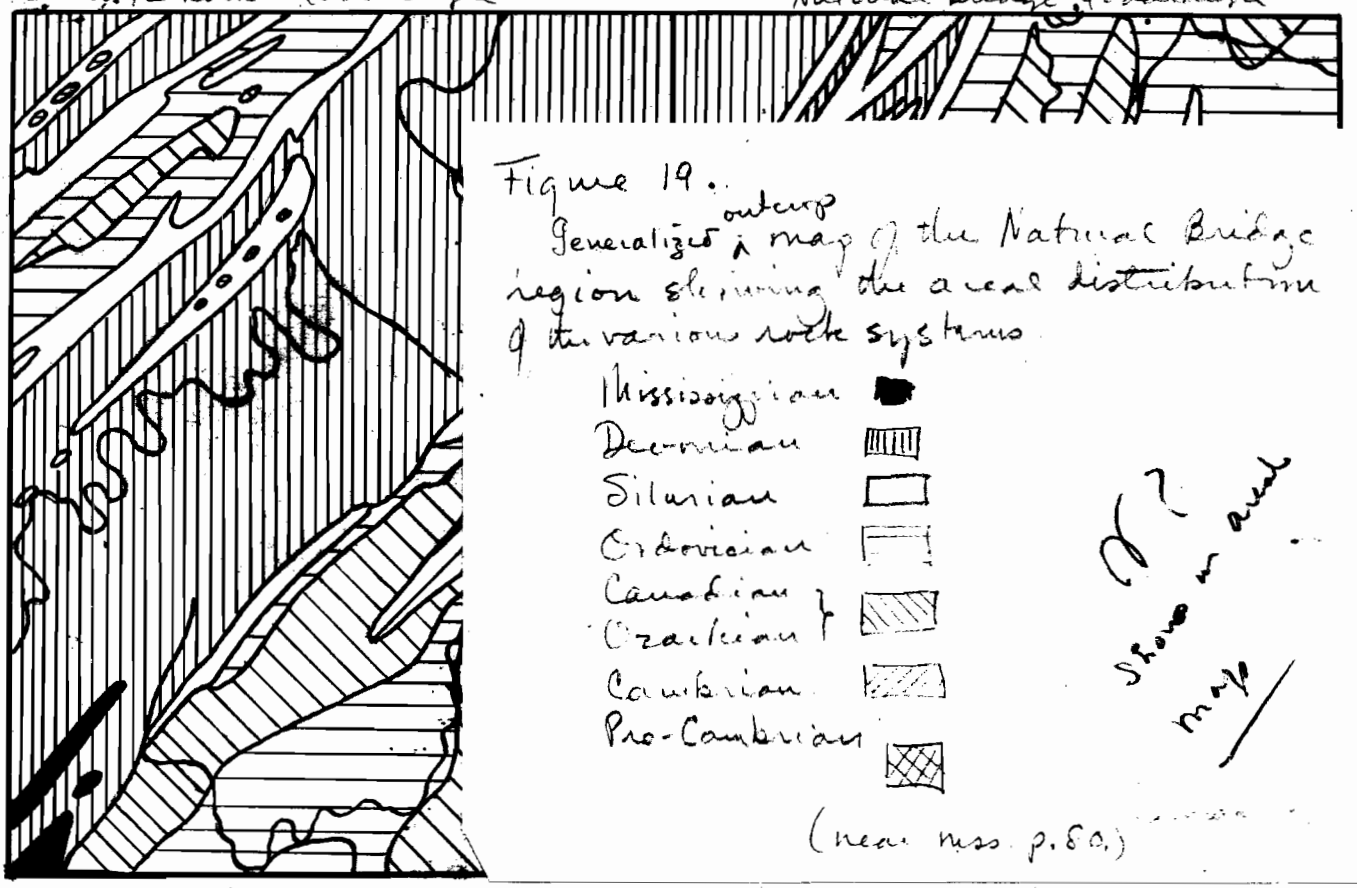


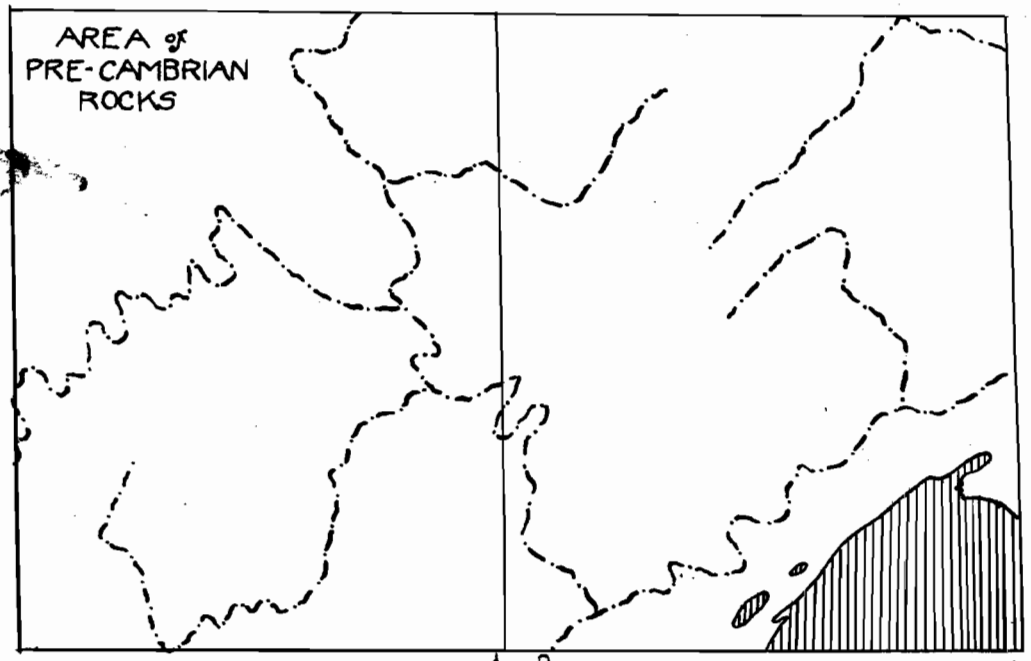
Figure 19.
Generalized outcrop map of the Natural Bridge region showing the areal distribution of the various rock systems.

- Mississippian
- Devonian
- Silurian
- Ordovician
- Canadian
- Ozarkian
- Cambrian
- Pre-Cambrian

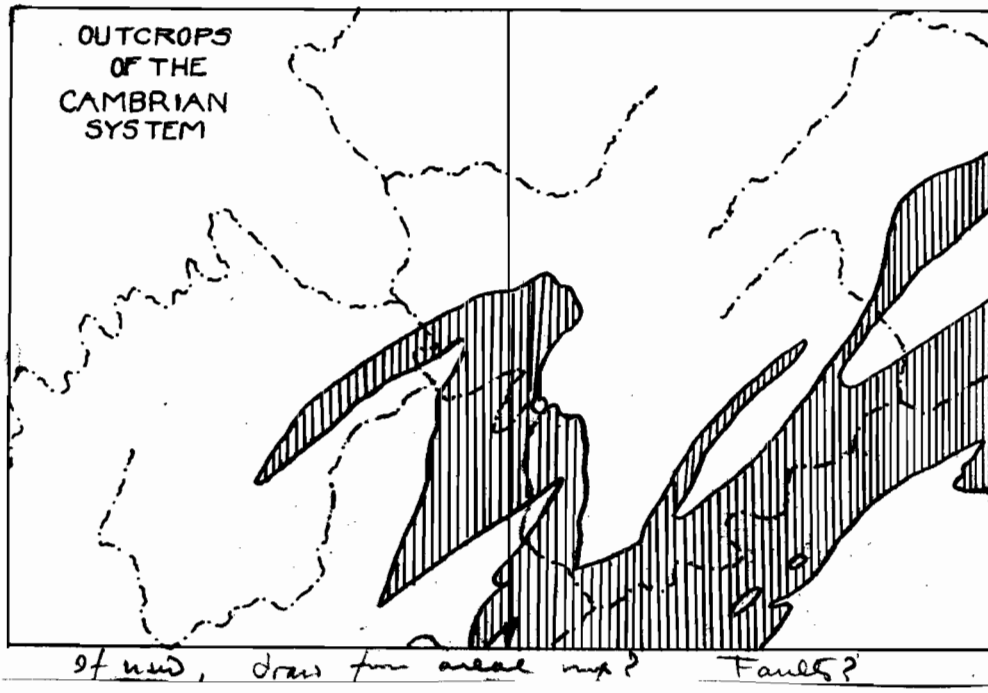
Show on area map

(near miss. p. 80.)

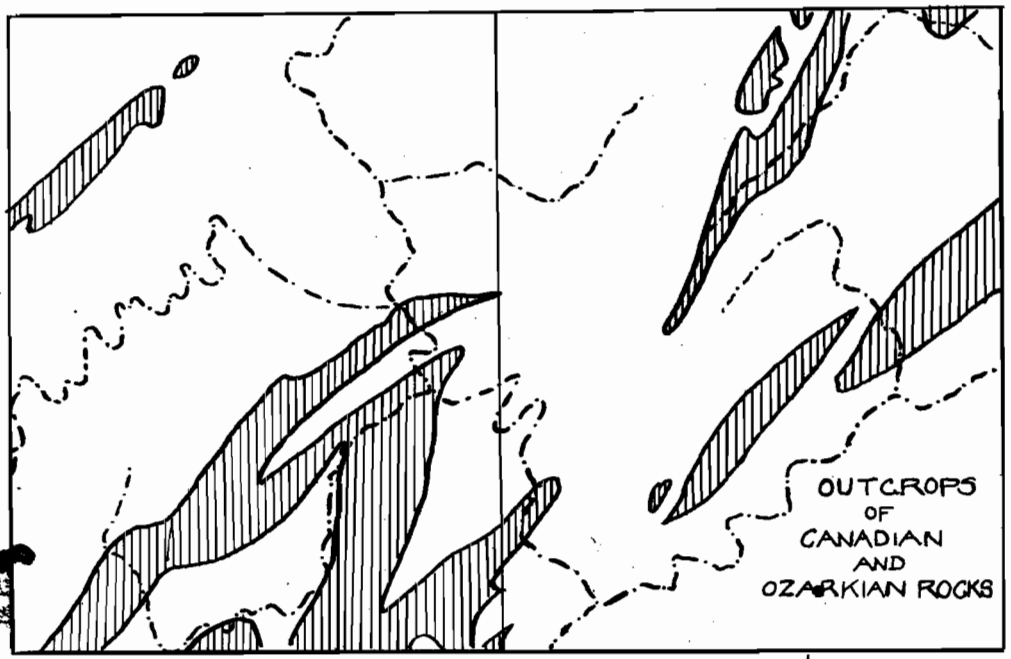
(Scale 4 miles to inch.)



do ?



If need, draw from areal map? Faults?



do

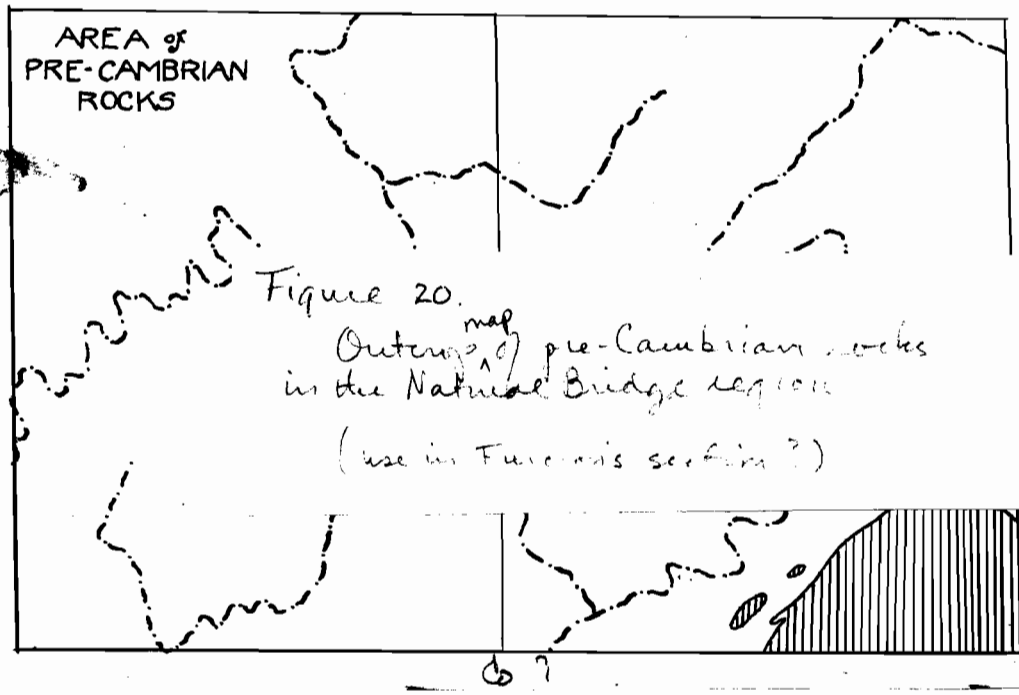


Figure 20.
Outcrops of pre-Cambrian rocks in the Natural Bridge region
(use in Furcron's section?)

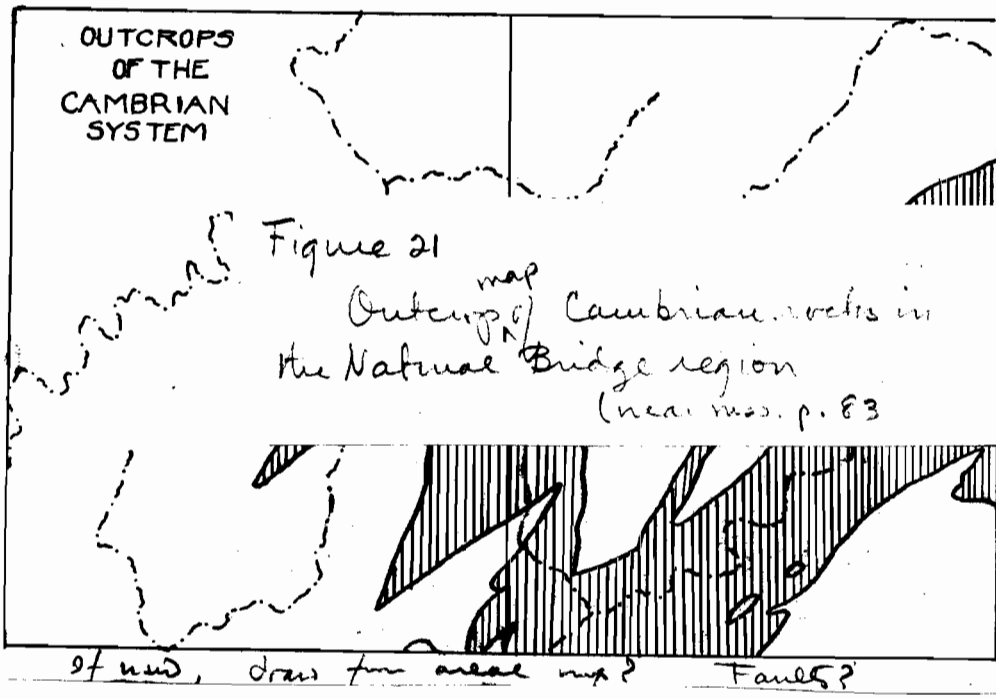


Figure 21
Outcrops of Cambrian rocks in the Natural Bridge region
(near mss. p. 83

If need, draw from areal map? Faults?

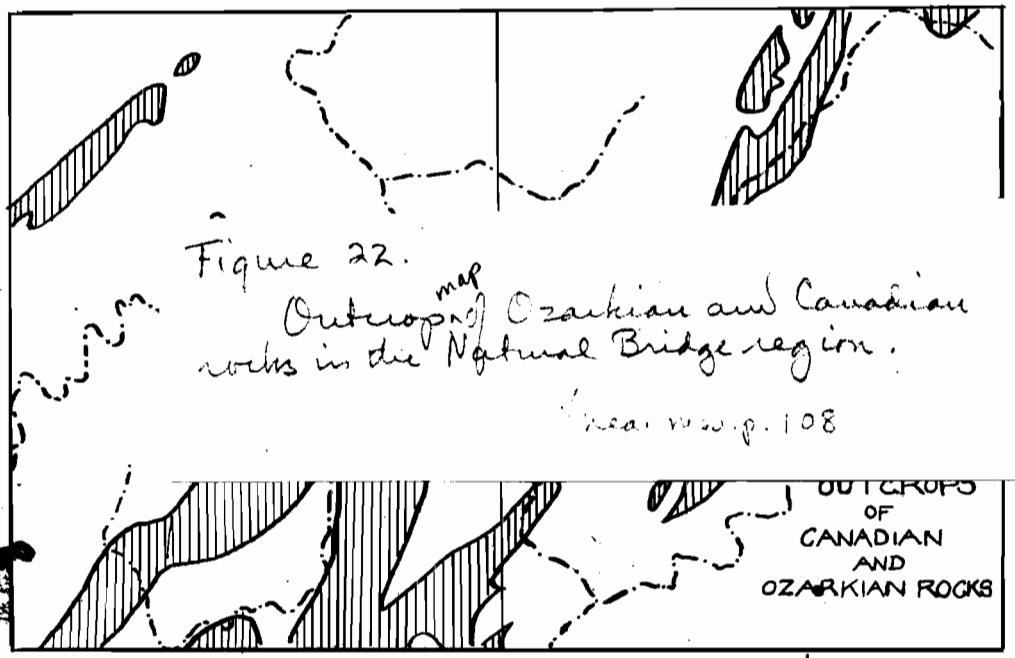
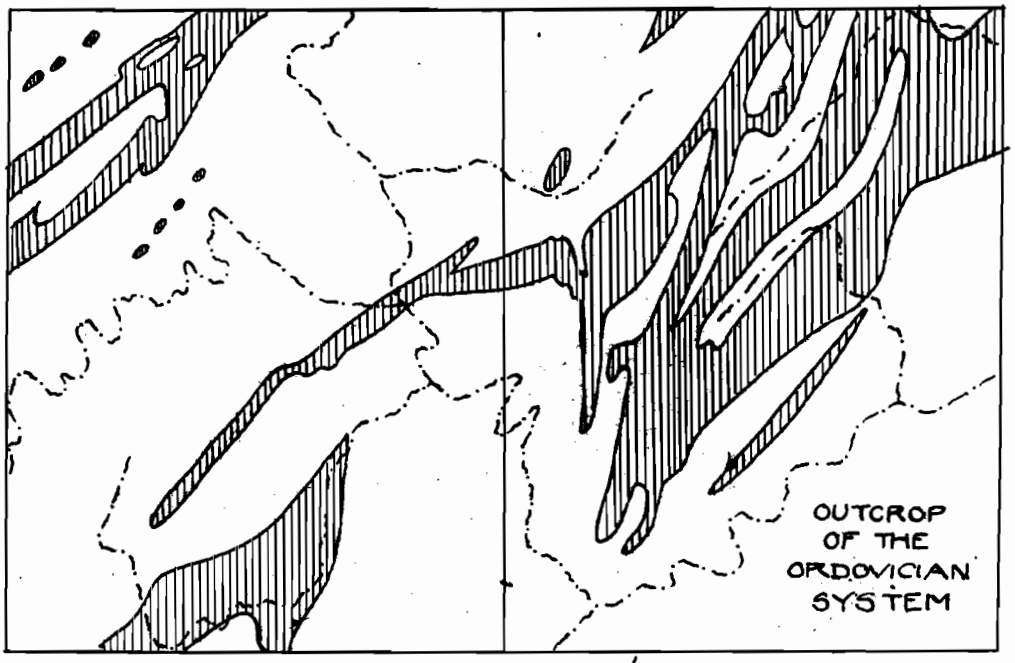
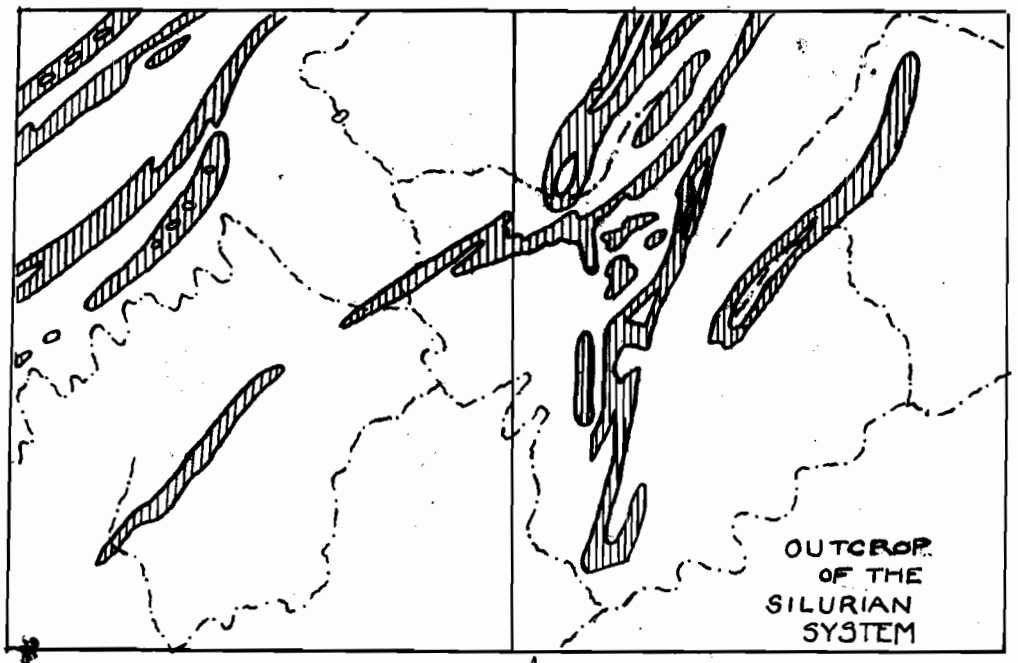


Figure 22.
Outcrops of Ozarkian and Canadian rocks in the Natural Bridge region.
(near mss. p. 108


OUTCROP
OF THE
ORDOVICIAN
SYSTEM

Co


OUTCROP
OF THE
SILURIAN
SYSTEM

Co ?

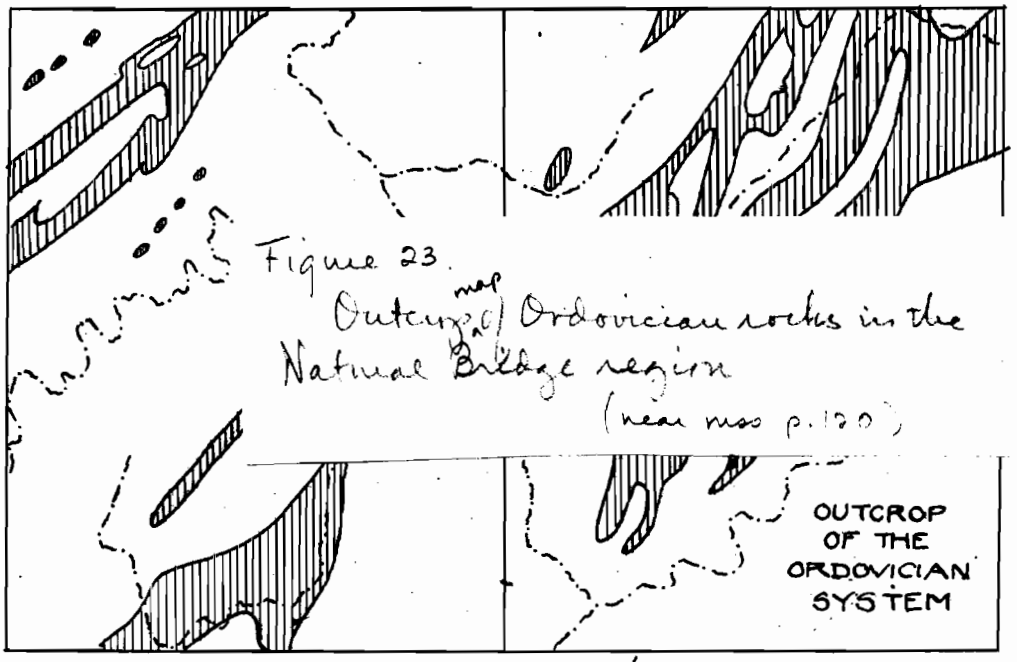


Figure 23.
Outcrop map of Ordovician rocks in the Natural Bridge region
(near mss p. 120)

Co

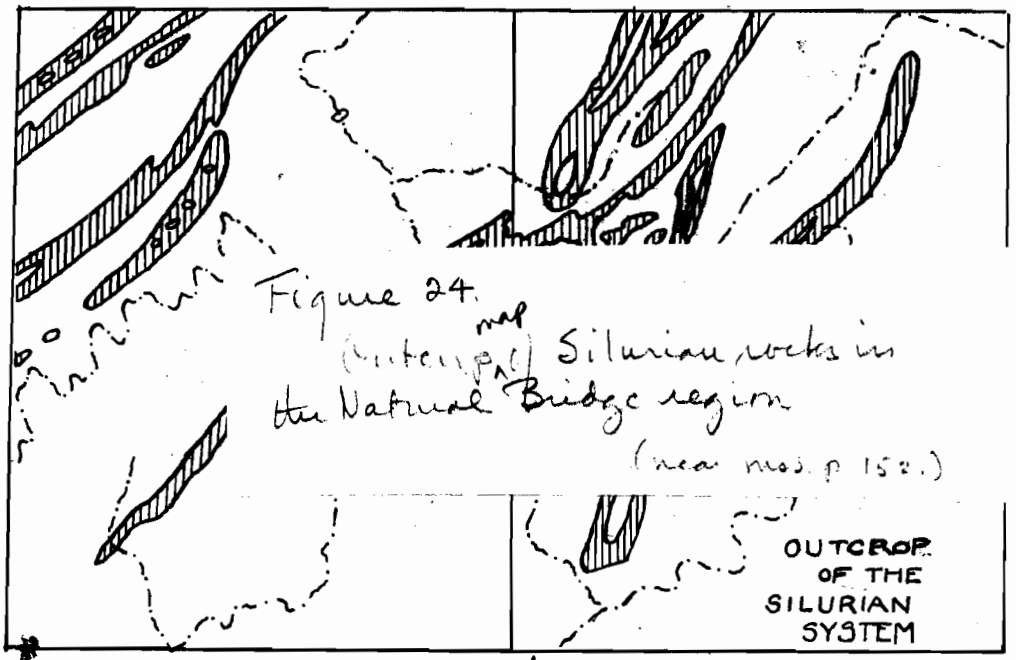
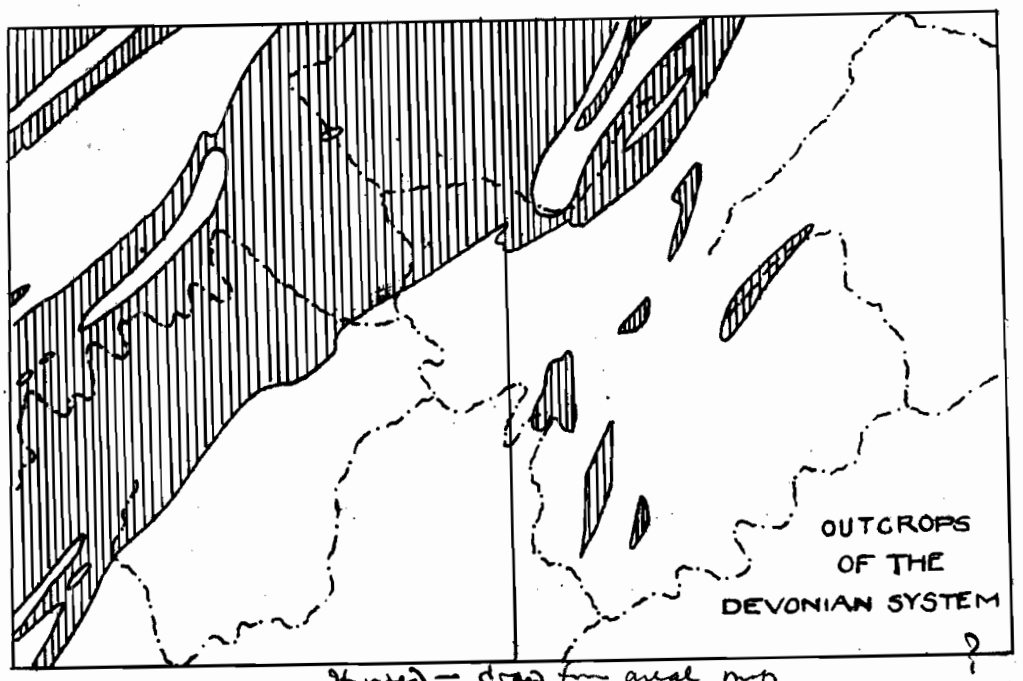
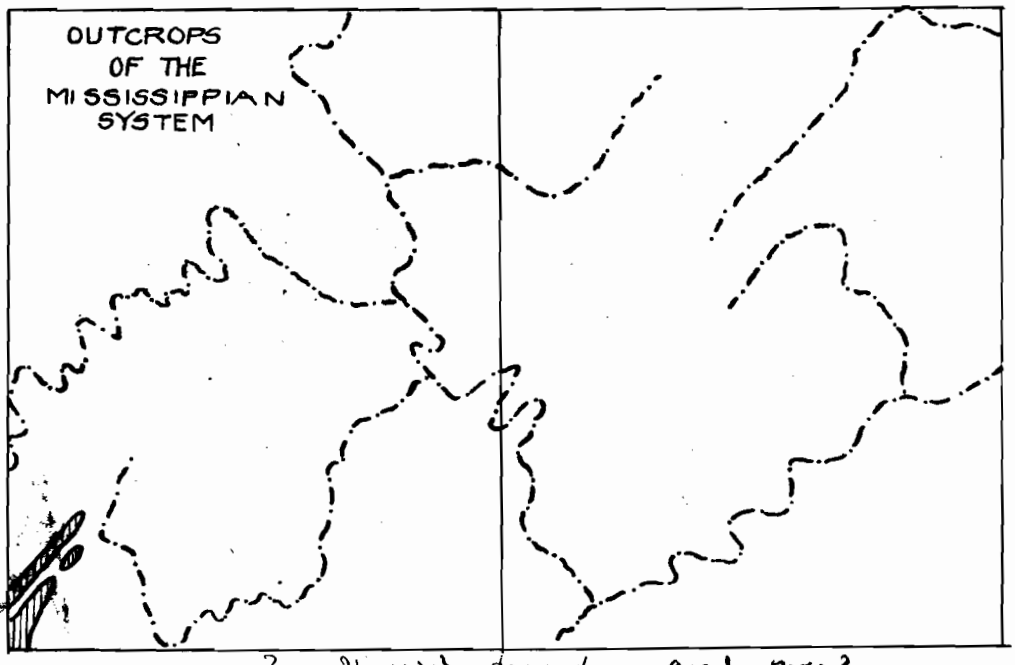


Figure 24.
Outcrop map of Silurian rocks in the Natural Bridge region
(near mss. p 152.)

Co ?



If used — draw from aerial map



? If used, draw from aerial map?

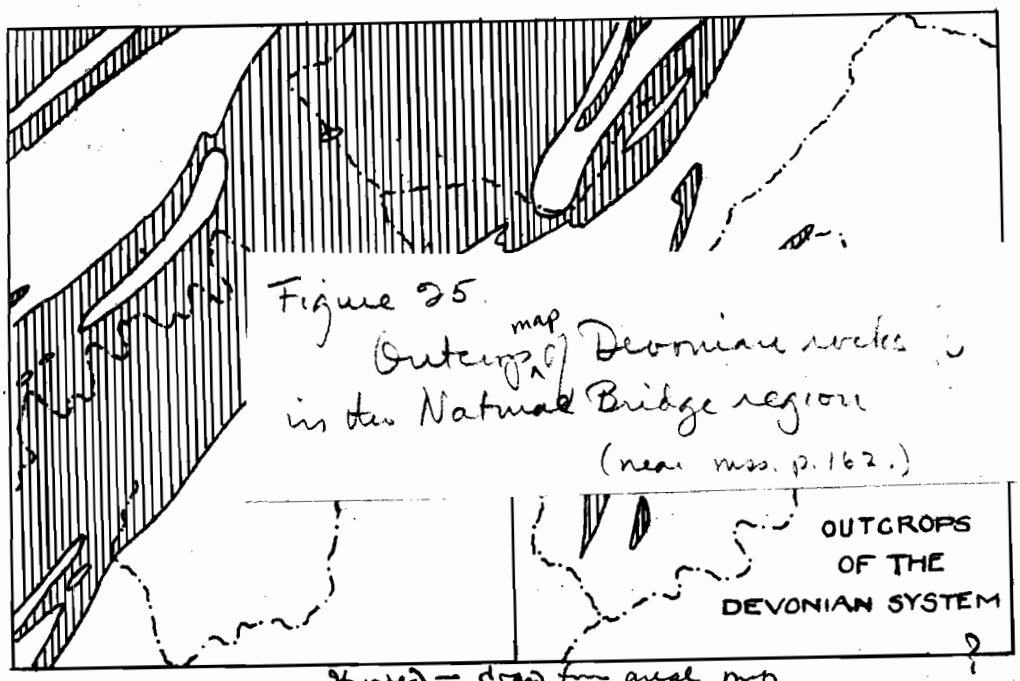


Figure 25.
Outcrop map of Devonian rocks in the Natural Bridge region
(near mss. p. 162.)

If used — draw from aerial map

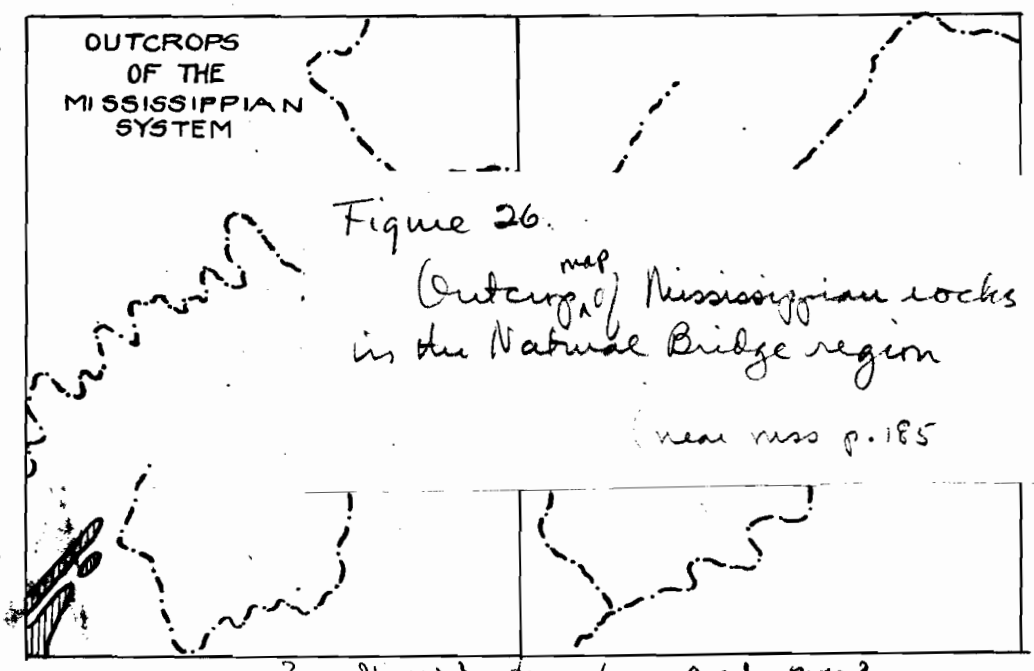
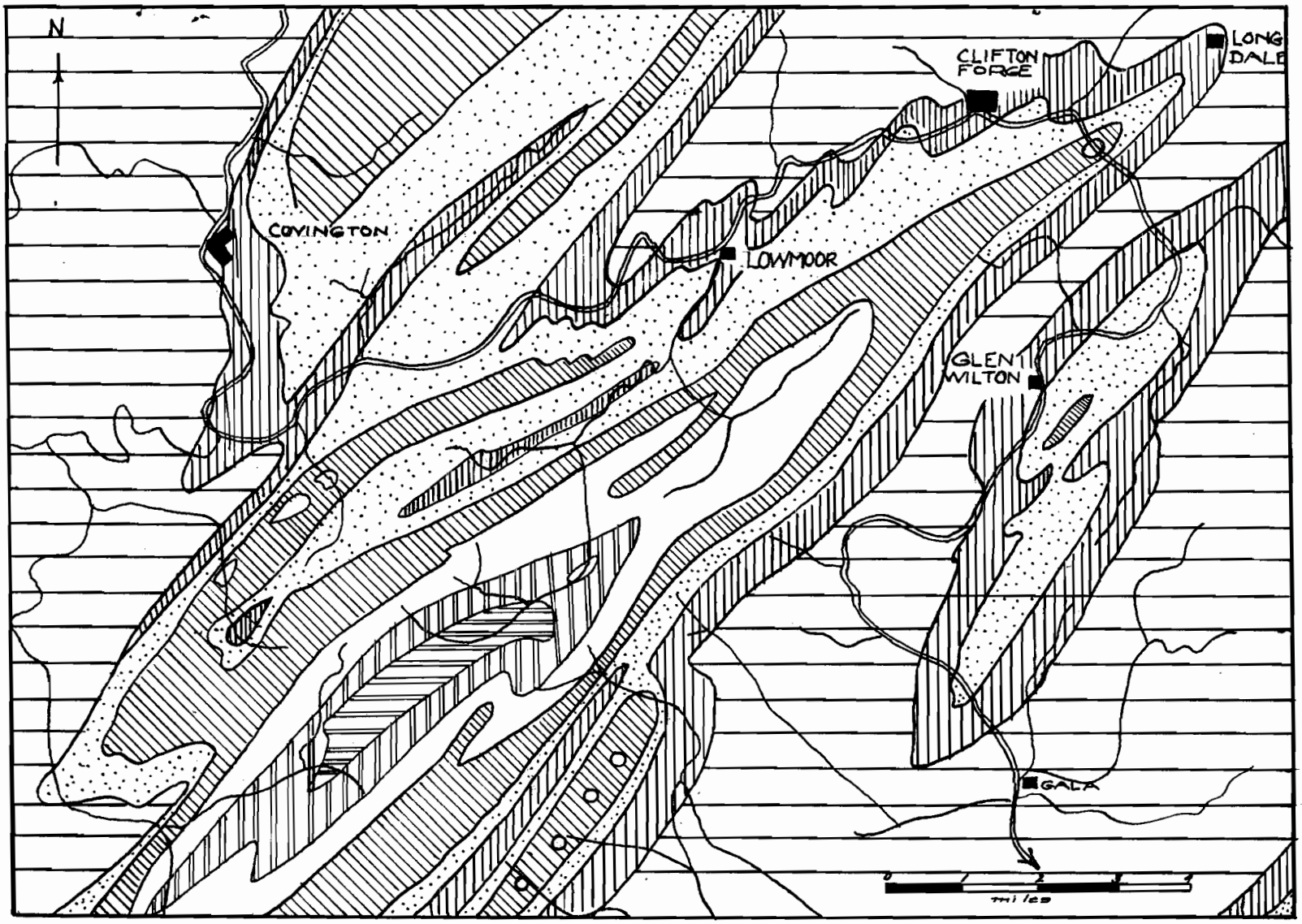


Figure 26.
Outcrop map of Mississippian rocks in the Natural Bridge region
(near mss p. 185

? If used, draw from aerial map?


N
CLIFTON FORCE
LONG DALE
COVINGTON
LOWMOOR
GLENTILTON
GALA
miles

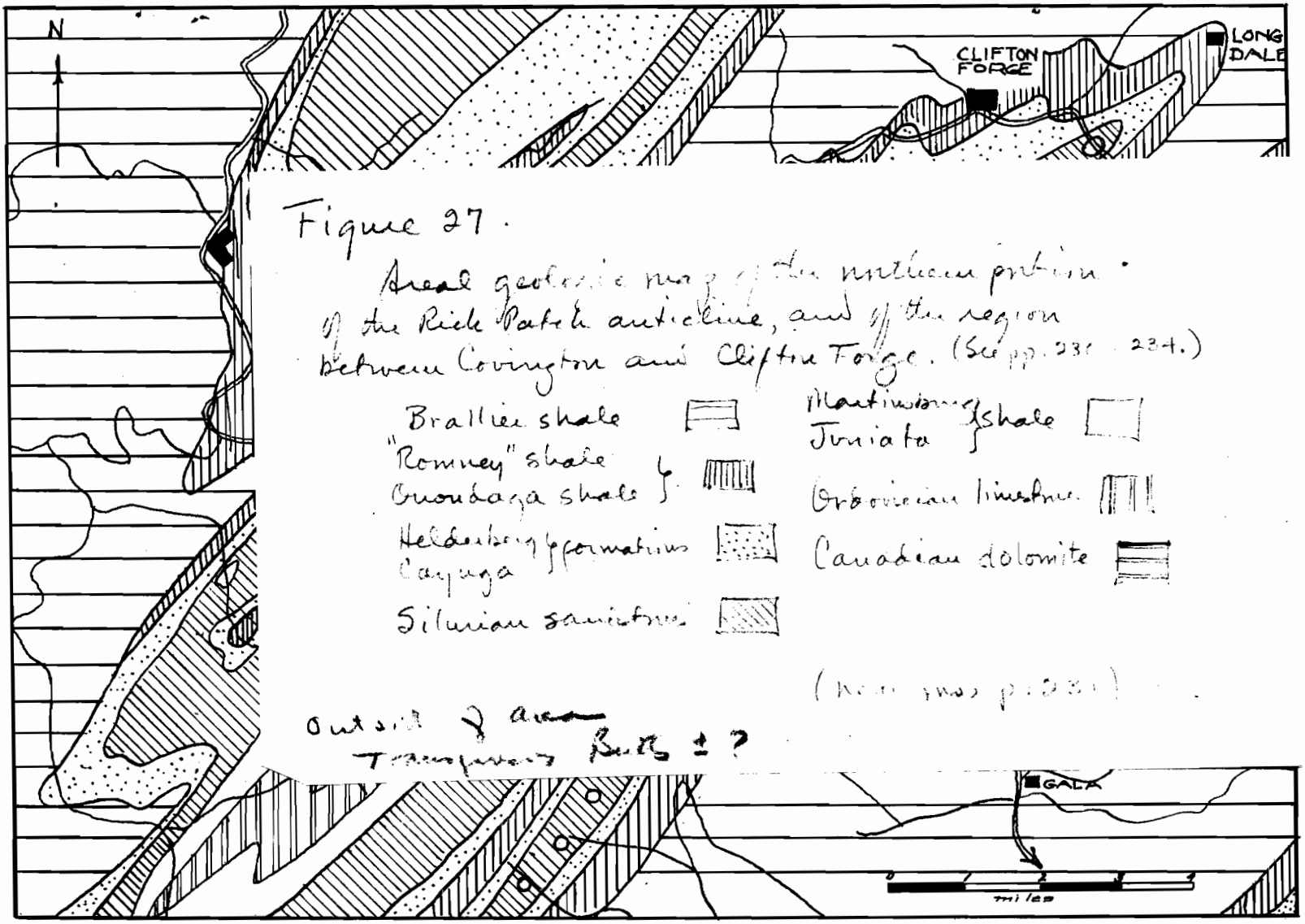


Figure 27.

Areal geologic map of the northern portion of the Rich Patch anticline, and of the region between Covington and Clifton Forge. (See pp. 230 - 234.)

Brallier shale
"Romney" shale
Onondaga shale
Helderberg formations
Cayuga
Silurian sandstone
Martinsburg shale
Juniata
Ordovician limestone
Canadian dolomite

(near map p. 231)

Outside of area
Transverse Bulls ± ?

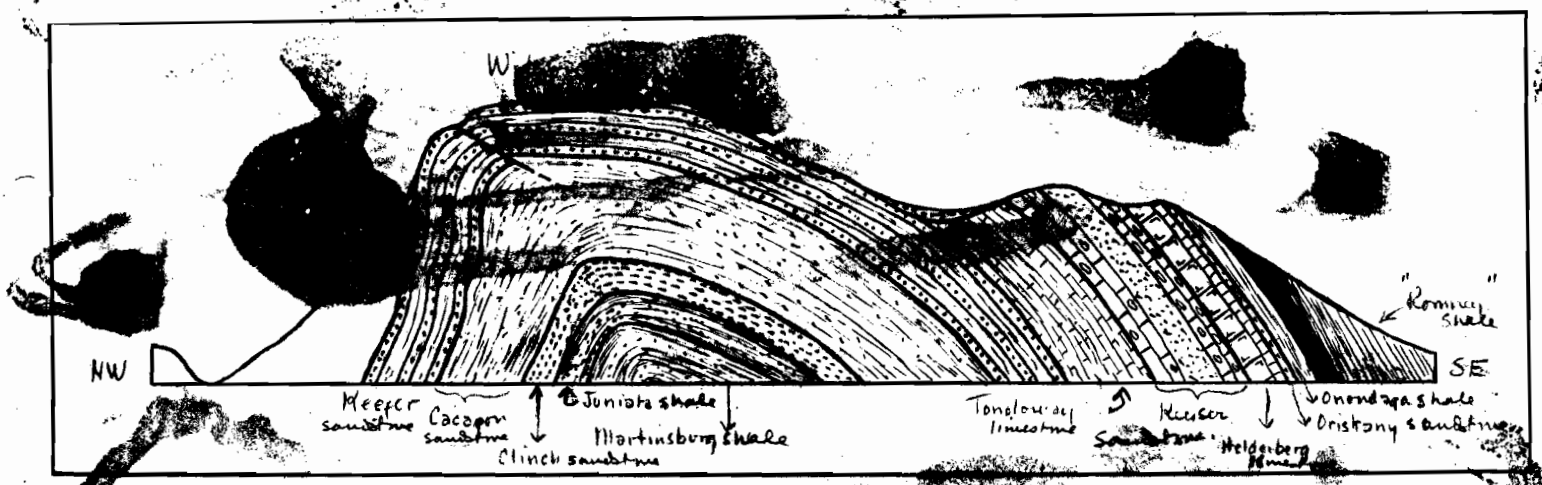


Figure 28. Cross section along James River through the gap at [illegible] Gate, showing the northeastern face of the gorge. (See p. 234; compare with Pls. 50,B and 51,A.)

(near mss p. 234)

Outlines of area

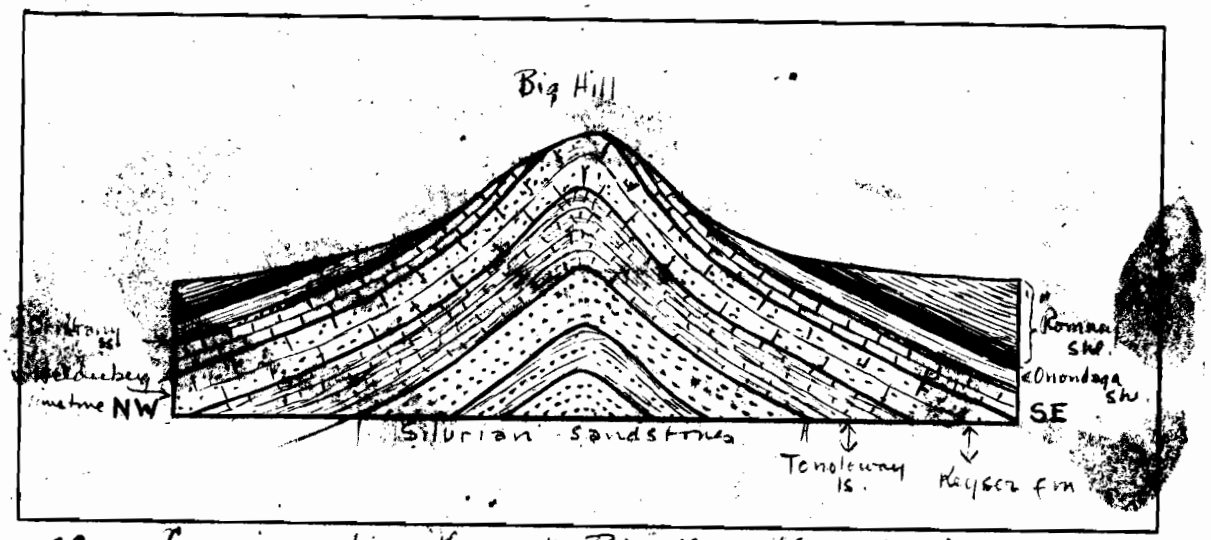


Figure 29. Cross section through Big Hill. (See p. 236.)

(near mss p. 236.)

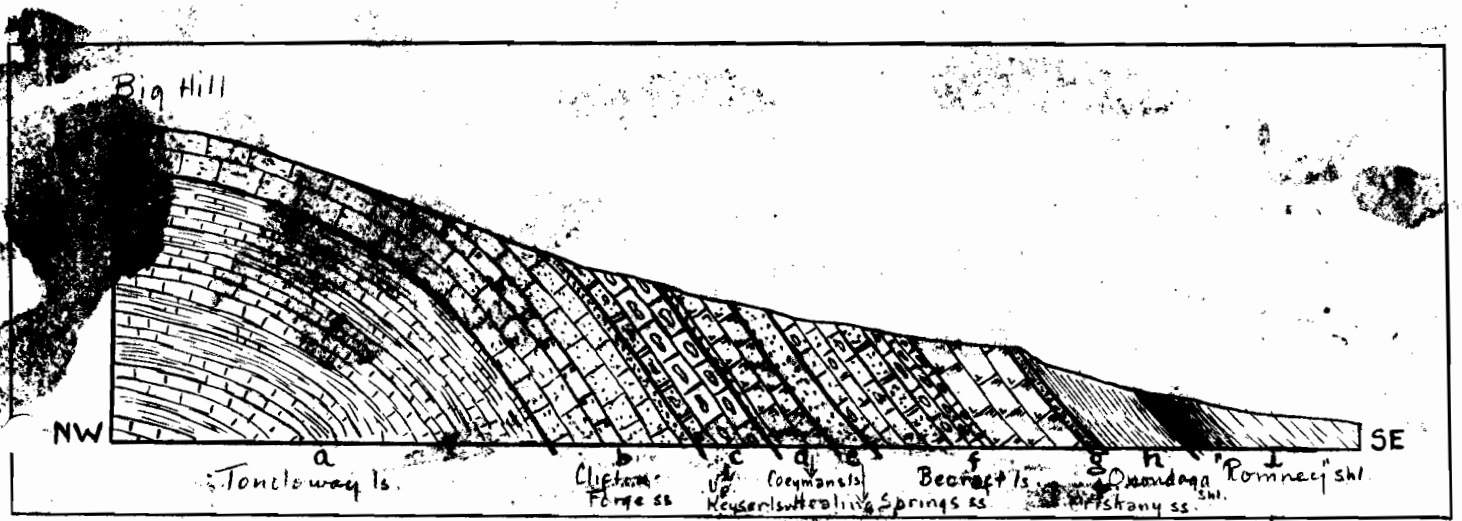


Figure 30. Cross section along railway cut at Prices Bluff at the southeastern end of Big Hill. (See p. 236.)

(near mss p. 236.)

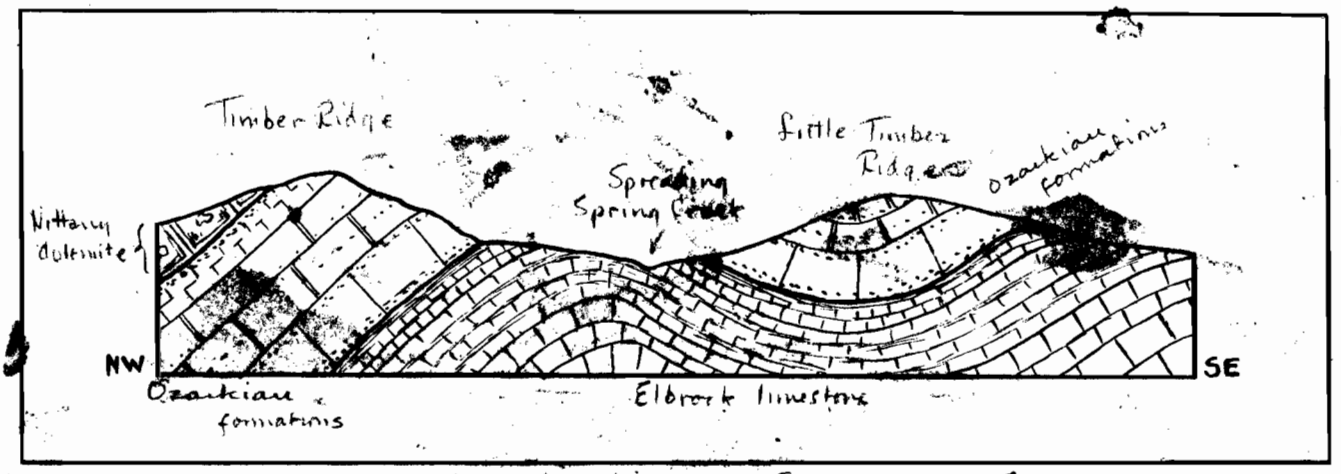
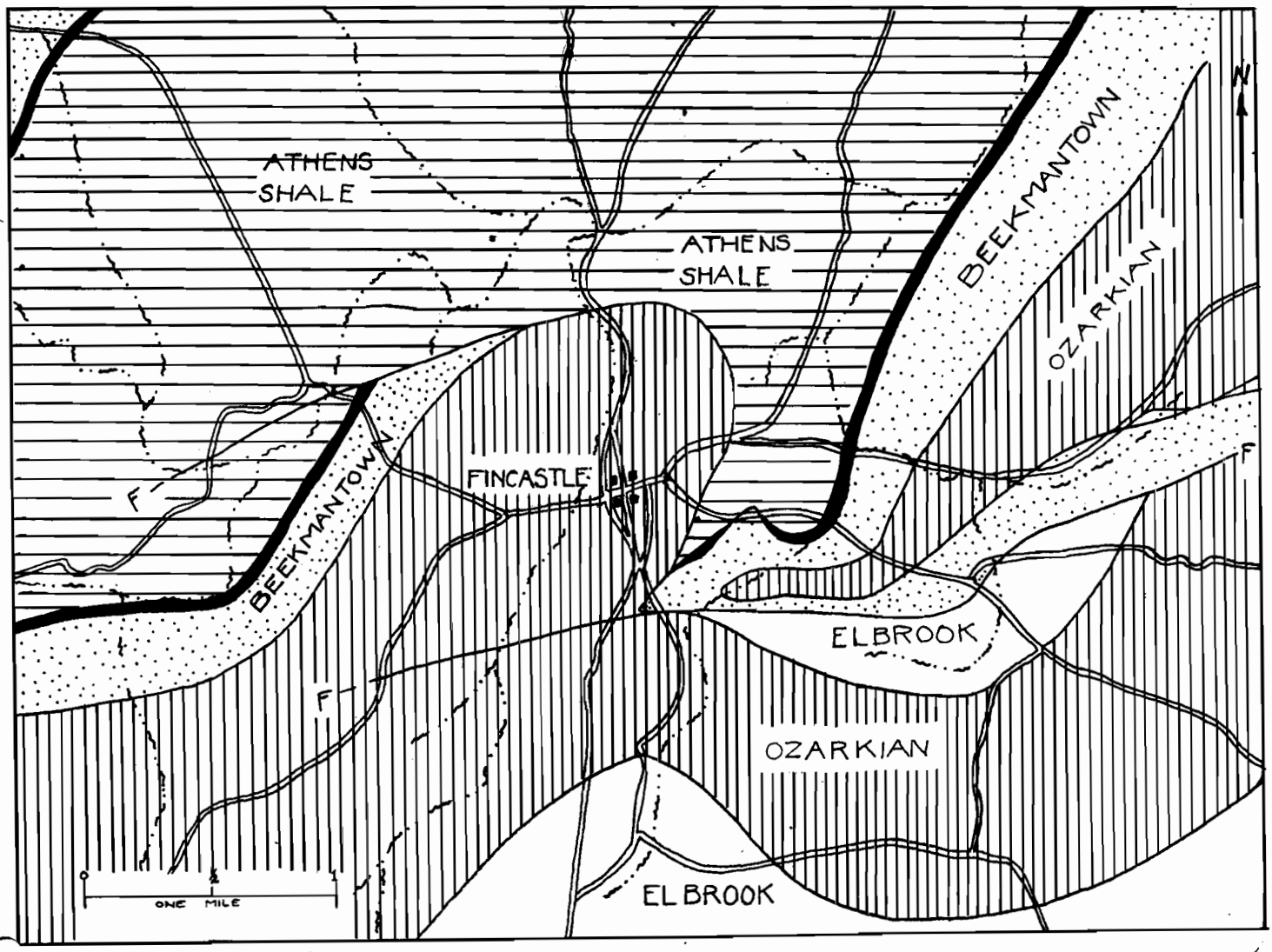


Figure 31. Cross section through the Spreading Spring anticline
(See p. 237.)
(near mss p. 237.)



Lenoir - Holston outcrop in black

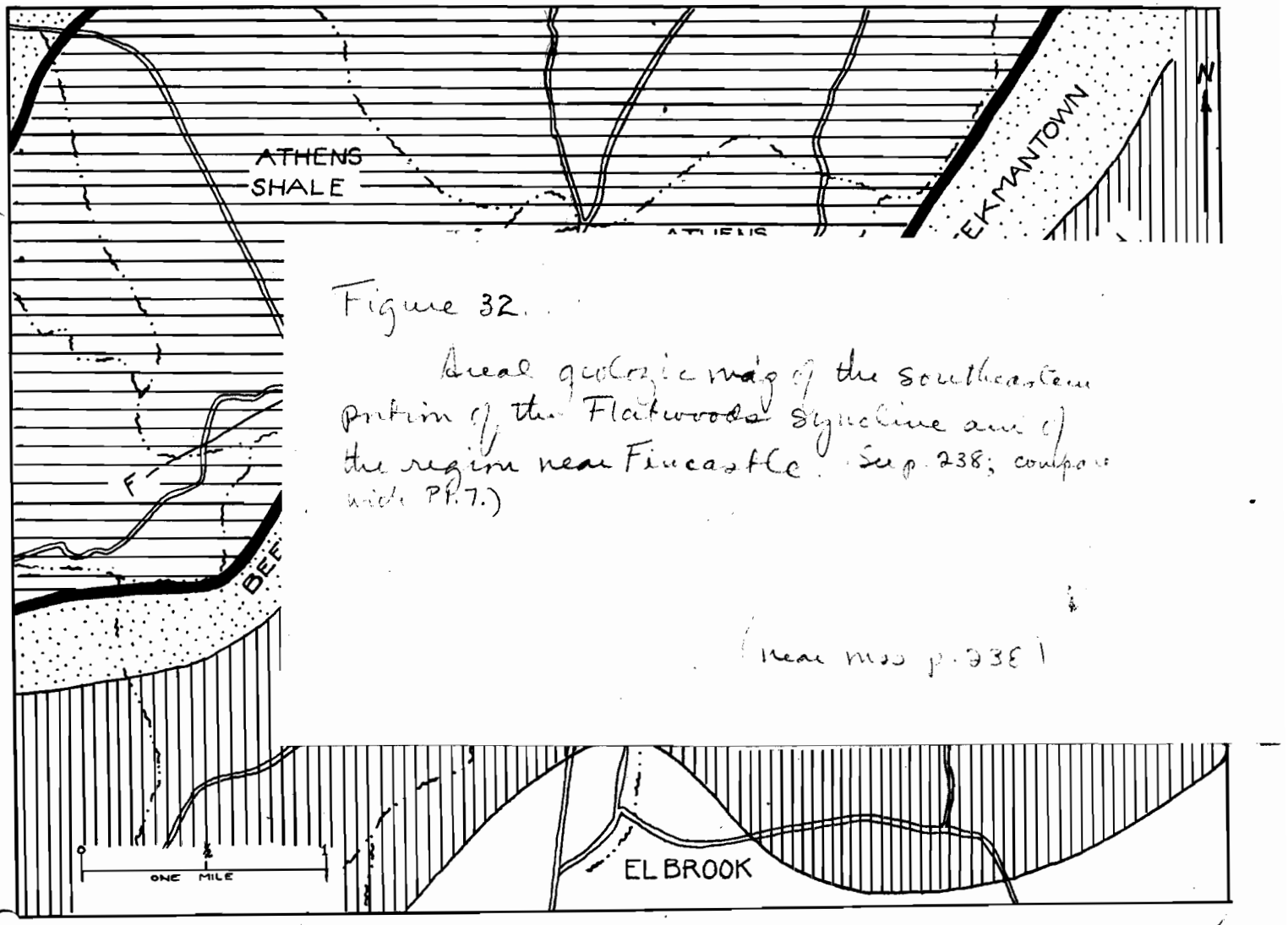
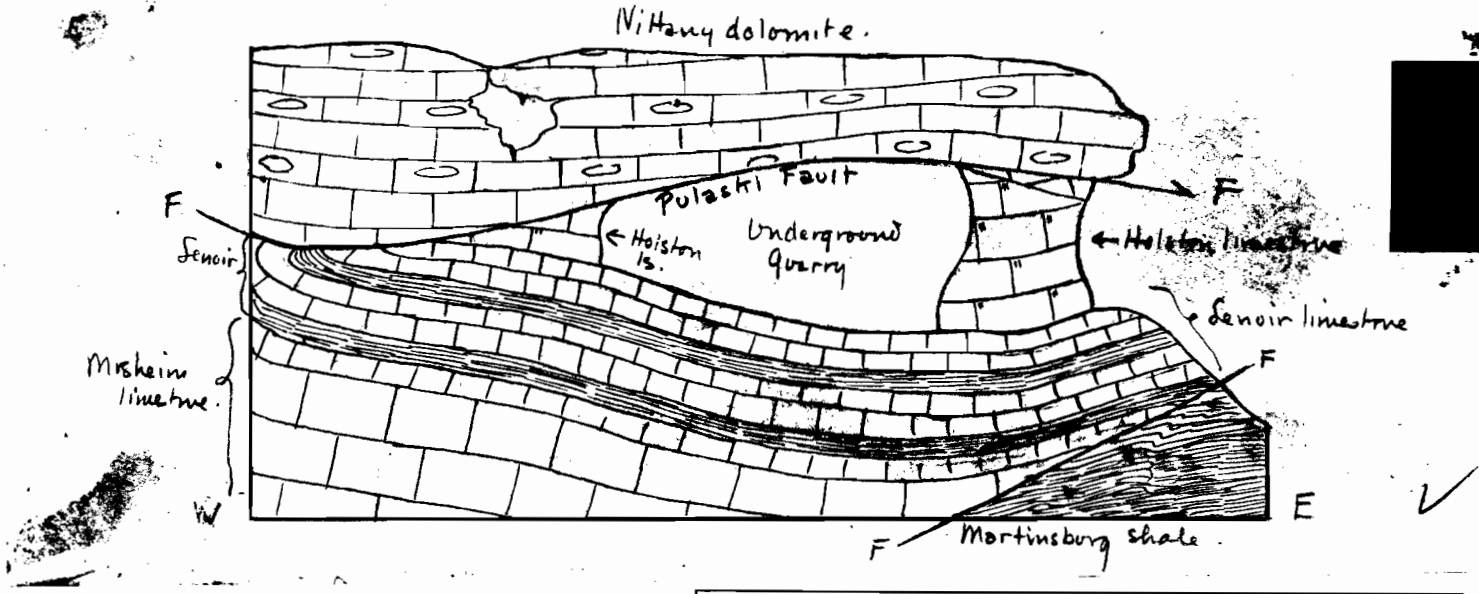


Figure 32.

Areal geologic map of the southeastern portion of the Flatwoods syncline and of the region near Fincastle. (See p. 238; compare with Pl. 7.)

(near mss p. 238)

Lenoir - Holston outcrop in black.



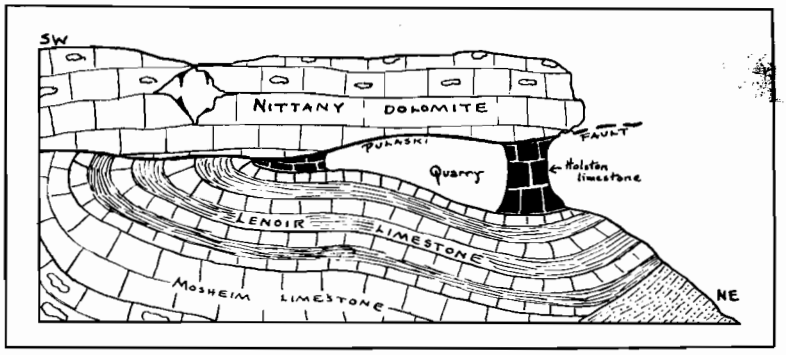


Figure 33. (Redraw)
[illegible] west [illegible] section through the abandoned [illegible] Lime Company quarry at Eagle Rock showing the [illegible] Pulaski overthrust [illegible]
(See pp. [illegible])
[illegible] p. 244

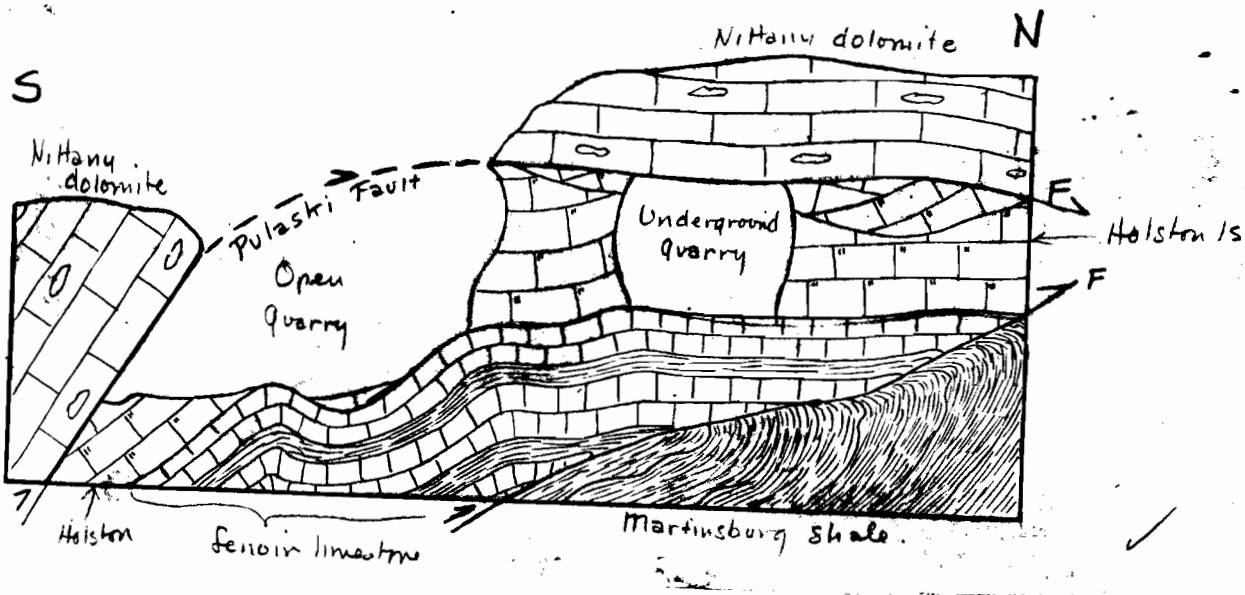
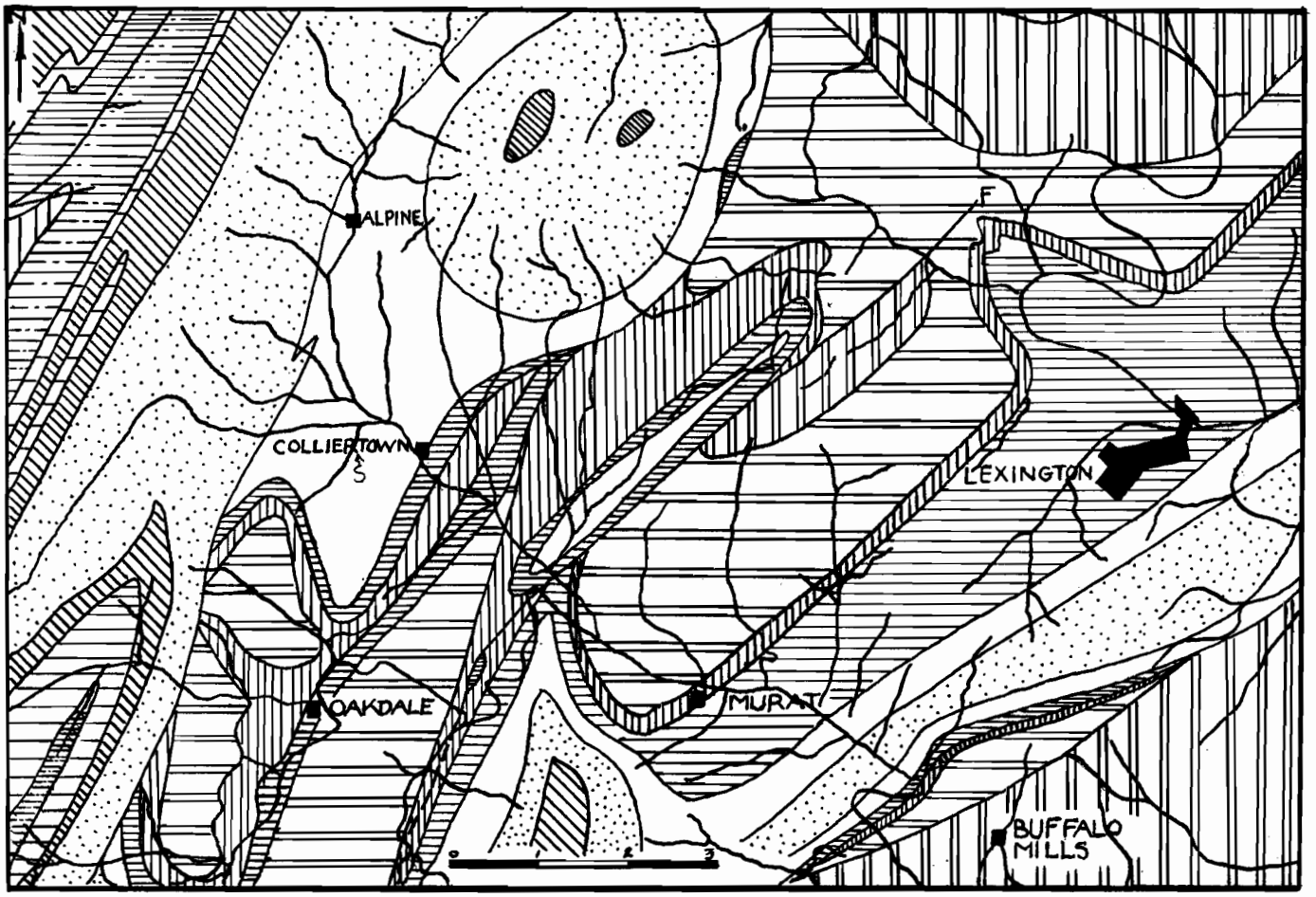


Figure 34.
Diagrammatic north-south section through the abandoned Moore Lime Company quarry at Eagle Rock
(See pp 244-246.)
[illegible] p. 245)


ALPINE
COLLIERTOWN
LEXINGTON
OAKDALE
MURAT
BUFFALO MILLS
F
0
1
2
3

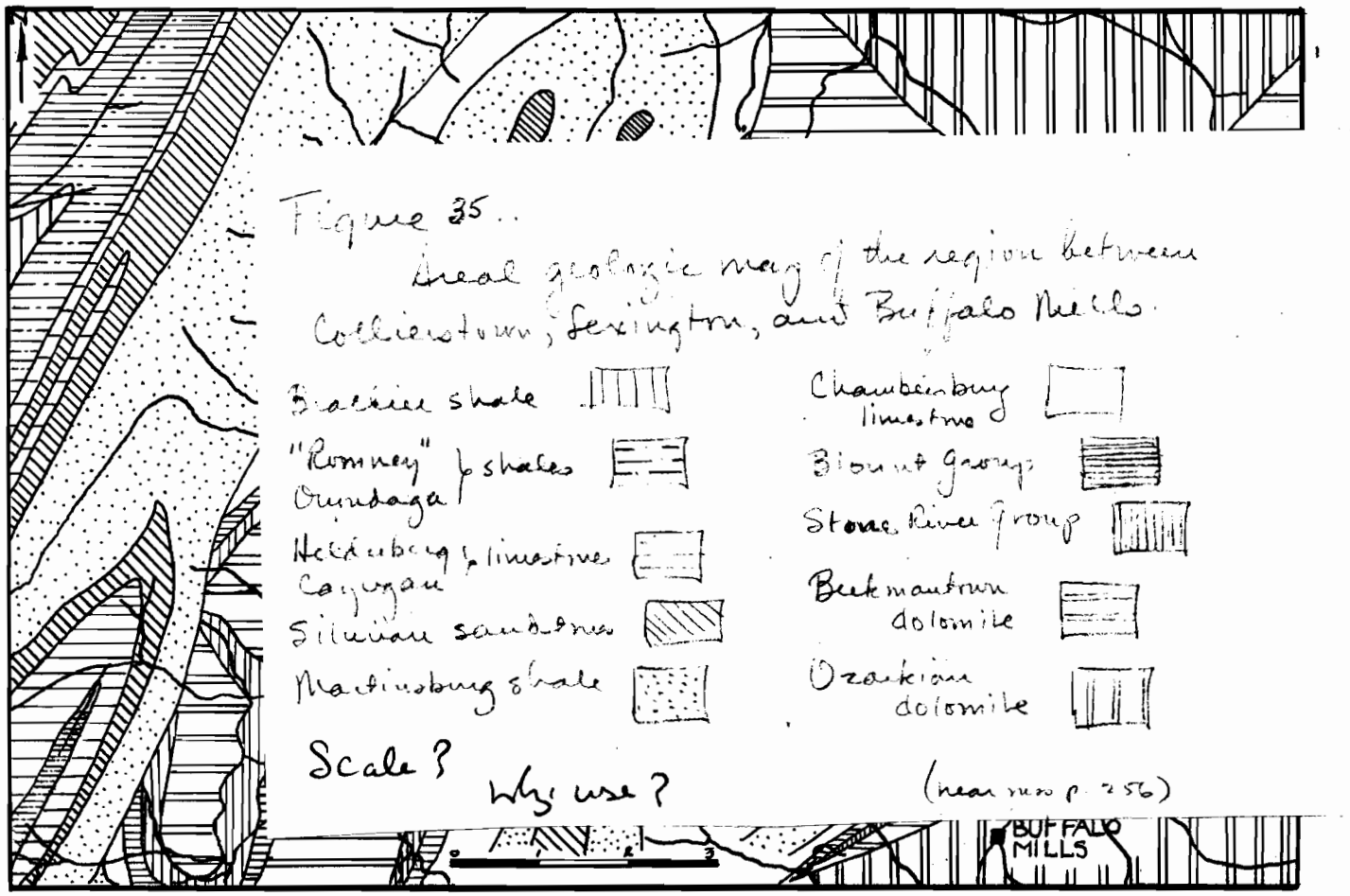


Figure 35.

Areal geologic map of the region between Collierstown, Lexington, and Buffalo Mills.

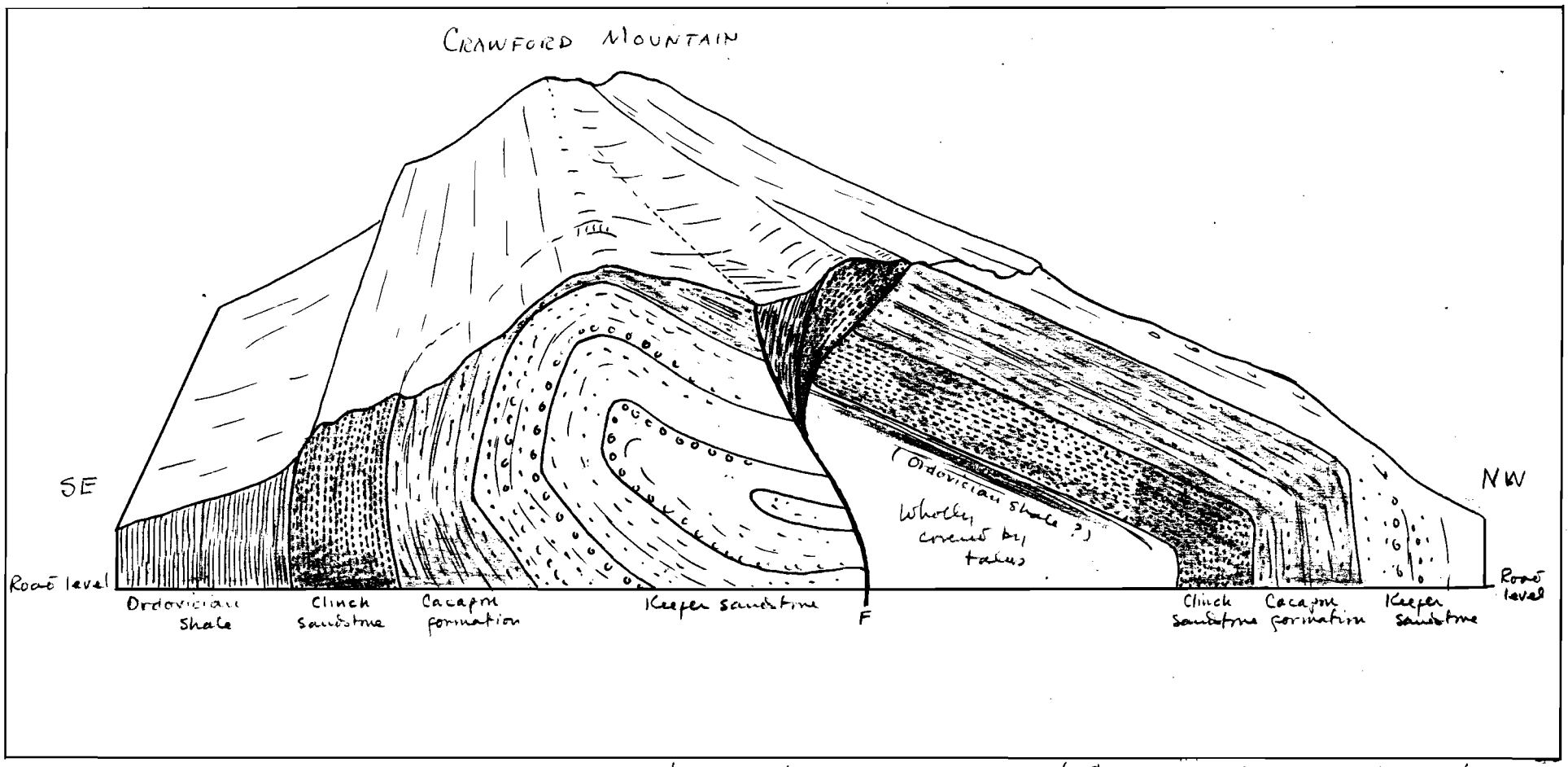


Figure 36. Diagrammatic cross section of the southwestern wall (Crawford Mountain) of the Eagle Rock gap. (Compare with Plate 58.) The slope northwest of the central fault is largely concealed by talus; its internal structure is unknown. No beds higher than Keefer sandstones were observed in the overturned fold southeast of the fault. Note the broken fold of Clinch sandstone thrust against the Cacapon formation near the top of the section. (See pp. 263-267.)

(near mss p. 264

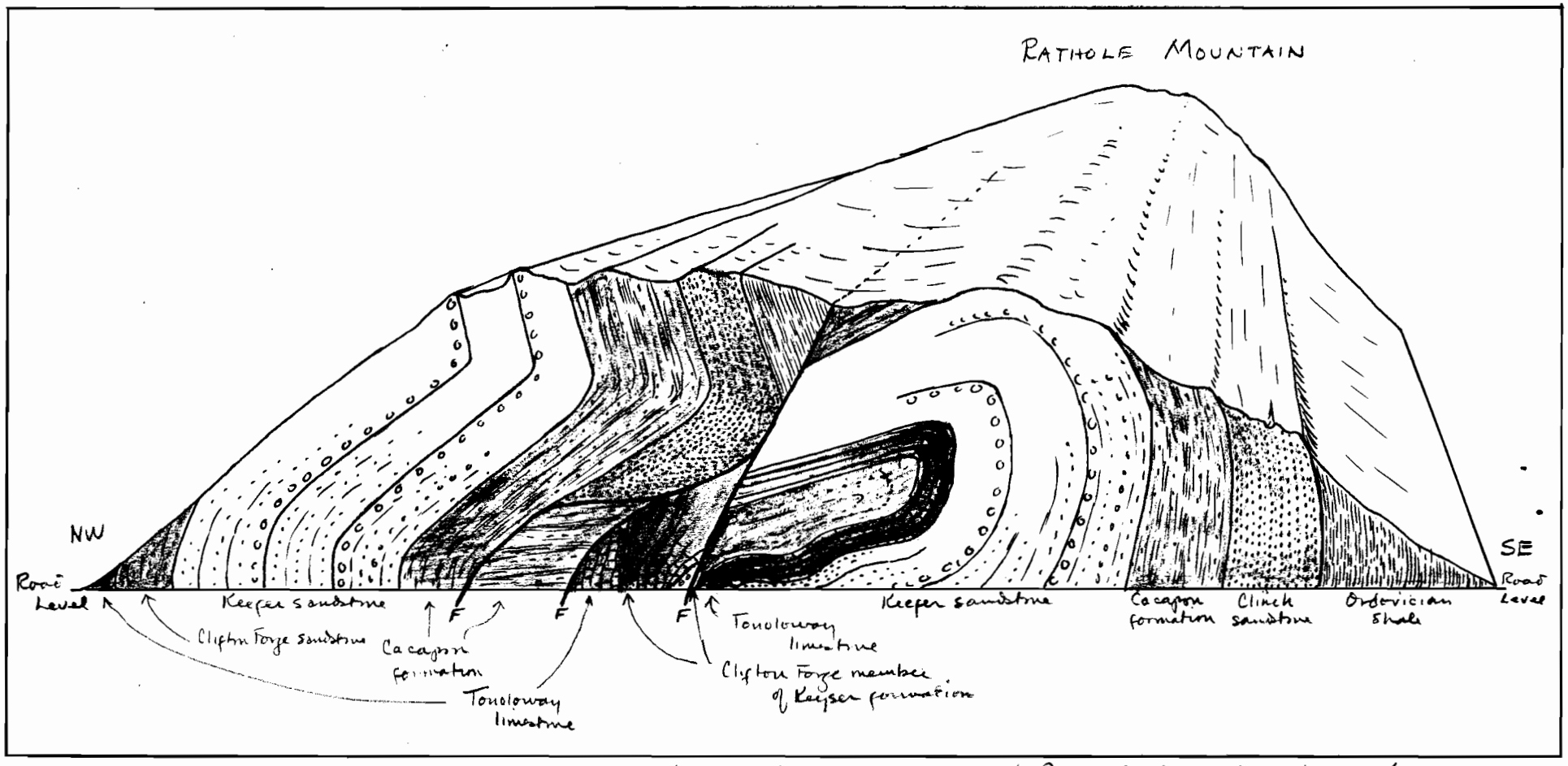


Figure 37. Diagrammatic cross-section of the northeastern wall (Rathole Mountain) of the Eagle Rock gap. (Compare with Plate 57 and figure 36.) This face of the gap is more thoroughly exposed as a result of the recent grading of State Highway 12. Note the presence of Tonoloway limestone in the center of the overturned Keefer fold, and the two smaller horsts northwest of the main fault. (See pp 263-267.)

(near miss page 264)

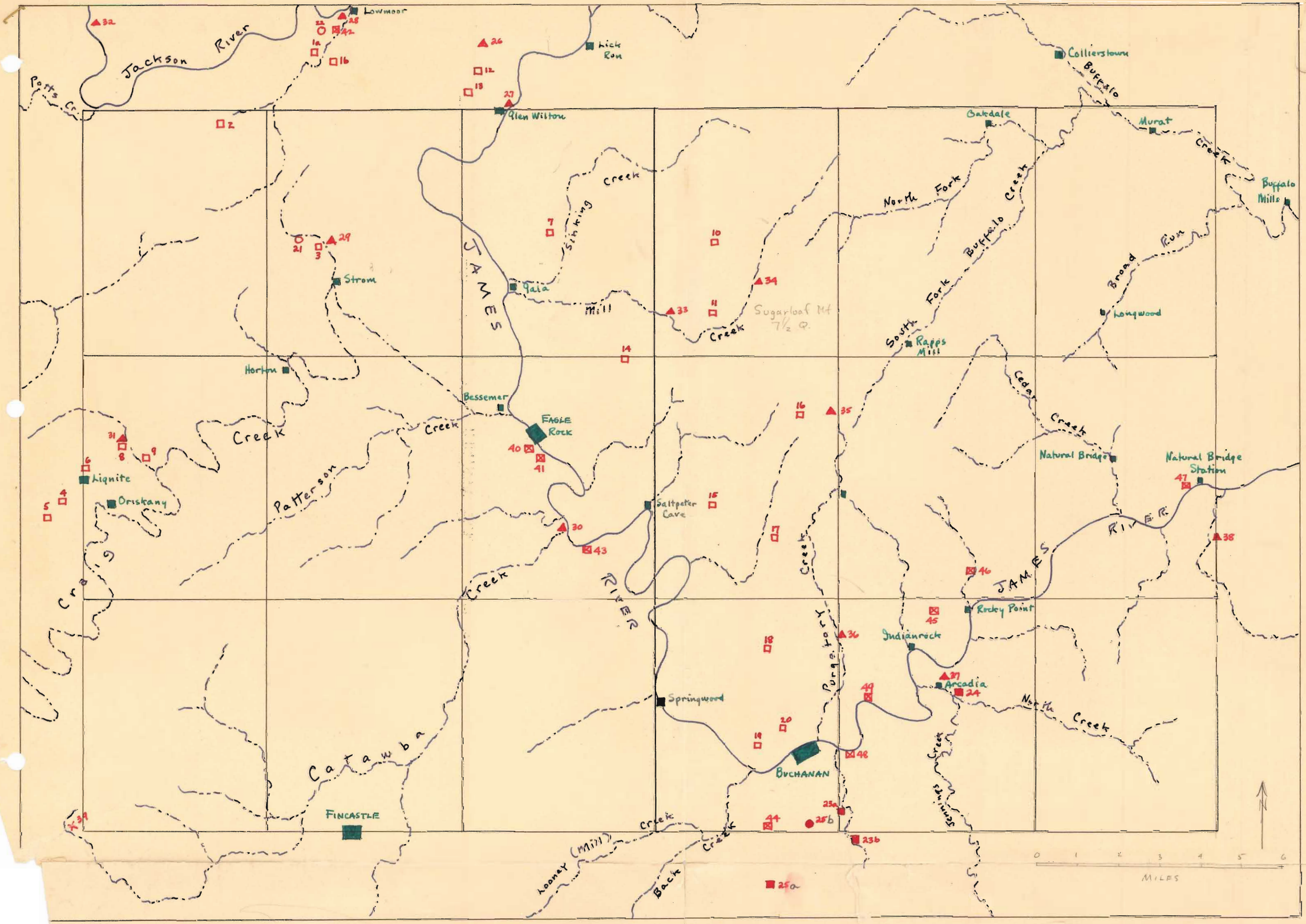


Figure 38.- Map showing location of the most important mines, prospects, quarries, and furnaces in the Natural Bridge region and immediately adjoining area.

(Note: legend on typewritten sheet attached)

(near bibl. page 291)

Legend for figure 38

□ Oriskany brown-ore mines
1 Lowmoor
2 Rich Patch
3 Roaring Run
4 Oriskany
5 Renwick
6 Narrow Bank
7 Big Hill
8 Grace Allen
9 Reid
10 Cook
11 Sandbank
12 Callie
13 Wilton
14 Sheets
15 Mays
16 Retreat
17 Karnes
18 Holmes
19 McCarty
20 Lee

○ Clinton hematite mines
21 Roaring Run
22 House Mountain

■ Blue Ridge hematite mines
23 Bearwallow Hollow
24 Jennings Creek
25a Pico

● Blue Ridge brown-ore mine
25b Bearwallow Hollow

▲ Iron furnaces
26 Callie
27 Princess
28 Lowmoor
29 Roaring Run
30 Salisbury
31 Grace
32 Covington
33 Rebecca
34 Jane
35 Retreat
36 Etna
37 Arcadia (Boyd)
38 Glenwood

× Coal
39 Stone Coal Gap

⊠ Lime or limestone quarries
40 Eagle Rock Lime Co.
41 Virginia Lime Products Co.
42 Lowmoor
43 Compton
44 Pico
45 E. Dillon (Indianrock)
46 Liberty Limestone Corp.
47 Sherwood
48 E. Dillon (Dillon Station)
49 V.I.C. (Buchanan)

(Virginia Iron, Coal, and Coke Co.)

→ Show locations on areal map.

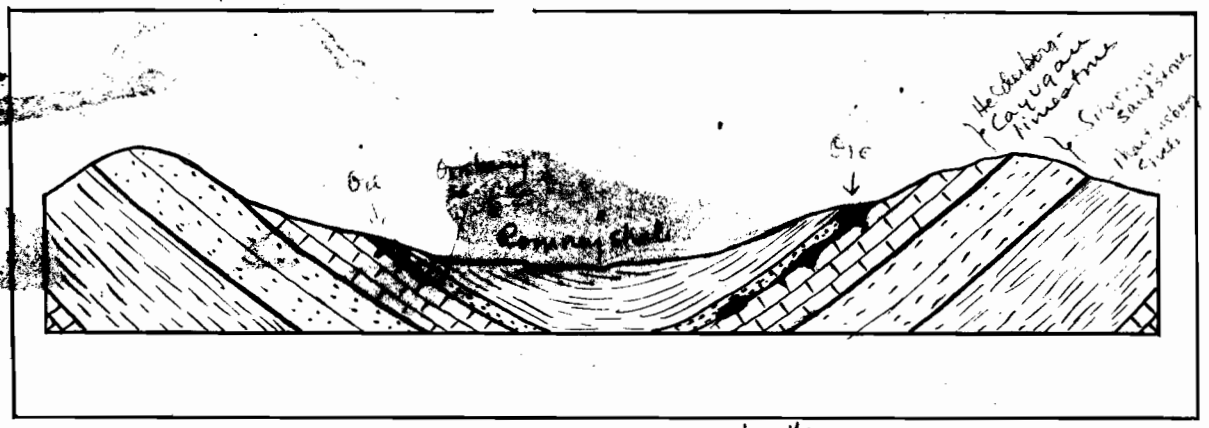


Figure 39. Generalized cross section showing the location of Oriskany brown iron-ore deposits. (see pages 306-7)

(near mss. p. 306)

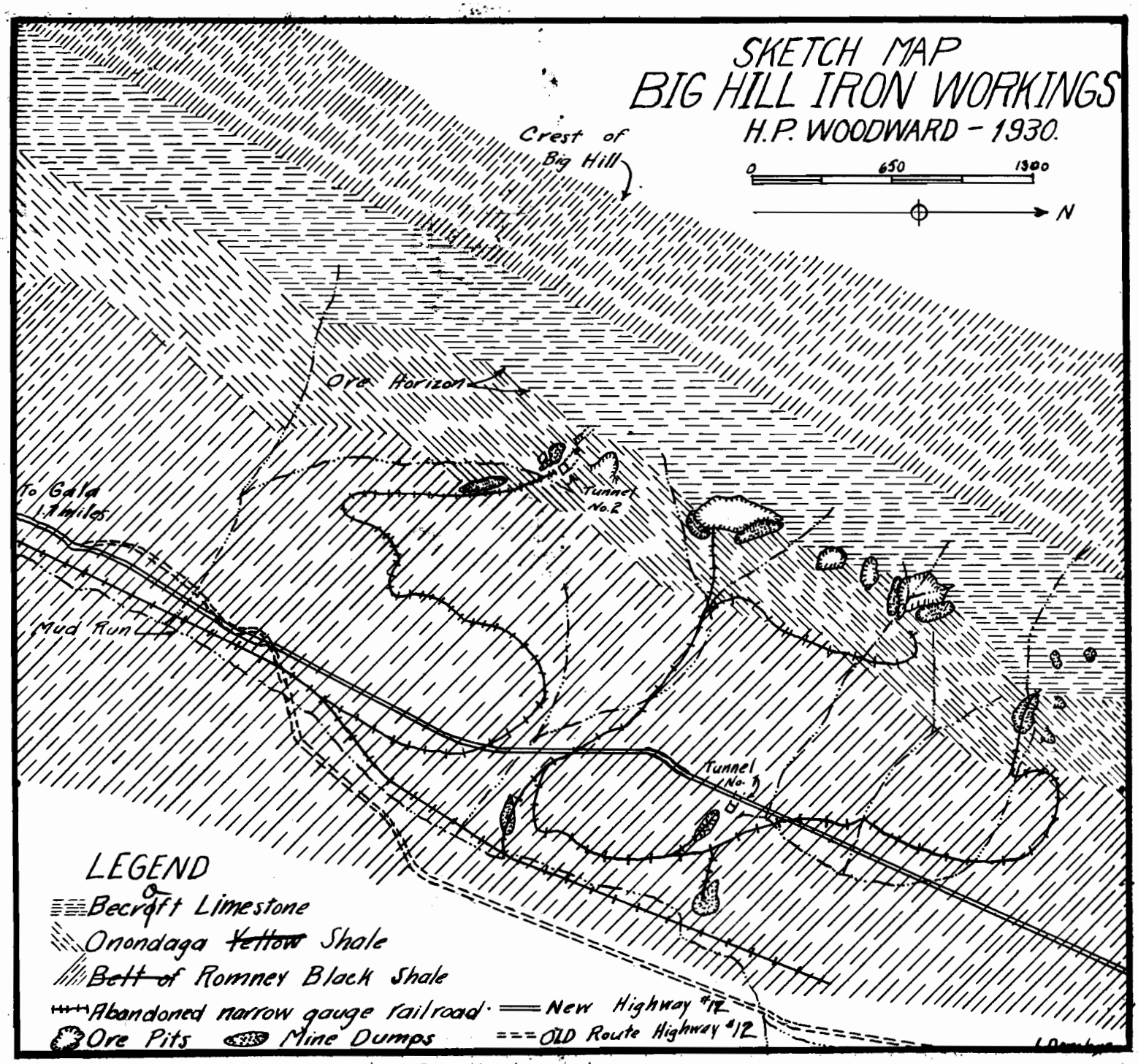


Figure 40. Sketch map of the Big Hill iron mines. (See p. 310-311.)

(near refs. p 310)

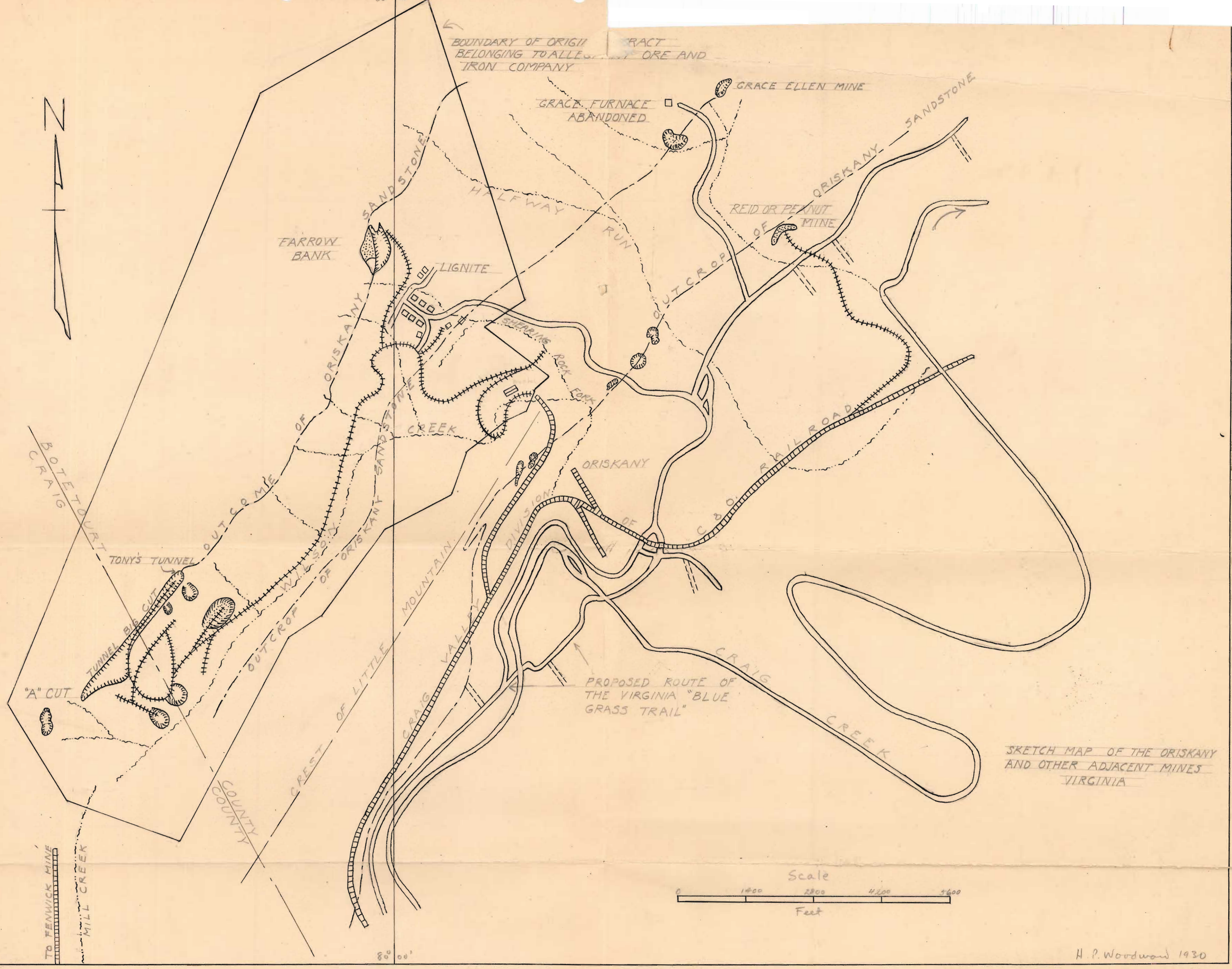
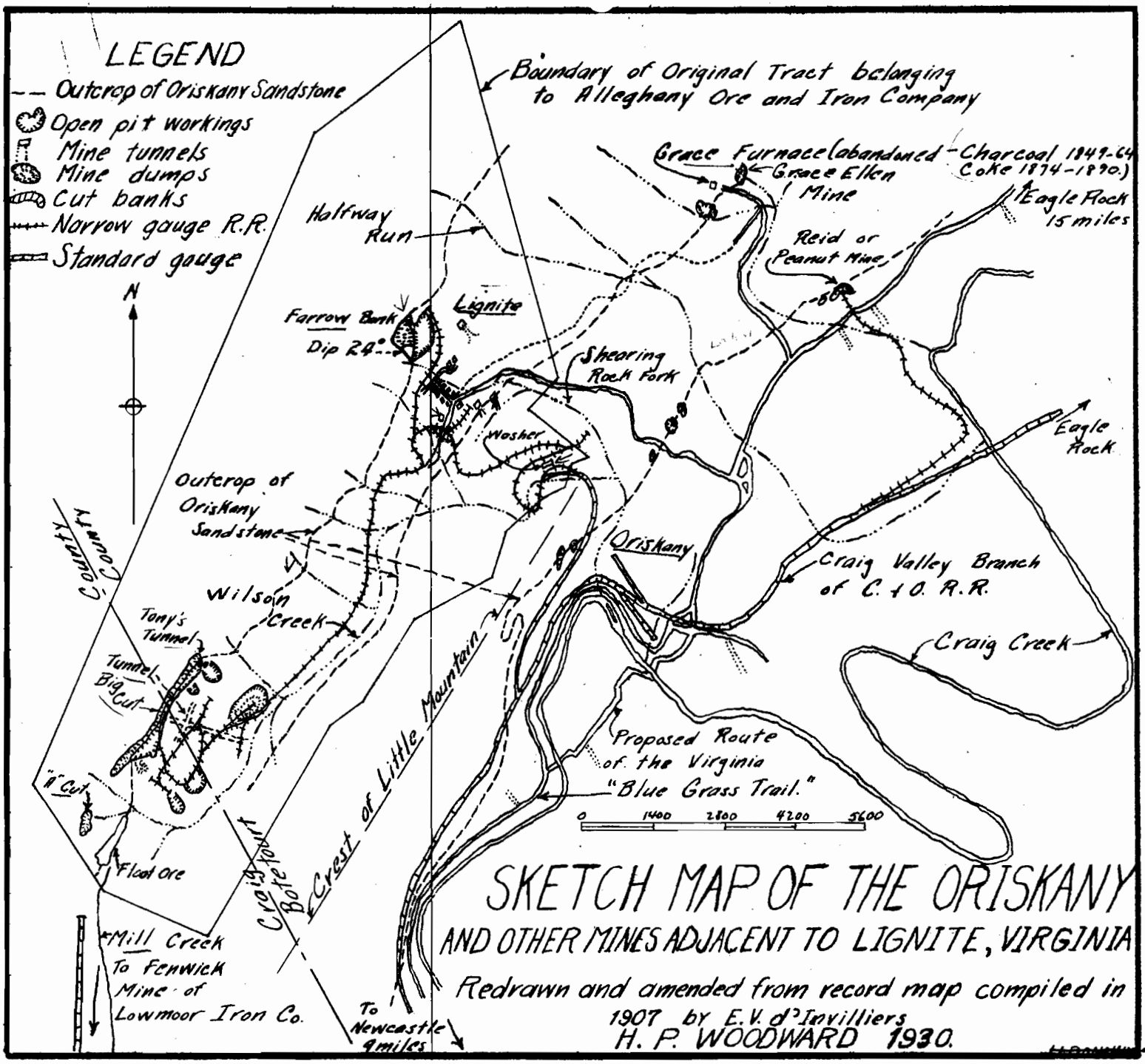


Figure 41. Sketch map of the Oriskany and other mines adjacent to Lignite, Virginia. Redrawn and amended from map compiled in 1907 by E. V. d'Invilliers. (See pp. 312-314.)

(near miss p. 312.)



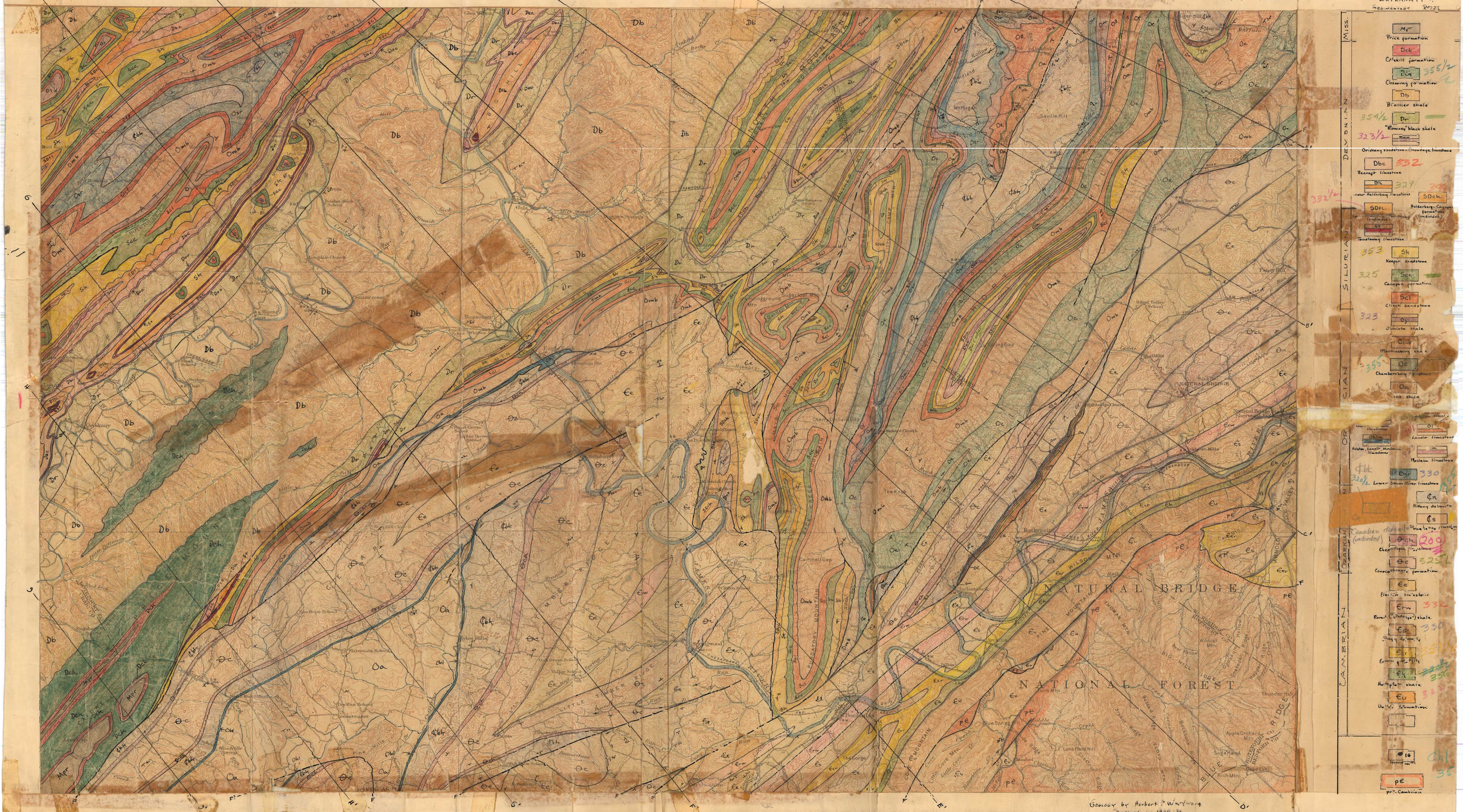
(Figure 41 duplicate)

(near mss. p. 312)

State Commission on
Conservation and Development

Virginia Geological Survey
Arthur Bevan, State Geologist

Bulletin , Plate 1



Base from United States Geological Survey maps of Eagle Rock and Natural Bridge quadrangles.

Geology by Herbert P. Woodward
Surveyed in 1928-32
pre-Cambrian mapping by A. S. Furcron

Geologic Map of the Natural Bridge Region, Virginia
Scale 1:62,000
Contour interval 50 feet

No. 204

Approximate scale of thicknesses for sections

Price	Mpr
Catskill	Dck
Chemung	Dch
Brallier	Db
"Romney"	Dr
Onondaga - Orisnany	Doo
Beereft	Doc
Helderberg	SDch
Konoloway	St
Keefer	Sk
Cacapon	Scc
Clinch	Scl
Juniata	Oj
Martinsburg	Omb
Chambersburg	Oc
Athens	Oa
Holston	Oh
Lenoir	Ol
Moshcim	Om
Stones River	Osr
Kittany	Obk
Stonehenge	Os
Chepultepec	Och
Conococheague	Cc
Elbrook	Ee
Rome ("Watauga")	Erw
Shady	Es
Erwin	Eer
Hampton	Eh
Unicoi	Eu
pre-Cambrian	pE

(Legend to [illegible] the [illegible] map.)

PLATE I

EXPLANATION

SEDIMENTARY ROCKS

(1)

The [illegible] of Quaternary is purposely omitted from the geologic map. If the [illegible] wishes to include it, a separate map showing its distribution will be sent upon request

QUATERNARY

Alluvium (Qal)
(floodplain deposits of recent streams)

--angular unconformity--

MISSISSIPPIAN

Price formation (Mpr)
(mainly sandstone with red shale in upper part and thin beds of conglomerate; containing thin bony coal seams in Stone Coal Gap; of Osage age; exposed in southwest part of Eagle Rock quadrangle only)

--unconformity--

DEVONIAN

Catskill formation (Dck)
(red shale and sandstone, unfossiliferous, mostly non-marine; exposed in southwest part of Eagle Rock quadrangle only)

Chemung formation (Dch)
(shale and sandstone, mostly gray and green, fossiliferous; outcrops restricted to Eagle Rock quadrangle)

Brallier shale (Db)
(greenish-gray shale and interbedded thin flaggy sandstone; of Portage age)

"Romney" black shale (Dr)
(dark-gray to black fissile shale; of Marcellus and Genesee age)

Onondaga shale (Doo)
(yellow-buff sandy shale with some greenish clay shale; mapped with Oriskany sandstone)

Oriskany sandstone
(coarse calcareous sandstone; mapped with overlying Onondaga shale, Doo)

--disconformity--

Becraft limestone (Dbc)
(massive gray fossiliferous limestone; middle portion with cherty zones; mapped separately in Rich Patch anticlinorium, Big Hill anticline, and Switzer Mountain belt; elsewhere mapped with Helderberg group, SDch)

Lower Helderberg group (Dlh)
(includes the Healing Springs sandstone, Coeymans limestone, and the Keyser formation; arenaceous cherty limestones and calcareous sandstones; most conspicuous member is the brown sandy Clifton Forge member of the Keyser formation; mapped separately in Big Hill anticline and the Deisher and Switzer mountain belts; mapped with Tonoloway limestone in the main Rich Patch anticlinorium, SDtl; elsewhere mapped with both Becraft and Tonoloway limestones, SDch)

--disconformity--

SILURIAN

Tonoloway limestone (St)
(thinly bedded shaly gray limestone; of Cayuga age; mapped separately in Big Hill anticline and the Deisher and Switzer mountain belts; mapped with the Lower Helderberg group in the main Rich Patch anticline, SDtl: elsewhere mapped with the Helderberg group, SDch)

--disconformity--

Keefer sandstone (Sk)
(massive friable to dense white and red sandstone; of Clinton age)

Cacapon formation (Scc)
(mainly red sandstone and red to green shale; of Clinton age)

Clinch sandstone (Scl)
(coarse cross-bedded massive gray quartzitic sandstone; of Medina age)

--unconformity--

ORDOVICIAN

Juniata shale (Oj)
(thinly bedded purplish-red sandstone and shale; of Richmond age; mapped separately in Rich Patch anticlinorium only; if present elsewhere, included with Martinsburg shale)

Martinsburg shale (Omb)
(calcareous and sandy shale, thin sandstone, and thin beds of impure limestone; of Trenton, Eden, and Maysville age)

Chambersburg limestone (Oc)
(mainly evenly thin-bedded bluish limestone, partly nodular and argillaceous; of Lowville age; exposed in Natural Bridge quadrangle only)

--disconformity--

Lowville limestone
(medium-bedded dark limestone and pure dove-colored limestone; not mapped separately; included with Lenoir limestone in Rich Patch valley, Oll)

--disconformity--

Athens shale (Oa)
(dark-gray to black shale with thin beds of limestone; contains massive pebble conglomerate near Pine Hills; of Mid-Chazy (Blount) age; absent in Rich Patch anticlinorium and in Rapps Mill anticline south of Rockbridge County, locally includes the Whitesburg limestone)

Holston limestone (Oh)
(light-colored massive crystalline limestone; of Chazy (lower Blount) age; mapped separately in Natural Bridge quadrangle (Oh) except in Rapps Mill anticline southwest of Rapps Mill where it is less than 5 feet thick and is included in the Lenoir outcrop; in the Eagle Rock quadrangle, mapped with the Lenoir limestone, Ohl; absent in Rich Patch valley)

Lenoir limestone (Ol)
(dark knobby medium-coarse limestone; of Stones River age; mapped separately in the Natural Bridge quadrangle; includes Holston limestone in Rapps Mill anticline southwest of Rapps Mill, Ol; in southern half of Eagle Rock quadrangle, mapped with Holston limestone, Ohl; in Rich Patch valley, mapped with Lowville limestone, Oll)

Moshein limestone (Om)
(light dove-colored compact limestone; of lower Stones River age; mapped separately in the Natural Bridge quadrangle, Om; absent in the Eagle Rock quadrangle)

Lower Stones River limestone (Osr)
(dark coarsely crystalline cherty limestone; absent in southern half of the Eagle Rock quadrangle and near Buratt)

--unconformity--

CAMBRIAN

Bellefonte dolomite
(thick-bedded massive dolomite, chert-producing; of Beekmantown age; mapped with Nittany dolomite, ¢bl)

Nittany dolomite (¢n)
(Thick-bedded massive dolomite, chert-producing; of middle Beekmantown age; mapped separately between Cedar Creek and Rocky Run, ¢n; elsewhere mapped with Bellefonte dolomite, ¢bl)

Stonehenge limestone (¢s)
(medium-bedded dark limestone and dolomite; of lower Beekmantown age; mapped separately between Cedar Creek and Rocky Run, ¢s; if present elsewhere, included with Chepultepec limestone, ~~Och~~)

--unconformity--

OZARKIAN

Chepultepec limestone (~~Och~~)
(medium to massive limestone and dolomite; of upper Ozarkian age; indicated in geologic sections with Conococheague dolomite as ~~Oz~~)

--disconformity--

Conococheague formation (Cc)
(massive to thinly bedded dolomite, limestone, and calcareous shale; thin zones of calcareous sandstone; indicated in geologic sections with Chepultepec limestone by Cz)

--unconformity--

CAMBRIAN

Elbrook limestone (Ce)
(thick-bedded to shaly argillaceous limestone, some pure dolomite; of late Cambrian age)

Rome ("Watauga") shale (Crw)
(red, purple, and green shale with thin interbedded bluish limestone and some calcareous sandstone; of early and middle Cambrian age)

Shady dolomite (Cs)
(dark to light massive dolomite and calcareous shale; of early Cambrian age; exposed in Natural Bridge quadrangle only)

--unconformity--

Erwin quartzite (Cer)
(irregularly bedded coarse quartzitic sandstone; of early Cambrian age; exposed in Natural Bridge quadrangle only)

Hampton shale (Ch)
(thinly bedded sericitic sandy shale; of early Cambrian age; exposed in Natural Bridge quadrangle only)

Unicoi formation (Cu)
(irregularly bedded sandstone, shale, quartzite, and hematite, with rhyolitic lava flows at base; of early Cambrian age; exposed in Natural Bridge quadrangle only)

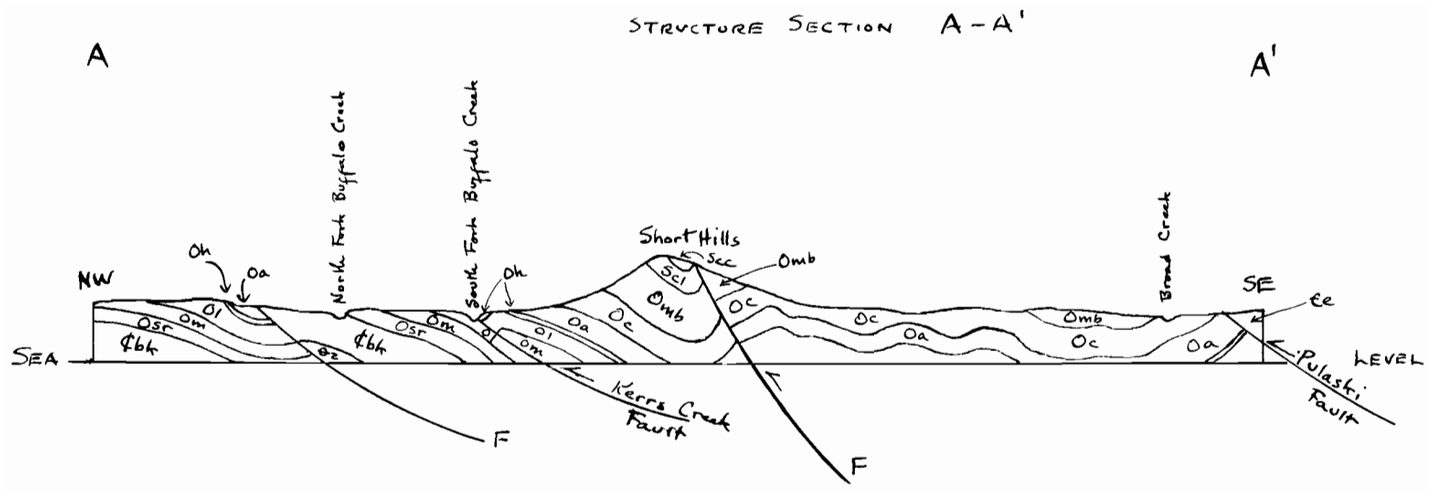
--angular unconformity--

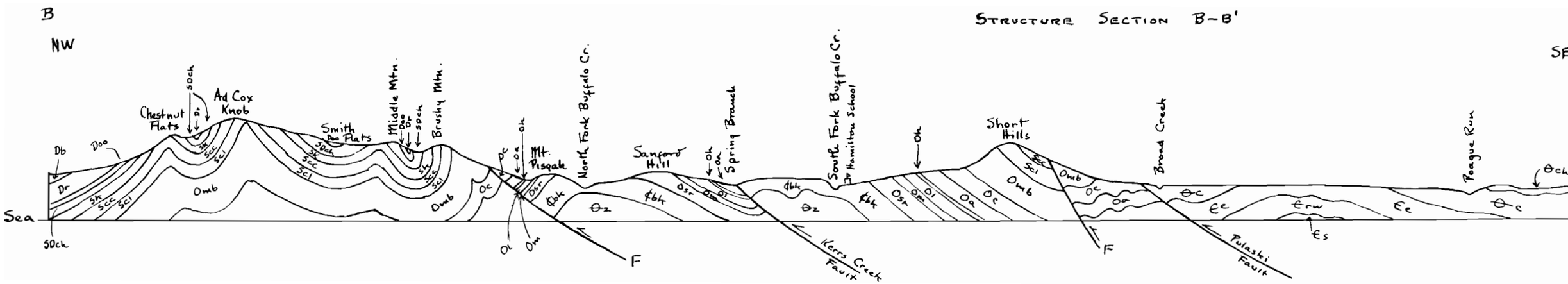
PRE-CAMBRIAN (pC)

(undifferentiated metamorphic and igneous rocks, including schist, gneisses, granite, and granodiorite; exposed in southeast portion of Natural Bridge quadrangle only)

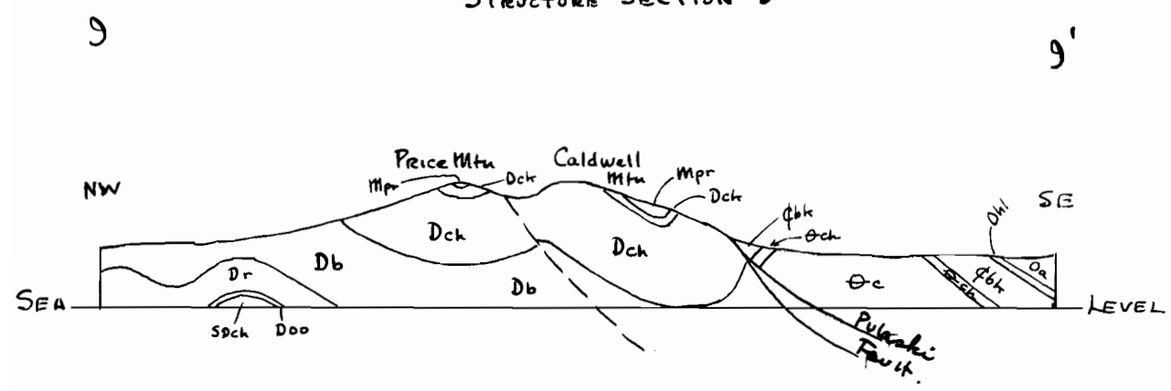
IGNEOUS ROCKS

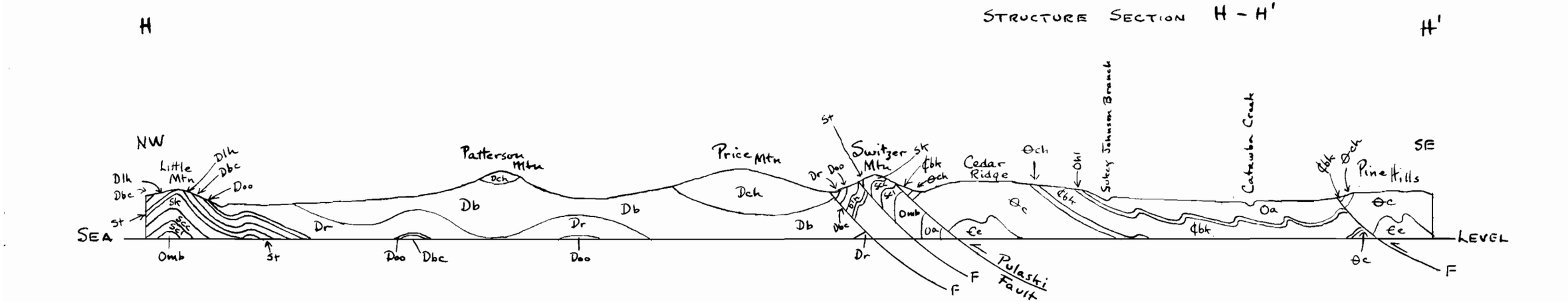
Peridotite and related rocks (26) (J_g)
(stocks and dikes; probably of Triassic age)


STRUCTURE SECTION A-A'
A
A'
NW
SE
SEA
LEVEL
North Fork Buffalo Creek
South Fork Buffalo Creek
Broad Creek
Short Hills
Scc
Omb
Scl
Oh
Oa
Ol
Osr
Om
Oc
Ꞓbk
Ꞓe
Kerrs Creek Fault
Pulaski Fault
F
F


B
NW
Structure Section B–B'
SE
Chestnut Flats
Ad Cox Knob
Smith Flats
Middle Mtn.
Brushy Mtn.
Mt. Pisgah
North Fork Buffalo Cr.
Sanford Hill
Spring Branch
South Fork Buffalo Cr.
Hamilton School
Short Hills
Broad Creek
Poague Run
Sea
SDch
Db
Dr
Doo
Sk
Scc
Scl
Omb
Oc
Oa
Ol
Om
Osr
Obk
Oz
Ec
Erw
Es
F
Kerrs Creek Fault
Pulaski Fault

STRUCTURE SECTION 9-9'





H
STRUCTURE SECTION H - H'
H'
NW
SE
SEA
LEVEL
Little Mtn
Patterson Mtn
Price Mtn
Switzer Mtn
Cedar Ridge
Sukey Johnson Branch
Catawba Creek
Pine Hills
Pulaski Fault
Dlh
Dbc
Doo
St
Sk
Scc
Scl
Omb
Dr
Db
Dch
Oa
Oc
Ohl
Ꞓbk
Ꞓe
F

Quaternary gravels and sands
Qal

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

VIRGINIA
EAGLE ROCK QUADRANGLE

(Lewisburg) 125000 — (Natural Bridge) 125000

80°00' — 55' — 50' — 45' — 79°45'
37°45' — 40' — 35' — 37°30'

(Lewisburg) 125000 — (Natural Bridge) 125000

(Christiansburg) 125000 — (Roanoke) 125000

(Roanoke 125000)

ENGRAVED JULY 1915 BY U.S.G.S.

R.B. Marshall, Chief Geographer.
Frank Sutton, Geographer in charge.
Topography by Albert Pike and T.F. Slaughter.
Control by Oscar Jones, R.S. Deemer, T.A. Green, H.S. Senseney, and N.A. Campbell
Surveyed in 1908 and 1913.

Slaughter
Pike

Scale 1/62500

1 0 1 2 3 4 Miles

1 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.
Datum is mean sea level.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1913.

Edition of 1915

EAGLE ROCK

Quaternary gravels and sands
Qal

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

VIRGINIA
NATURAL BRIDGE SPECIAL MAP

(Natural Bridge 125000) (Lexington 125000)

79°45' 40' (Natural Bridge 125000) 35' 79°30'
37°45' 37°45'

NORTH MOUNTAINS
SANDBANK
MOUNTAIN
BRUSHY MTN
MIDDLE MTN
BIGGS MTN
PANTHER MTN
CAMP MOUNTAIN
LITTLE CAMP MTN
SHORT HILLS
BACK CREEK MOUNTAIN
PURGATORY MOUNTAIN
COVE MOUNTAIN
WILSON MTN
THOMAS MTN
BIG HILL RIDGE
PINE RIDGE
FLOYD MTN
BLUE RIDGE
NATURAL BRIDGE
NATIONAL FOREST

Chestnut Flats
Ad Cox Knob
Smith Flats
Sinking Creek
Rocky Ct
Bobbs Hollow
Bearwallow
Winding Ridge
South Branch
Limestone Hollow
TRAMROAD
Jane Furnace (RUINS)
Rebecca Furnace (RUINS)
ROCKY FORD
Mill Creek
Wildcat Mtn
Prisehouse Mtn
Grassy Mtn
Scurff Mtn
Stampingground Mtn
Sugarloaf Mtn
Garden Mtn
Gully Mtn
Orebank Mtn
Turkeypen Hollow
Hickory Hollow
Brushy Mtn
Mt Carmel Church
Saltpetre Cave
Green Spur
Mt Benlah Church
Calvary School
Horseshoe Bend
Rich Hill
Round Mtn
Peter Branch
Clifton School
Springwood
CHESAPEAKE & OHIO R.R.
David Run
Lung Run
Buchanan
The Gorge
Cartmell Gap
Gray Ledge
Indianrock
Arcadia
Thrill
Solitude
Tory Hollow
Reidland
Piny Knob
Mt Pisgah
Saville Hill
North Branch
Sanford Hill
The Pinnacle
Oakdale
Bull Run
Middle Creek
Buffalo Creek
Kiger Hill
Mural
Buffalo Lick Run
South Branch
Hamilton School
Seceder Church
Longwood
Fancy Hill
Rocky Run
Indian Lodge ROAD
Rural Valley School
VALLEY ROAD
Cedar Creek
Spring Gap
Red Mills
BOUNDARY LINE
Buck Hill
NATURAL BRIDGE
Highbridge Church
Natural Bridge Sta
Sherwood PO
Cherry Orchard Gap
Dunkard Church
Karnes Spring
The Knob
Rockypoint
Gilmore Mills
Gilmore Hollow
Big Hollow Br
Rutrough Run
Mill Mtn
Cave Mtn
Fancy Hill
Wildcat Mtn
Bear Hollow
Opossum Ridge
Snakeden Ridge
Hopper Ridge
Thunder Hill
Fork Mtn
Blue Sprigg Hill
Middle Creek
Southside Ridge
Lone Field Hill
Mumford Chestnut Ridge
Bryant Ridge
Buzzard Ridge
Cornelius Backbone Ridge
Apple Orchard Mtn
Sugarland
Dead Log
Rich Mtn
Little Cove Mtn
Yellowstone Ct
Mortella Ct
Jennings Creek
Lick Run
Trimble Run
Sprouts Run
Drumming Hill
Caney Run
Arnold Valley

ROANOKE RIVER DIVISION
JAMES RIVER DIVISION
SHENANDOAH
CHESAPEAKE & OHIO R.R.
NORFOLK & WESTERN R.R.
OLD CANAL
TRAMROAD
ROAD
TRAIL
BOTETOURT CO
ROCKBRIDGE CO
BEDFORD CO

(Eagle Rock) (Roanoke 125000) (Lexington 125000)

ENGRAVED JULY 1907 BY U.S.G.S.

H. M. Wilson, Geographer.
Van. H. Manning, in charge of section.
Topography by Van. H. Manning, Albert Pike, J. W. Bagley, W. H. S. Morrey, Fred Graff, Jr., and R. L. Harrison.
Control by Oscar Jones.
Surveyed in 1905-1906.

APPROXIMATE MEAN DECLINATION 1906

Scale 1/62500
1 0 1 2 3 Miles
1 0 1 2 3 Kilometers

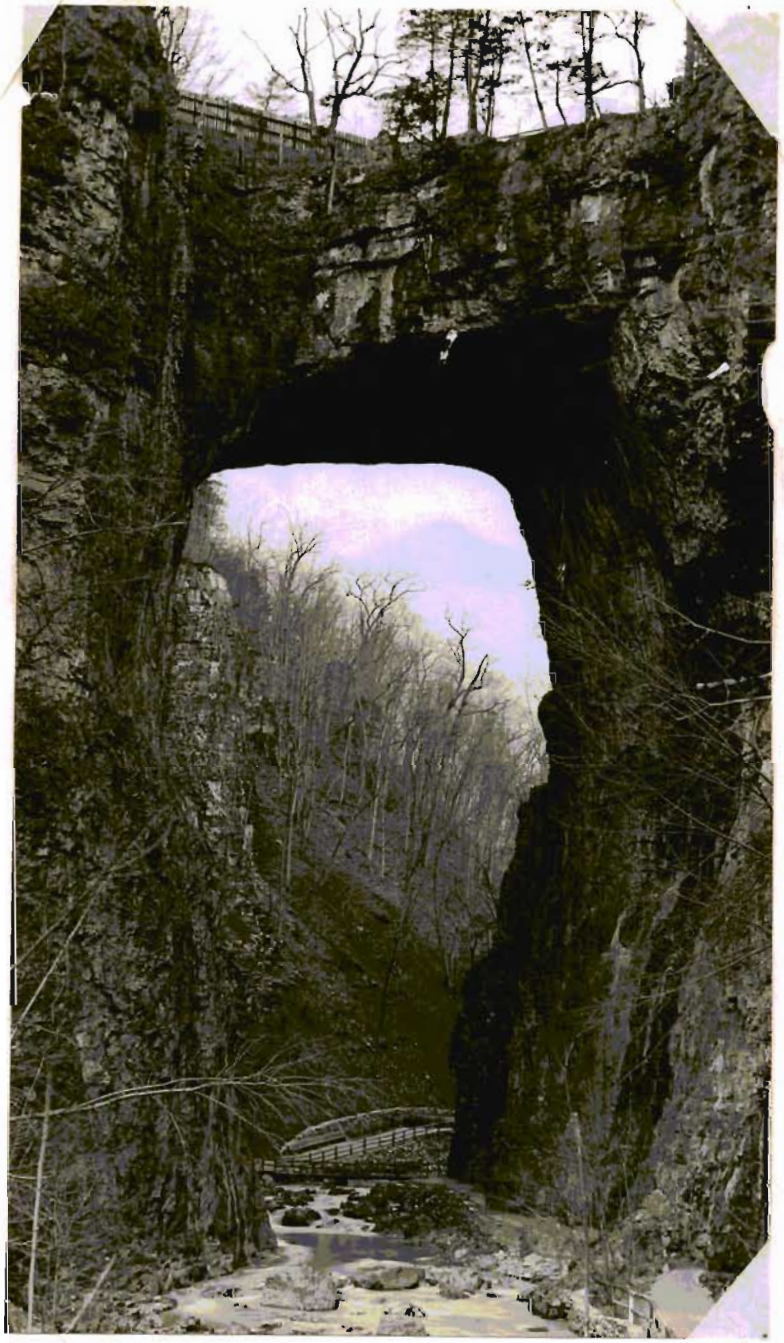
Contour interval 50 feet.
Datum is mean sea level.

Edition of Nov. 1907, reprinted 1922.

NATURAL BRIDGE SPECIAL

PLATE 3

(Frontispiece)



Natural Bridge, viewed from the south. This April view shows the fluted undersurface of the bridge and the vertical walls of the gorge of Cedar Creek. U. S. Highway 11, which crosses the arch is protected by the board fence, visible above the bridge. For a description of Natural Bridge, see pages 48 to 66. (Compare with Pl. 20.)

PLATE 5

(Near manuscript page 19)

Note alternate view

A. The village of Buchanan, viewed from the flank of Purgatory Mountain. The main Blue Ridge forms the background; its foothills come down nearly to James River. (See p. 27.)

Note alternate view

B. The village of Eagle Rock, viewed from the eastern pinnacle of Crawford Mountain. (See pp. 27 and 329.)

PLATE 6

(Near manuscript page 20)

A. The blunt southwestern end of Short Hills, viewed northeastward from a point near Dunkard Church. (See pp. 20 and 240.)

B. Short Hills, viewed southward from the crest of North Mountain, 2 miles west of Alpine. The northern end of Green Hill is visible at the extreme right. (See pp. 20, 45, and 240.)

Fincastle and the Fincastle Valley. View looking north. This village, once the seat of Fincastle County which then extended to Mississippi River, is one of the oldest settlements west of the Blue Ridge. The wooded ridge in the center is Pine Hills. Aeroplane photograph by Underwood and Underwood. (Courtesy of Roanoke Chamber of Commerce.) (See pp. 20,23,27,36 and 41.)

PLATE 8

(Near manuscript page 21)

Note alternate view

A. Apple Orchard Mountain, elevation 4,224 feet above sealevel, viewed southward from Arnold Valley. (See pp. 21 and 35.)

B. The crest and summit of Rich Patch Mountain, maximum elevation 3,728 feet above sealevel, viewed from Craig Creek, near Horton. (See pp. 21 and 230.)

PLATE 9

(Near manuscript page 25)

A. Subsoil pinnacles of Nittany dolomite produced by unequal decomposition and exposed by removal of residual soil. Near abandoned lime quarry along State Highway 12, 1 mile southwest of Eagle Rock. (See pp. 25, 114, and 188.)

B. The gullied outcrop of Conococheague limestone near Midway School, 5 miles southwest of Eagle Rock. The gully in the central foreground is 6 feet deep; all have resulted from improper cultivation. Gullies of this type are especially common on the steep slopes of the Appalachian ridges. (See pp. 25 and 108.)

PLATE 10

(Near manuscript page 28)

A. The irregular foothills of Rich Patch Mountain, viewed southwestward from a point near Hooks Mill. An excellent stand of timber covers many of these ridges. (See pp. 25, 37 and 231.)

B. The headwaters of Sloan Branch in the heart of the James River range east of Eagle Rock. Viewed northeastward from the flank of Sugarloaf Mountain. (See pp. 25 and 321.)

PLATE 11

(Near manuscript page 29)

A. The floodplain of James River, south of Purgatory Mountain, 1 mile above Buchanan. View looking east. (See pp. 28 and 77.)

B. The floodplain of James River, 1 mile north of Eagle Rock. View looking north. (See p. 77.)

PLATE 12

(Near manuscript page 29)

A. During the period of 1920-1924, Lignite was a thriving mining camp, housing over 100 families; now it is largely abandoned. (See pp.28 and 312.)

B. A new concrete bridge carries State Highway 12 across James River at Eagle Rock. View looking northeast toward Rathole Mountain. Keefer sandstone ledges form the rock wall opposite the bridge; the wooded slope east of the cliffs is developed on Cacapon sandstone; Clinch ledges are visible on the extreme right slope of the mountain. (See pp, 29, 158-159, and 264-265.)

PLATE 13

(Near manuscript page 33)

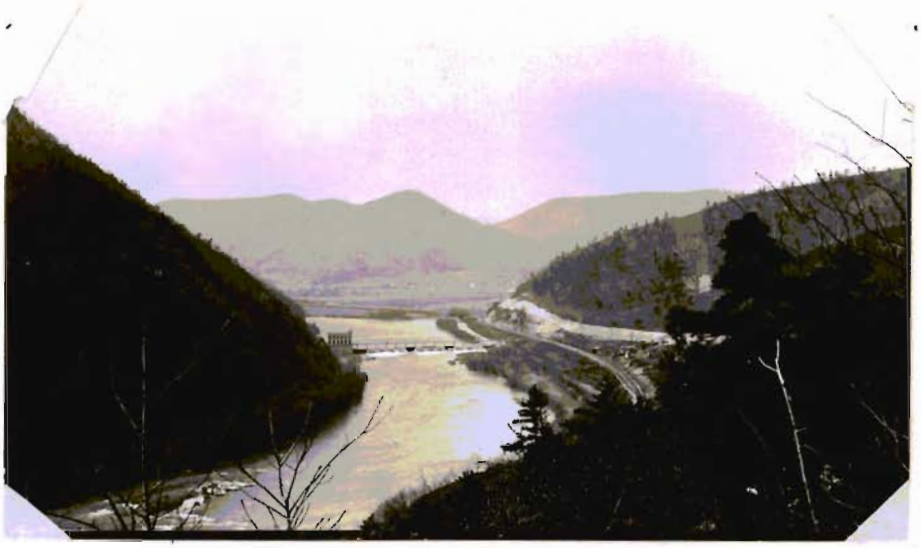
A. The symmetrical cone-like end of Purgatory Mountain, viewed from the south. Summit elevation, 3,081 feet above sealevel. The trace of the Pulaski overthrust fault swings around this point. (See pp. 20 and 241.)

B. Montgomery Knob, elevation 3,593 feet, viewed southwestward from Hooks Mill up the valley of Finley Branch. The cap on the knob is formed by a shallow syncline of Clinch sandstone; the slopes are developed on Martinsburg shales. (See pp. 144 and 230.)

PLATE 14

(Near manuscript page 35)

Note alternate view



A. The gorge of James River through the Blue Ridge above Balcony Falls. View faces northwestward. (See pp. 35 and 68.) The sag in the central background is the Sallings Mountain windgap. (See p. 74.)

B. Entrance of James River into its gorge above Balcony Falls. View faces southeastward from the floodplain near Glascow. (See above.)

PLATE 15

(Near manuscript page 38)

Panoramic view looking northeastward up James River valley. Rich Patch Mountain forms the central background; Rocky Hill is at the extreme right. The Iron Gate watergap of James River is visible at the head of the valley. (See pp. 38, 43, 157, and 230.)

Poor fr & tone

PLATE 16

(Near manuscript page 39)

Note alternate view

A. The Upland peneplane as developed on Rich Patch Mountain. View looking northwestward from Craig Creek valley. (See pp. 39 and 230.)

B. The level crest of Pine Mountain southeast of Indianrock, viewed southwestward from James River near Arcadia. This surface may represent an intermediate erosional level between the Upland and Valley-floor peneplanes. (See p. 44.)

PLATE 17

(Near manuscript page 42)

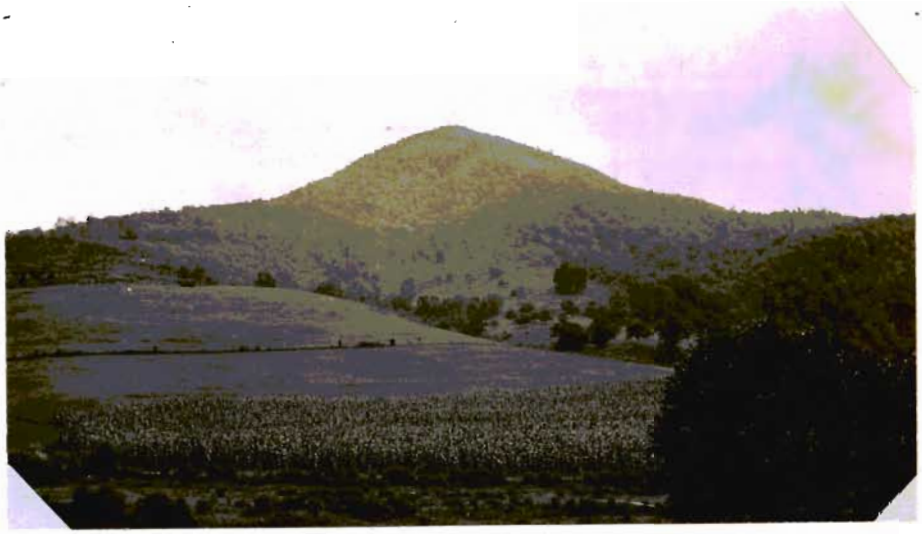
A. The rolling Valley-floor peneplane between David and Long runs, 3 miles west of Buchanan. View looking southward from hillcrest near Springwood. (See pp. 41 and 105.)

B. The level surface of the Valley-floor peneplane as developed near Bessemer. View looking northward through the Eagle Rock gap of James River. The Upland peneplane, on Rich Patch Mountain, is faintly visible in the distant background. (See pp. 42 and 263.)

PLATE 18

(Near Manuscript page 45)

A. The Knob, elevation 2,682 feet, 6 miles north of Buchanan, viewed northwestward from Lee Highway. (See p. 72.) No Silurian sandstone is present at the top of this knob.



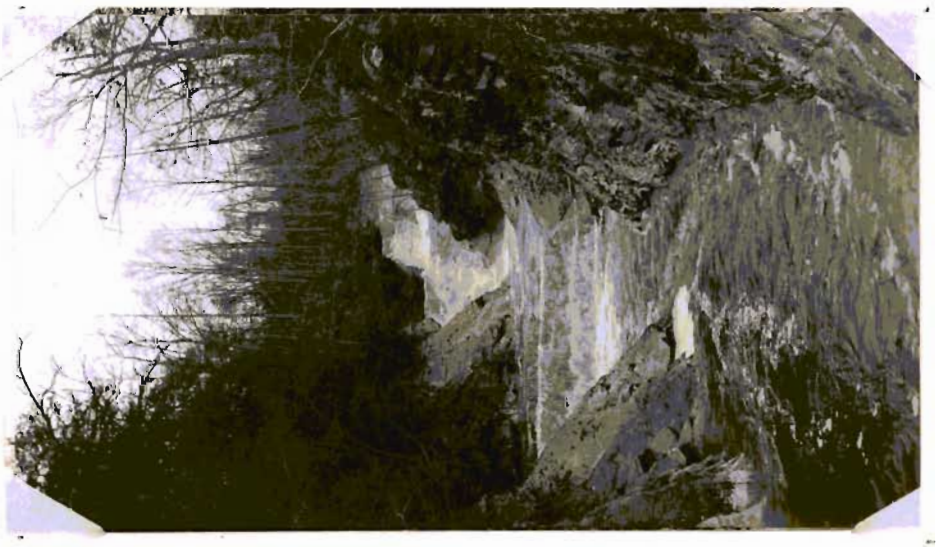
B. The northern end of Short Hills, viewed southward from a point 2 miles west of Murat. (See pp. 20, 45, and 240.)

PLATE 19

(Near manuscript page 51)

B. Cedar Creek, viewed southward from the arch of Natural Bridge. (See p. 51.)

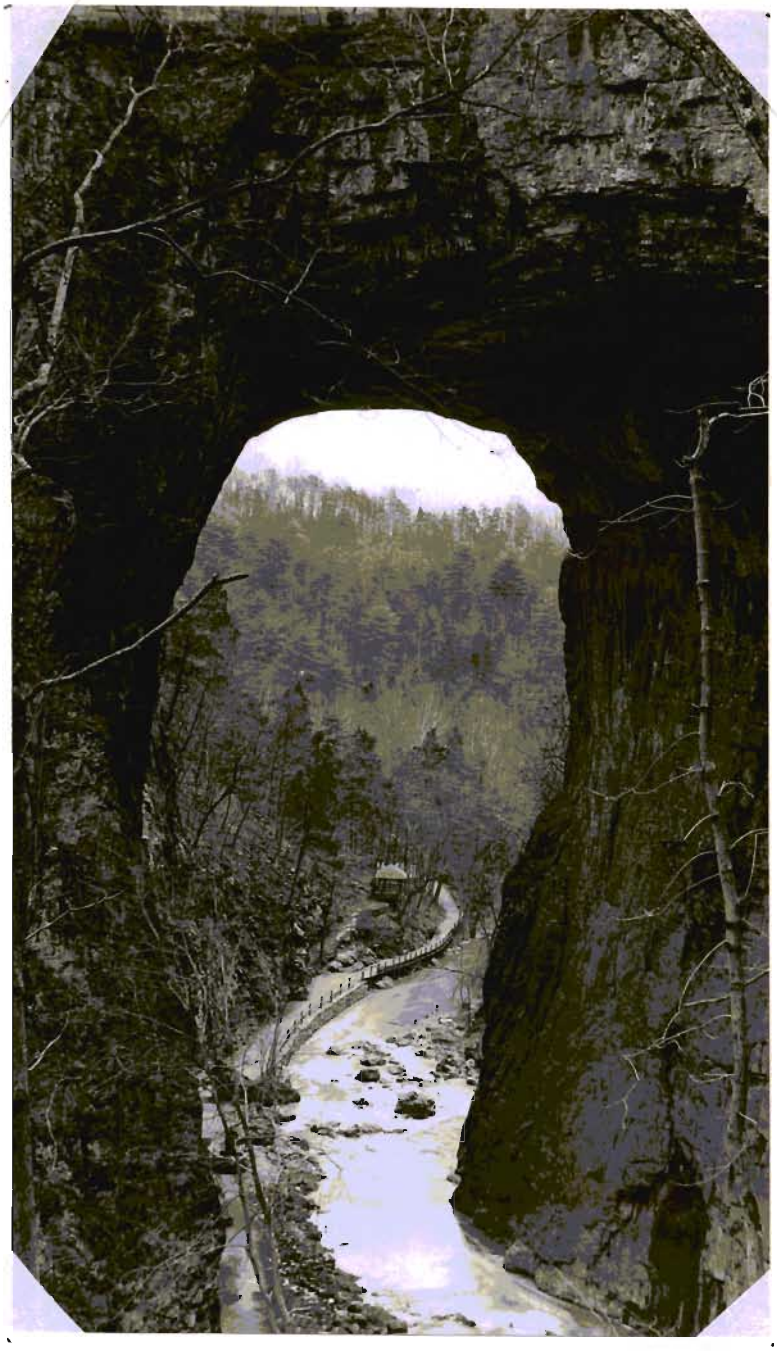
why use?



A. Lace Falls of Cedar Creek, 1 mile above Natural Bridge. (See p. 51.)

PLATE 20

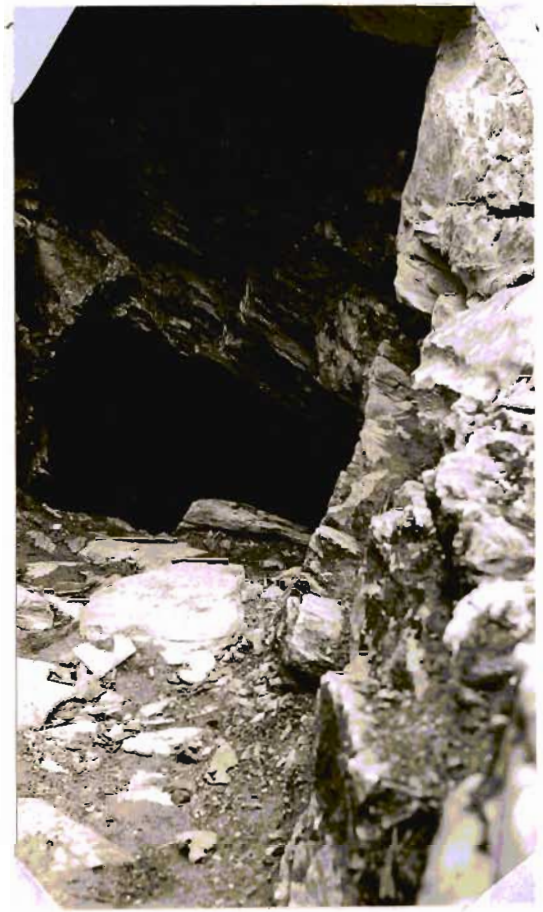
(Near manuscript page 52)



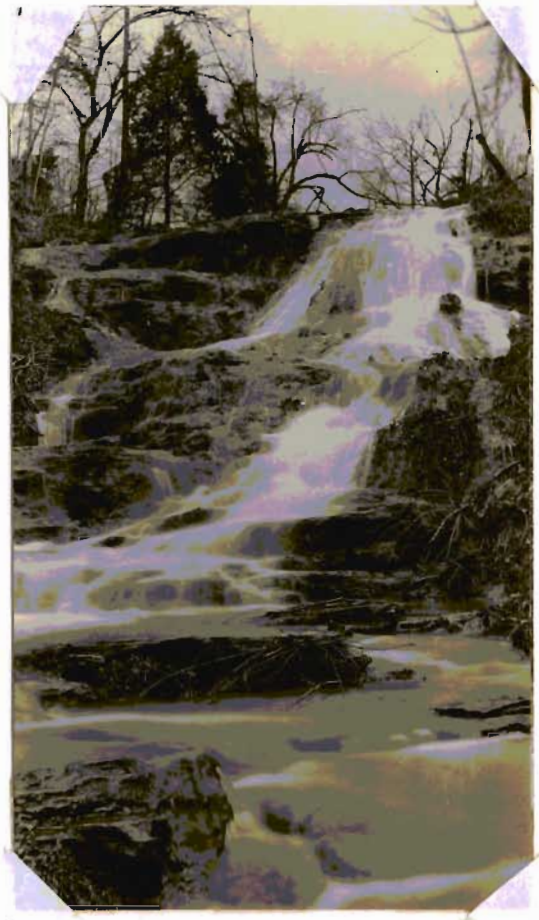
The arch of Natural Bridge, viewed from the north.
(See pp. 51-52.)

PLATE 21

(Near manuscript page 59)



A. The entrance to "Lost River" in the gorge of Cedar Creek, above Natural Bridge. (See p. 60.)



B. Cascade Creek, near its discordant junction with Cedar Creek, immediately below Natural Bridge. (See p. 59.) (Note alternate view)

PLATE 22

(Near manuscript page 62)

August view of Natural Bridge, looking northward from Pine Laden. (See p. 62.) Compare with Pl. 23.

Cline 1 = Pls. 3, 20, 22, 23.

PLATE 23

(Near manuscript page 62)

April view of Natural Bridge, looking northward from Pine Laden. Compare with Pl. 22.

PLATE 24

(Near manuscript page 68)

A. The watergap of James River at Eagle Rock viewed from the south; Rathole Mountain is at the right, Crawford Mountain is at the left. (See pp. 67 and 263.) Compare with view below.

B. The rocky face of Rathole Mountain and the Eagle Rock Gap of James River, viewed from the northeast across the floodplain of Craig Creek.

PLATE 25

(Near manuscript page 73)

Note alternate view

A. "The Gorge", a prominent windgap in the Blue Ridge foothills, 1½ miles south of Buchanan. The main Blue Ridge forms the central background. (See p. 73.) Compare with view below.

B. A view of the gorge looking northwestward.

PLATE 26

(Near manuscript page 77)

A. The confluence of James River (right) and Craig Creek (left) floodplains, viewed northeastward from the crest of Rathole Mountain. (See pp. 42-43 and 77.)

B. The fertile James River floodplain above Eagle Rock, viewed northward from top of Crawford Mountain.

PLATE 27

(Near manuscript page 85)

A. The coarse conglomerate at the base of the Unicoi formation inclosing various pebbles of pre-Cambrian crystalline rocks. Near Snowden, at Balcony Falls of James River. (See p. 85.)

B. Contact of thin-bedded Hampton shale (above) and massive Unicoi sandstones (below) along U.S. Highway 501 near Balcony Falls. (See pp. 93 and 95.)

PLATE 28

(Near manuscript page 96)

A. Basal contact of Erwin quartzite (above) upon Hampton shale (below) along U. S. Highway 501 near Balcony Falls. (See pp. 95 and 97.)

B. Prominent jointing in a massive bed of Erwin quartzite, exposed along U. S. Highway 501 northwest of Balcony Falls. (See pp. 96 and 269.)

PLATE 29

(Near manuscript page 99)

Note alternate views

A. Folded sandstones of the Erwin quartzite, exposed along James River near Dillons Quarry. (See pp. 97 and 227.)

B. Massive Shady dolomite in a quarry face near Pico camp, 3 miles southwest of Buchanan. (See pp. 100 and 341.)

PLATE 30

(Near manuscript page 102)

Note alternate view

A. Sharp-crested Blue Ridge foothills of Erwin quartzite, rising from the confluent floodplains of James and North rivers, east of Glascow. (See pp. 34, 68, 83, and 97.)

B. Rounded hills on the Rome ("Watauga") outcrop southwest of Buchanan. (See p. 102.)

PLATE 31

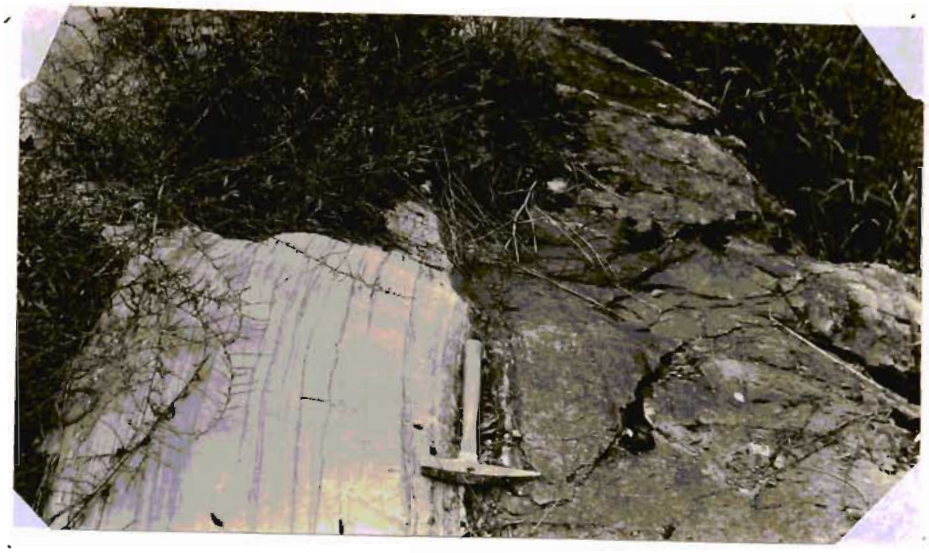
(Near manuscript page 104)

A. Sharp hogback ledges of Rome ("Watauga") shale near mouth of Purgatory Creek, east of Buchanan. (See p. 102.)

B. Hackly Elbrook limestone along Lee Highway, ½ mile south of bridge over Buffalo Creek. Notice several vertical joints in the ledges. (See pp. 104 and 268.)

PLATE 32

(Near manuscript page 109)

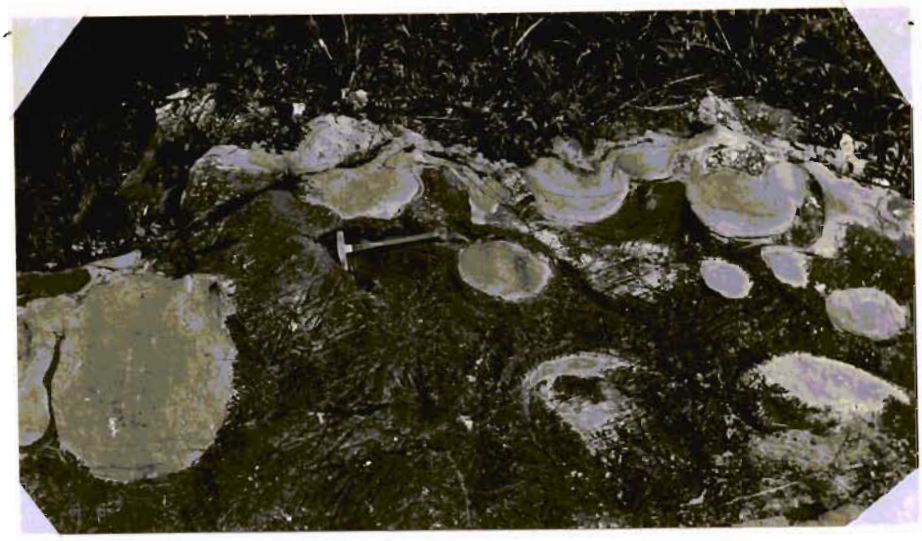


A. Contact of dolomite (left) and limestone (right) within the Conococheague formation, 1 mile southeast of Natural Bridge along State Highway 249. (See p. 109.)

B. Irregular calcite veins in the Conococheague formation along Lee Highway, 2 miles north of Natural Bridge. (See p. 109.)

PLATE 33

(Near manuscript page 111)



A. Cryptozoa in the Conococheague formation along Lee Highway, 2 miles northeast of Buchanan. (See p. 111.)

B. Sandstone bed in the Conococheague formation, 1 mile south of Fancy Hill. (See p. 109.)

PLATE 34

(Near manuscript page 114)

A. Canadian (Nittany) dolomite along Lee Highway, ½ mile north of bridge over Buffalo Creek.
(See p. 114.)

B. Lower Stones River limestone in Rich Patch valley, 1 mile southwest of Rich Patch School.
(See p. 121.)

PLATE 35

(Near manuscript page 121)

The two illustrations below were used in the article "Paleozoic cherts of west-central Virginia", Journal of Geology, vol. 39, 1931, pages 282-3.

If desirable, they may be used again in the Natural Bridge report; and the cuts from which they were made are in the Survey files.

A.

FIG. 1.—Chert on exposure of the Lower Stones River limestone. Rich Patch Valley, Alleghany County, Virginia. (See pp 121-122.)

B.

FIG. 2.—Residual chert in weathered soil of the Nittany dolomite, Rich Patch Valley, Alleghany County, Virginia. (See pp 114-115.)

PLATE 36

(Near manuscript page 125)

A. Horizontal surface of Lenoir limestone showing laminated character and structural unconformity. Sugartree Hollow, 6 miles southwest of Eagle Rock. (See p. 125.)

B. Gently folded shaly limestone at base of Athens shale near Dunkard Church. (See pp. 133 and 138.)

PLATE 37

(Near manuscript page 135)

A. Jointed black Athens limestone along Buffalo creek, south of Collierstown. (See pp. 133 and 268.)

B. Pebbly conglomerate in Athens shale, 1½ miles north of Lincastle. (See pp. 135-136.)

PLATE 38

(Near manuscript page 141)

A. Knobby phase of Chambersburg limestone along Buffalo Creek, south of Collierstown. (See pp. 141-142.)

B. Reticulated surface of Chambersburg limestone near Alpine, 4 miles north of Oakdale. (See p. 141.)

PLATE 39

(Near manuscript page 142)

Note alternate view

?

A. Green Hill, elevation 3,250 feet. View looking southward from North Mountain up the valley of Black Creek. (See p. 142.)

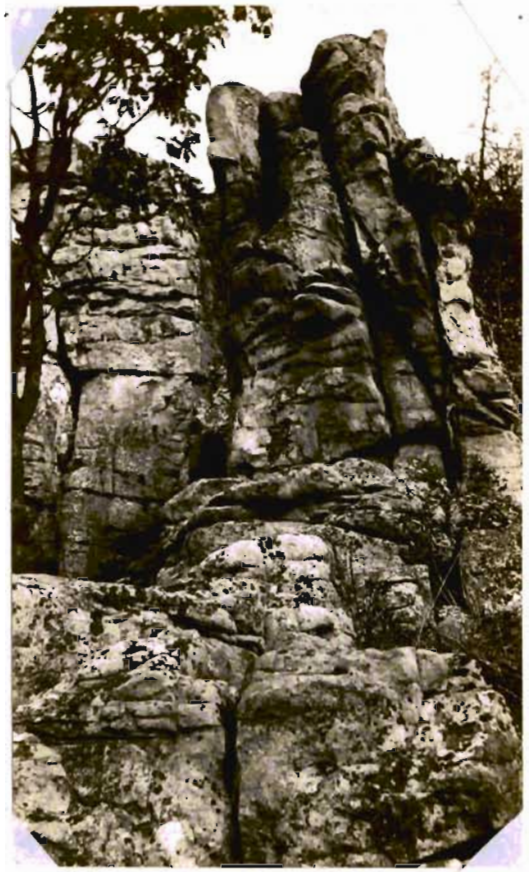
Poor for ½ tone

B. House Mountains, elevation 3,612 feet, 10 miles west of Lexington; viewed from crest of North Mountain, 2 miles west of Alpine. (See p. 154.)

PLATE 40

(Near manuscript page 144)

A. Shaly (Eden) phase of the Martinsburg formation along Barbers Creek road in Rich Patch valley, 2 miles southwest of Mountain Valley School. (See p. 144.)



B. Towers of lichen-covered Clinch sandstone on Rathole Mountain, near Eagle Rock. (See p. 153.)

PLATE 41

(Near manuscript page 154)

why use?

A. Heartsblood, the col between Panther (left) and Camp mountains (right), viewed from the southeast. (See p. 147.)

do?

Note alternate view

B. The gorge of Back Creek through Rich Hill, 1 mile east of Horseshoe Bend of James River, view looking east. An excellent arch of Keefer sandstone is exposed on both walls of this gorge. (See p. 154, and Section 22, p. 213.)

Not shown

PLATE 42

(Near manuscript page 155)

A. Purplish shale and shaly sandstone of the Juniata formation, Hays Gap. (See p. 149.)

B. Massive red Oriskany sandstone near Hooks Mill at southwestern end of Bearwallow Mountain. (See p. 155.)

PLATE 43

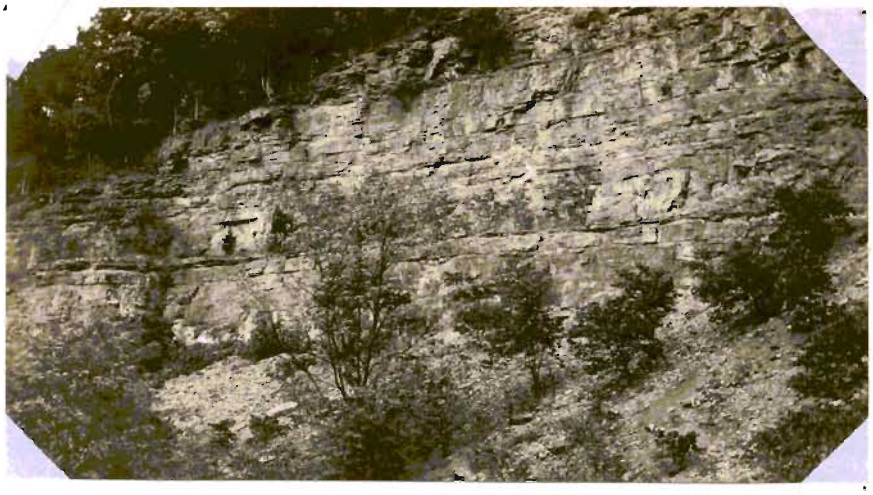
(Near manuscript page 158)

A. Ledges of Keefer sandstone along road at head of Roaring Run, 1 mile southeast of Hooks Mill. The beds evince much shearing and minor displacement. (See p. 158.)

B. Massive beds of Keefer sandstone in the Eagle Rock Gap near east end of new bridge over James River. (See pp. 158 and 263-265.)

PLATE 44

(Near manuscript page 160)



A. High quarry face of Tonoloway limestone along the Chesapeake and Ohio Railway; Prices Bluff at the southwestern end of Big Hill. (See p. 160.)

B. Black slaty zones at contact of Healing Springs sandstone (above) and Coeymans limestone (below). The hammer lies in the center of a 3-foot transitional zone between the two formations. Prices Bluff, southwest end of Big Hill. (See pp. 168-169.)

PLATE 45

(Near manuscript page 172)

A. Oriskany sandstone exposed at Prices Bluff, southwest end of Big Hill. The shale slope above the dark sandstone is formed by Onondaga shale; Becraft limestone underlies the Oriskany. (See pp. 172 and 174.)

B. Mural cliff of Brallier shale along Potts Creek, near the extreme northwestern corner of the Eagle Rock quadrangle. (See pp. 179-180.)

PLATE 46

(Near manuscript page 187)

Note alternate view

A. Stratified high-level gravels of James River, ½ mile above Buchanan. (See p. 187.)

Photo does not show it

B. Contact between peridiotite stock and Ordovician limestone, Torfy Hollow, 3 miles southwest of Oakdale. The material to the right of the hammer is igneous; the hammer handle points toward the limestone. (See pp. 190-191.)

PLATE 47

(Near manuscript page 188)

A. Quaternary deposits of travertine along Lapsleys Run, 1 mile north of Zion Hill Church. (See p. 188.)

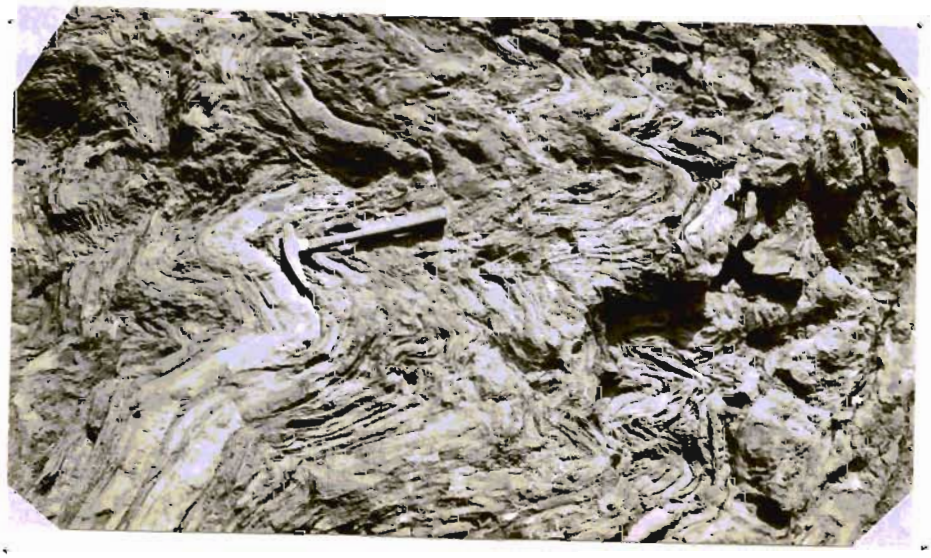
Note alternate view

B. Solution channels and cave deposits along Cedar Creek, ½ mile below Red Mills. (See pp. 60 and 188.)

PLATE 48

(Near manuscript page 227)

A. Gentle folds in Unicoi sandstones along U. S. Highway 501 near Snowden. The arch to the right of the figure is an anticline; the downfold in the center is a syncline. (See pp. 86 and 227.)



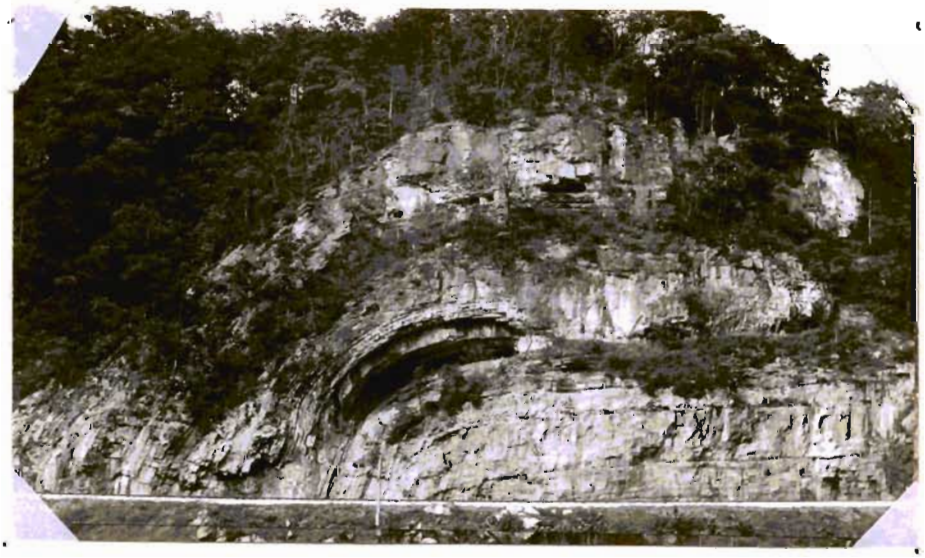
B. Closely contorted Tonoloway limestone, Eagle Rock gap of James River. (See pp. 160 and 227.)

PLATE 49

(Near manuscript page 228)

A. Gentle folds in Chambersburg limestones, 3 miles west of Collierstown, viewed north toward the two House Mountains. (See pp. 154 and 235.)

Note alternate view



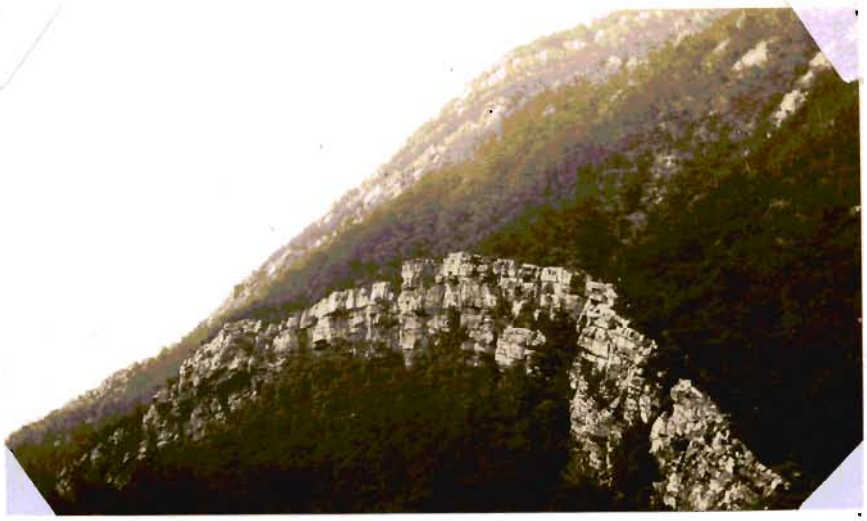
B. Anticlinal fold in the Shady dolomite 3/4 miles below Buchanan. View looking northeast across James River; tracks of the Chesapeake and Ohio Railway at base of cliff. (See p. 241.)

PLATE 50

(Near manuscript page 234)

Note alternate view

A. A symmetrical anticline of Brallier shale along the south wall of Craig Creek valley, 1.5 miles southeast of Strom. (See p. 241.)



B. The "Rainbow Arch" at Iron Gate. The curved ledge in the foreground is Clinch sandstone; below it is a wooded slope developed on Juniata and Martinsburg shales. The upper ledges are Keefer sandstones; the central wooded slope hides the Cacapon shales and sandstones. (See pp. 67, 154, 158 and 234.) Compare with Pl. 52, A.

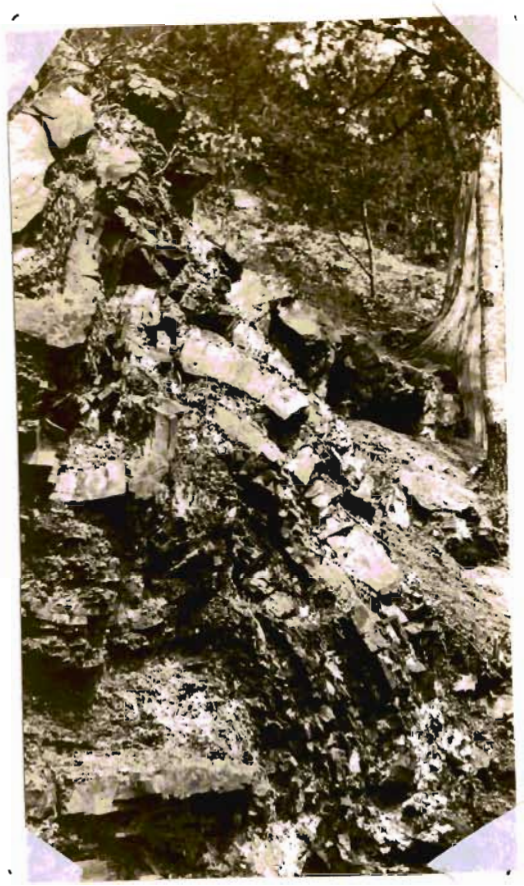
PLATE 51

(Near manuscript page)

Panoramic view of Rich Patch Mountain and its eastern line of foothills. The gently sloping surface of the latter is the crest of an anticline that plunges southwestward. (See pp. 45 and 231.)

(Near manuscript page 234)

A. The sharp northern elbow of Keefer sandstones in the Rainbow Arch at Iron Gate. (See pp. 67, 154, 158, and 234.) Compare with Pl. 50, B. (Note alternate view)



B. Small folds in Brallier shale along Little Patterson Creek, 4 miles west of Eagle Rock. (See p. 241.)

PLATE 53

(Near manuscript page 241)

Note alternate view

A. Remarkable folds within the Unicoi formation exposed on Dove Mountain 2½ miles southeast of Buchanan. View looking southwestward across the gorge of Bearwallow Creek. State Highway 43 slowly ascends the valley. (See pp. 78, 227, and 254.)

B. A small vertical fault in the Conococheague formation along Lee Highway 3 miles northeast of Buchanan. (See p. 227)

PLATE 54

(Near manuscript page 244)

Note alternate view

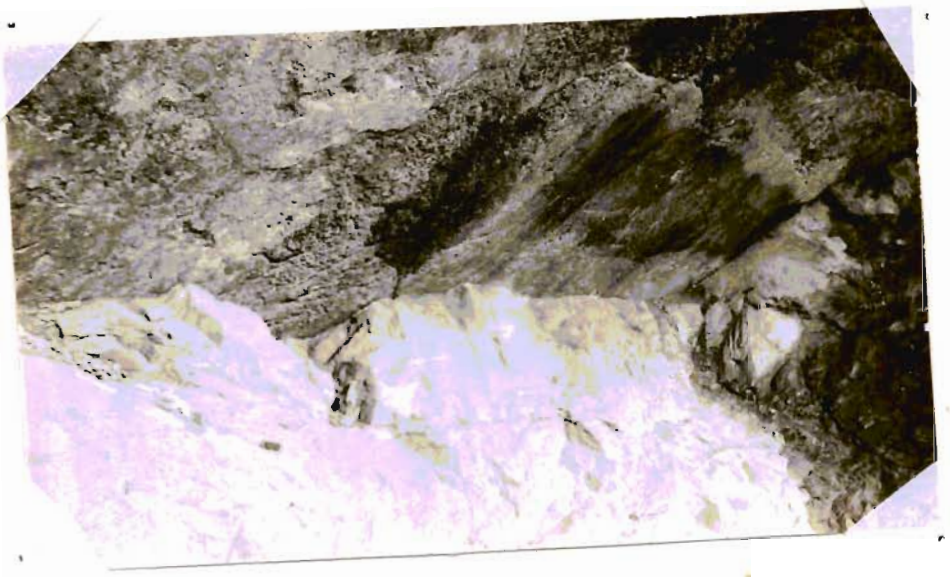
A. Quarry face along Lee Highway near Highbridge Church showing Elbrook limestone overthrust upon crumpled Athens shale. The fault contact rises diagonally across the cliff from the lower right corner of the view. (See pp. 138 and 244.)

B. A small block of Elbrook limestone overthrust upon "Romney" shales which partially enfold the limestone at extreme left (near hammer) and at extreme upper right. The fault plane is near the base of the ledge below which are the Devonian shales. One mile southeast of Saltpetre Cave, ½ mile east of James River. (See pp. 246-247.)

PLATE 55

(Near manuscript page 245)

A. Underground limestone mine at Eagle Rock, formerly operated by the Moore Lime Company. The hanging wall is the overthrust mass of Nittany dolomite in the Pulaski fault block. The quarry opening represents Holston limestone largely removed except for supporting pillars. (See pp. 128 and 244-246.)

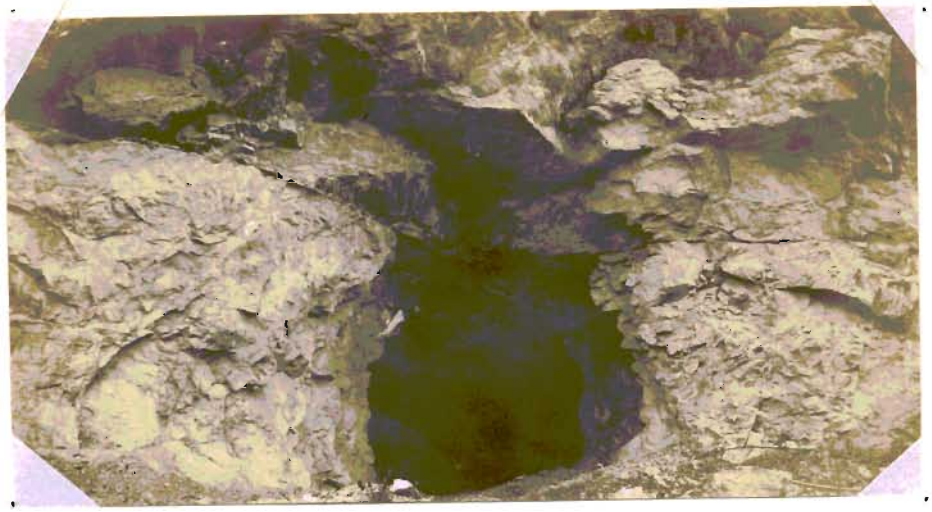


B. The knife-edge contact of Nittany dolomite, above, and Holston limestone, below the plane of the Pulaski overthrust in the quarry shown above. The sharp, clean-cut nature of the thrust is clearly visible. The sloping under surface of the fault plane is very smooth and somewhat slickensided.

Note: These photographs were used by the author in the paper - "Fault-line phenomena near Eagle Rock, Va.", in A.J.S. Vol. 36, Feb. 1936, pp. 135-143

PLATE 56

(Near manuscript page 246)



A. Face of cliff along James River opposite Eagle Rock, showing the entrance to the underground limestone mine, or quarry, formerly operated by the Moore Lime Company. The dark rock in the upper part of the cliff is Nittany dolomite faulted upon Holston limestone. The outcrop of the fault plane in the cliff is clearly visible. (Height of opening 20 feet). (See pp. 244-246.)

B. View within quarry figured above. The Holston limestone is partially removed between a sloping foot wall of Lenoir limestone (normal contact) and a sloping hanging wall of Nittany dolomite (faulted overburden). (See pp.128 and 244-246.)

PLATE 57

(Near Manuscript page 263)

Panoramic view of the northeastern face of the Eagle Rock Gap; Rathole Mountain in foreground. The white disconnected ledge in the center is a faulted portion of Clinch sandstone. This formation is also visible at the extreme right on the wooded hill slope. Other prominent ledges are Keefer sandstones. Compare with Pl. 58. (See pp. 154 and 264.)

PLATE 58

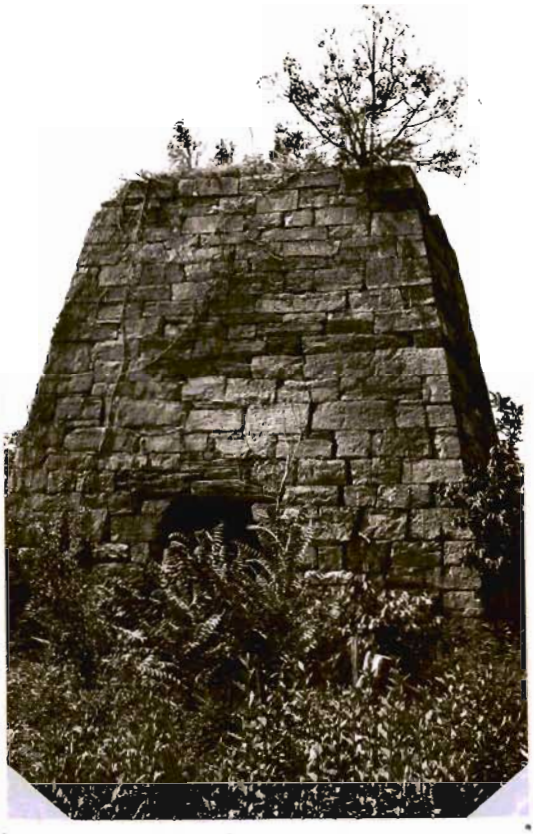
(Near manuscript page 264)

Panoramic view of the southwestern face of the Eagle Rock Gap; Crawford Mountain in foreground. Note the overturned synclinal fold of Keefer sandstone at left of view. The ~~two~~ massive ledges at the extreme right are also Keefer sandstones. Compare with Pl. 57. (See pp. 263-264.)

or for both Pl's ?

PLATE 59

(Near manuscript page 304)



A. The abandoned stack of Glenwood furnace, near Elk Creek, Arnold Valley. (See pp. 298, 304, and 323.)

B. The ruins of Retreat furnace, abandoned in 1849, near head of Purgatory Creek, 1½ miles northeast of Dunkard Church. (See pp. 317 and 322.)

PLATE 60

(Near manuscript page 305)

A. The abandoned stack of the Roaring Run charcoal furnace, located on Roaring Run, 1 mile north of Strom. (See pp. 311 and 323.)

B. Ruins of the Catawba charcoal furnace on Catawba Creek, 1 mile southwest of the southwestern corner of the Eagle Rock quadrangle. (See p. 323.)

PLATE 61

(Near manuscript page 313)

A. Narrow Bank of the Alleghany Ore and Iron Company, ½ mile north of Lignite. Residual masses of Oriskany brown iron ore may be seen in the residual soil which has been stripped off by steamshovels. (See p. 313.)

B. The "big cut" at the Oriskany iron mine, showing residual Oriskany limonite and cover of residual soil. (See pp. 312-313.)

PLATE 62

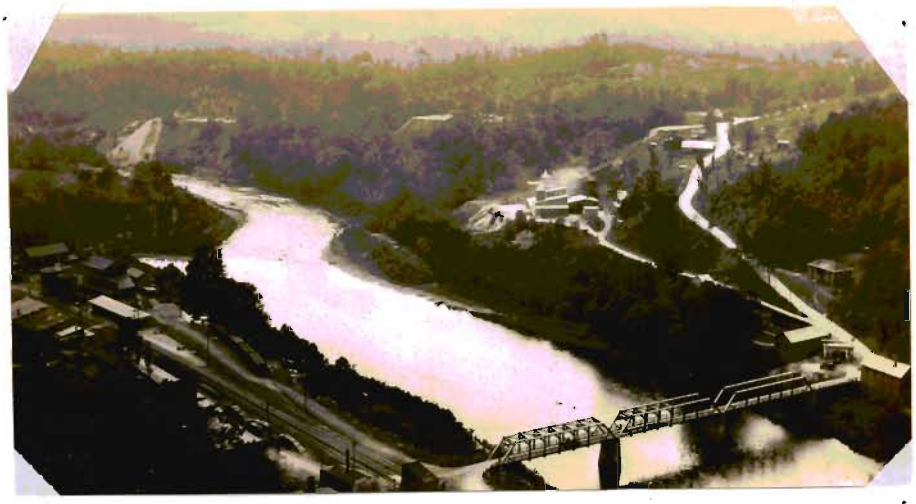
(Near manuscript page 331)

A. The Virginia Iron, Coal, and Coke Company's quarry in Shady dolomite near Buchanan. View looking southeast across James River. (See p. 331.)

B. Shady dolomite exposed in high face of quarry shown above. (See p. 331)

PLATE 63

(Near manuscript page 329)



not good
for better photo

A. Limestone quarry operations at Eagle Rock, viewed southeastward from Rathole Mountain. Notice large dumps in central background along river, and active kilns and crusher near the town. The old bridge shown in this view was replaced by a new concrete structure in 1933-34. (See p. 329.)

B. Quarry operations, now inactive, in the Shady dolomite, 3 miles southwest of Buchanan. (See p. 341.)

PLATE 64

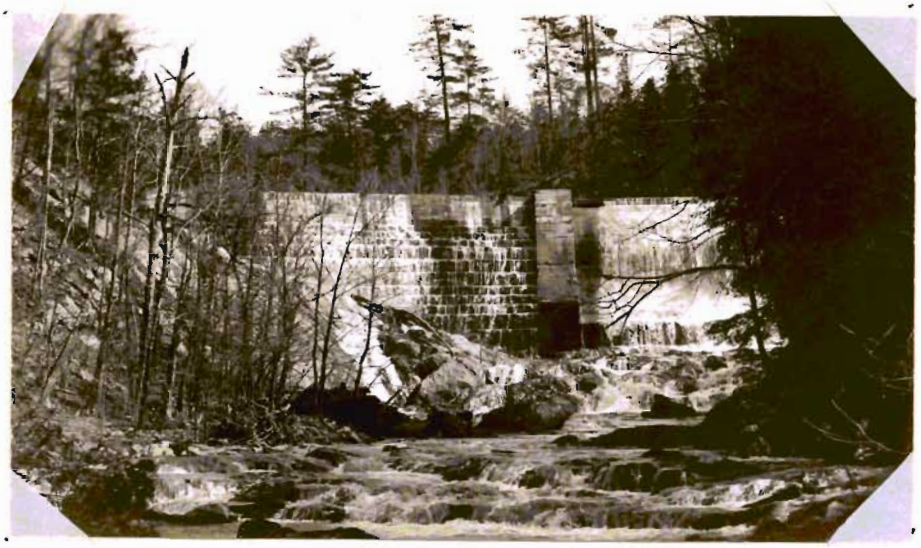
(Near manuscript page 341)

A. Inactive underground mine, or quarry, in the Becraft limestone, in the valley of Carne Creek, 1 mile west of Lowmoor. (See p. 341.)

B. Inactive limestone mine in Holston limestone near Eagle Rock. The sloping hanging wall of this opening is the undersurface of the Pulaski overthrust fault. (See p. 329.) Compare with Pl. 55.

PLATE 65

(Near manuscript page 348)



A. Small power dam on Cedar Creek, 1 mile below Natural Bridge. (See pp. 51 and 348.)

B. Large sink in Chambersburg limestone, ½ mile north-northeast of Collierstown. (See pp. 78 and 348.)

[redacted] ridge region. (Place near miss p. 82)

Geologic System			Formational Names	Group Name
Mississippian	Lower		Price formation	Osagian
Devonian	Upper		Catskill formation Chemung formation Brallier shale "Romney" black shale Onondaga shale Oriskany sandstone	
	Middle			
	Lower		Becraft limestone Healing Springs sandstone Coeymans limestone Keyser Formation { Upper Keyser limestone, Clinton Forge sandstone, Lower Keyser limestone	Helderberg
Silurian	Upper		Tonoloway limestone	Cayuga
	Middle		Keefer sandstone Cacapon formation.	Clinton
	Lower		Clinch sandstone	Medina
Ordovician	Upper		Juniata shale Martinsburg Shale { Maysville division, Eden division, Trenton division	Cincinnati
	Middle		Chambersburg limestone Lowville-Moccasin formation	Black River
	Lower		Athens shale Whitesburg limestone Holston limestone	Blount
			Lenoir limestone Mosheim limestone Lower Stones River limestone	Stones River
Canadian	"Cambro-Ordovician"		Bellefonte dolomite Nittany dolomite Stonehenge limestone	Beekmantown
Ozarkian			Chepultepec limestone Conococheague formation	
Cambrian	Upper		Elbrook limestone Rome ("Watauga") shale Shady dolomite	
	Lower	Calcareous Division		
		Arenaceous Division	Erwin quartzite Hampton shale Unicoi formation	Chilhowie

VIRGINIA DIVISION OF MINERAL RESOURCES LIBRARY

Why use? - Include in "Explanation" & real geol. map.

TABLE 2.— Thickness and distribution of Paleozoic formations in the Natural Bridge region

(Place near mss p. 80)

AGE	FORMATIONS	Thickness: Eagle Rock Quadrangle, North of Pulaski Fault	Eagle Rock Quadrangle, South of Pulaski Fault	Natural Bridge Quadrangle, North of Pulaski Fault	Natural Bridge Quadrangle, South of Pulaski Fault	Average
Mississippian	Price formation	1000'–	absent	absent	absent	1000'
Devonian	Catskill formation	525'				525'
	Chemung formation	2890'±				2890'
	Brallier shale	2000'±		2000'–		2000'
	"Romney" black shale	1000'±		1000'–		1000'
	Onondaga shale	35-70'		20-30'		30-70'
	Oriskany sandstone	2-15'		0-5'		2-15'
	Becraft limestone	55-110'		20-130'		20-180'
	Healing Springs sandstone	15-30'		0-5'		0-30'
	Coeymans limestone	25'		20'±		20'±
	Upper Keyser limestone	20-30'		35'	absent	20-35'
	Clifton Forge sandstone	70-100'		140'±		70-140'
	Lower Keyser limestone	0-30'		50'		0-50'
Silurian	Tonoloway limestone	130'±	100'±	75'±		75-180'
	Keefer sandstone	160-200'	325'	145-260'		145-325'
	Cacapon formation	200-250'	110'	125-250'		110-250'
	Clinch sandstone	50-120'	170'	170-260'		50-260'
Ordovician	Juniata shale	0-300'	0-12'	absent		0-300'
	Martinsburg shale	1200'±	1500'	1500'		1500'±
	Chambersburg limestone	absent	absent	500'±		0-500'
	Lowville-Moccasin formation	0-65'	0-5'	absent		0-65'
	Athens shale	absent	1500'±	5-300'	0-400'	0-1500'
	Whitesburg limestone		0-10'	0-10'	0-10'	0-10'
	Holston limestone		5-40'	18-125'	80'±	0-125'
	Lenoir limestone	175-230'	120-165'	50-170'	160-240'	50-240'
	Mosheim limestone	absent	0-5'	6-30'	25-160'	0-160'
	Lower Stones River limestone	0-320'	absent	0-250'	90-130'	0-320'
Canadian	Bellefonte dolomite	300'±		200-500'	300'	0-500'
	Nittany dolomite	600'±	625-800'	500-600'	500'	500-800'
	Stonehenge limestone	Not exposed	absent	Not exposed	0-30'	0-30'
Ozarkian	Chepultepec limestone		0-300'		200-500'	0-500'
	Conococheague formation		1200-2500'		2000-2500'	1200-2500'
Cambrian	Elbrook limestone		1800'		1500'	1500-1800
	Rome ("Watauga") shale		Not exposed		1100'±	1100'±
	Shady dolomite				1200-1300'	1200-1300'
	Erwin sandstone				775'±	775'
	Hampton shale				475'±	475'
	Unicoi formation				3000 ±	3000'
Total thickness		10,450'–11,540'	7,450'– 9,340'	6,580'– 8,250'	11,400'– 13,000	19,250–24,375'

why are separately?

TABLE 15. — Discharge, Temperature, and analysis of spring water, Natural Bridge region.[1] (near mss page 349)

NO.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Average
Estimated Discharge	gal per min.	2	4,000	3,000	630	350	500	100	100	100	300	2	6,000	5,000	3,500	1,400	1,300	1,290	1200	1000	700	630	450	360	250	250	180	125	—
	Sec. feet												6.8	5.6	3.9	1.6	1.5	1.5	1.3	1.13	1								
Temperature	Water	39.2	51.9	57.5	59	50.1	51.2	54.2	52	53.9	64.6	47.1	51	53.1	51.1	52.3		53.6	53.5	51.2	58	46	54.1	51	53.7	54.6	51.4	54.8	
	AIR	(38)	(36)	(34)	(36)	(40)	(35)	(43)	(36)	(38)	(43)	(39)	(42)	(46)	(47)	(46)		(48)	(43)	(44)	(43)	(46)	(47)	(41)	(48)	(56)	(40)	(50)	
Proximate Analysis (Parts per million)	Disolved Solids	880	173	149	184	304	157	251	12	166	84	568	131	140	138	172	No Analysis Available	228	77	97	99	124	207	50	228	209	123	233	199.38
	Fe.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—	—	—	—	—
	Ca	64	50	52	56	66	44	56	2	60	20	56	36	40	40	60		90	24	28	32	52	56	14	60	48	40	48	45.53
	Na	206	7	13	5	7	4	17	5-	5-	4	142	7	5	8	5-		9	5	7	5	5-	14	5-	12	17	7	12	20.69
	HCO_3	144	188	160	151	344	173	276	10	180	96	444	142	163	150	190		250	86	110	113	133	224	56	256	22	141	252	171.31
	SO_4	540	5	9	40	7	2	3	2	8	2	20	6	1	5	5		7	1	1	3	5	7	2	6	6	2	3	26.84
	Cl	1.6	0.7	0.8	0.8	0.9	1.0	1.7	0.5	0.8	0.4	106	0.8	0.6	0.9	0.7		1.2	0.5	0.9	0.5	1.2	1.0	0.3	1.0	0.8	0.7	1.2	4.90
	NO_3	1.2	5.8	1.4	0.67	4.0	5.8	10.0	0.15	2.5	0.50	0.25	1.9	1.6	3.3	4.3		5.9	1.9	1.7	0.05	2.9	6.4	0.15	3.2	7.5	1.4	12.0	3.32
	$CaCO_3$	238	150	115	160	278	141	203	3.5	150	73	335	111	125	114	156		200	64	79	86	106	168	39	194	163	105	194	140.02

1. Compiled from "Springs of Virginia", by W. D. Collins and others, Virginia Commission on Conservation and Development, Division of Water Resources and Power, Bull. 1, 1930.

Legend for Table 15

1. Mineral spring; 1 mile northeast of Fincastle; Athens shale.

2. Bridleys spring; 1/4 mile north of Hooks Mill, at head of Roaring Run; Lowville limestone.

3. Blue spring; at head of Blue Spring Creek, 6 miles southwest of old Rich Patch Post Office; Martinsburg shale.

4. Bridleys spring; along Roaring Run, 500 feet southeast of #2; Lowville limestone.

5. Simmonds spring; 5 miles north of Fincastle; Nittany dolomite.

6. Kemsey spring; on Carne Creek, 1 1/4 miles north of Rich Patch Post Office; Lowville limestone.

(sic)

7. Flowing spring; 3.6 miles northeast of Fincastle, 1 mile southeast of Kyles Mills; Nittany dolomite.

8. Carne Creek spring; on Carne Creek, 1 1/4 miles north of Rich Patch Post Office; Martinsburg shale.

9. Spring; on Blue Spring Creek, 0.2 miles southwest of #3; Lowville limestone.

10. Lithia spring; 3.2 miles east of Gala, 1 mile above Daggers Springs; "Romney" black shale.

11. Daggers springs; 2.8 miles east of Gala on Mill Creek, 100 feet east of road; "Romney" black shale.

12. W. C. Karnes spring; 6.5 miles north of Buchanan on Purgatory Creek; contact of Lenoir and Holston limestones.

13. Black spring; 1.2 miles northeast of Rapps Mill on South Fork of Buffalo Creek; Canadian dolomite.

14. J. H. Ayers spring; 4.5 miles northeast of Rapps Mill on South Fork of Buffalo Creek, 2 miles south of junction with North Fork; Canadian dolomite.

15. J. G. McCorkle spring; 1.4 miles west of Murat on Buffalo Creek; Athens shale.

16. Spring; near southeast bank of James River, 0.3 miles southwest of Virginia Iron Coal and Coke Co. quarry; Shady dolomite.

17. Ira Dickson spring; at Murat, on Buffalo Creek; Holston limestone.

18. Keagon spring; 2 miles north of Rapps Mill, at head of Spring Branch; Nittany dolomite.

19. Henderson spring; 0.8 miles southwest of Rapps Mill, near road; Canadian dolomite.

20. Spring; 4 miles east of Gala, on southeast side of Sheets Mountain; "Oriskany" sandstone.

21. C. B. Leech spring; 1 mile southwest of Oakdale in creek bed; Canadian dolomite.

22. J. S. Pogue spring; on Lee Highway 5 miles southwest of Natural Bridge; Holston limestone along fault.

23. Spring; 1 mile east of Daggers Springs, on east side of Mill Creek; "Oriskany" sandstone.

24. Schoolhouse spring; on Lee Highway 0.7 miles north of Natural Bridge Station; Elbrook limestone.

25. Spring; on Lee Highway, 2.5 miles northeast of Buchanan; Conococheague limestone.

26. Spring; 5.5 miles north of Buchanan, on Purgatory Creek; Chambersburg limestone.

27. S. R. Leckley spring; at Nancy Hill Post Office; Conococheague limestone.