THE GEOLOGY OF ROANOKE COUNTY, VIRGINIA AND VICINITY

by

Herbert P. Woodward

Introduction

Chapter I, Introductory Description

Chapter II, Physiography

Chapter III, Stratigraphy - missing

Chapter IV, Geologic Structure - missing

Chapter V, Mineral Resources

Chapter VI, Water Resources - missing

No plates

No maps

These chapters are probably parts of a thesis submitted in connection with work for the Ph.D. degree --Faculty of Pure Science, Columbia University. Degree was received in 1932. Thesis was published as Virginia Geological Survey, Bulletin 34, 1932, under the title: Geology and mineral resources of the Roanoke area of Virginia.

see also Thesis File.

VIRGINIA

TABLE OF CONTENTS

Introduction

	Page
General nature of the report	i
The geologic map	ii
Previous geologic work	iv
Acknowledgments	viii

Chapter I

Introductory Description

Location	1
Relief and drainage	2
Descriptive geography	4
Soil	5
Climate	8
Vegetation	9
Development	10

Chapter II

Physiography

General statement	16
Physiographic provinces	19
Erosion levels	21
The Summit Peneplane	22
The Upland Peneplane	24
Intermediate Levels	28
The Valley-Floor Peneplanes	31
Trenches cut below the Valley-Floor Peneplane.....	37

Page

Drainage development 39

General summary of the physiographic history 41

Chapter III

Stratigraphy

General statement 36

The Pre-Cambrian group 37

Sedimentary rocks 47

Arenaceous Lower Cambrian group 49

Unicoi formation 51
Hampton shale 55
Erwin quartzite 57

Calcareous Cambrian group 61

Shady dolomite 62
Watauga shale 65
Elbrook formation 73

Cambro-Ordovician group 76

Copper Ridge formation 77
Nittany dolomite 81

Ordovician group 85

Chazyan formations 86
Mosheim member 88
Holston " 88
Murat " 90
Whitesburg " 91
Athens shale 93
Martinsburg shale 99

Silurian group 106

Clinch sandstones 107
Clinton formation 111

Devonian group 114

Giles formation 116
Marcellus-Genesee black shales 119
Brallier shale 124
Chemung formation 127

CHAPTER V

MINERAL RESOURCES OF THE ROANOKE AREA

	Page
General statement	208
Metals	211
Iron and manganese	211
General statement	211
Blue Ridge Hematite	212
Griffin specular mine	214
Mines near Blue Ridge Springs	214
Grubb specular mine	215
Edith mine	215
Lemon or St. Clair mine	216
Cundiff bank	216
Dewey mine	217
Ironville mine	217
Clinton hematite	218
Brown ores along the Blue Ridge	220
General statement	220
Mines south of Roanoke at the edge of the Roanoke Valley	226
Rorer mine	226
Gale mine	228
Griffin mine	230
Starkey mine	230
Castle Rock and Turner mine	231
Iron Bluff Farm prospect	231
Poor Mountain mines	232
Mines along the southeast side of the Blue Ridge in the Glade Creek Valley	234
Lynchburg or Grubb mines	234
Upland or Crozer mine	235
Buford bank	236
Mines along the northwest side of the Blue Ridge in the Fincastle Valley	237

Page

Stoner mine 237
Murray bank 238
Gowan bank 239
Deal bank 240
White bank 240
Houston mines 241

Oriskany iron and manganese ores 244

Limestone magnetites 246

Titaniferous magnetites 247

Pyrite and pyrrhotite 247

Summary of iron and manganese deposits. 248

Lead and zinc 250

General statement 250

Specific deposits 251

Martin and Wertz prospects 251
Bonsacks prospect 253
Langhorne and Wills prospects 254
Other lead and zinc prospects 255
Summary of lead and zinc prospects.. 256

Minor metalliferous occurrences 256

Gold 256

Silver 259

Copper 259

Arsenic 260

Nickel and cobalt 261

Fuels 263

Coal in Roanoke County 263

General statement 263

Brushy Mountain belt 264

North Mountain belt 265

Fort Lewis Mountain belt 267

Summary of coal deposits 268

Page

Oil and gas 268

Other non-metallic resources 271

Limes and cements 271

General statement 271

Cambrian limestones 274

Ozarkian and Canadian limestones 275

Ordovician limestones 275

Devonian limestones 278

Summary of cement deposits 278

Clays and shales 279

General statement 279

True sedimentary clays and shales 281

Watauga shales 282
Elbrook shales 284
Athens shales 284
Marcellus-Genesee shales 286
Mississippian shales 286

Residual clays from decomposition of bed rock 287

Residual clays of the crystalline area. 287
Residual clays of the Shady dolomite .. 288
Residual clays of the Elbrook formation 289
Residual clays of the Copper Ridge formation 291
Residual clays of the Nittany dolomite. 292

Transported clays of floodplain origin ... 293

Summary of clays and shales 294

Titanium and apatite (Nelsonite) 295

General statement 295

Description of deposits 299

Minor non-metallic resources 301

Page

Asbestos 301

Barite 302

Bentonite 304

Construction stone and crushed stone 305

Glass sand 307

Graphite and talc 311

Marl 312

Millstones and buhrstones..... 312

Ocher 313

Sand and gravel 313

General Summary of the mineral resources of the Roanoke area 315

Selected references on the mineral resources of the Roanoke area 320

CHAPTER VI

WATER RESOURCES OF THE ROANOKE AREA

Acknowledgments 323

General statement 323

Surface waters 324

Subsurface or ground waters 328

General statement 328

Springs 332

Common springs 335
Crystal spring 335
Moomaw springs 336
Big Cook spring 337
Muse spring 338
River spring 338
Smith spring 338
Lake spring 339
Cave spring 340
Big spring 340

THE GEOLOGY OF ROANOKE COUNTY, VIRGINIA AND VICINITY

by

Herbert P. Woodward

INTRODUCTION

VIRGINIA DIVISION OF MINERAL RESOURCES LIBRARY

GEOLOGY OF ROANOKE COUNTY, VIRGINIA AND VICINITY

INTRODUCTION

The present report has developed from a geologic investigation of the water resources of the Roanoke area, carried on in the interests of the Roanoke Water Works. This original survey was initiated by Dr. Charles P. Berkey in the spring of 1926 and was continued by the writer through three and one half months of field work during the summer of that year, at the end of which time a report was submitted to the Roanoke Water Works by Doctor Berkey and the writer. Considerable geological data other than that pertaining to the water resources was collected during the field work of 1926. This material was augmented by an exhaustive research through the geologic literature, and all available data upon the Roanoke area was compiled and prepared in the form of a general report on the region. This report was submitted with the permission of the Roanoke Water Works to the Virginia Geological Survey for acceptance as one of their bulletins. In March 1927, that Survey authorized the publication of such a report, and made an appropriation to support two months of additional field work which was carried out during June and August 1927.

The report in its present form is intended to serve as a guide to the geology of the area tributary to the city of Roanoke. It also includes a statement of the past, present, and future possibilities of the natural economic resources of that area.

The geologic map.

The geologic map which accompanies this report has been platted upon the Christiansburg and Roanoke quadrangles of the United States Geological Survey topographic map. The data for this geologic map has been compiled from previously published maps and from a personal survey of the area during six months of field work in the summers of 1926 and 1927.

The base map is somewhat inaccurate as to topography and culture, and the forty years which have elapsed since the original topographic survey have made many changes in location of roads and villages. In consequence, accuracy of platting the geologic map has depended upon the accuracy of the base map. For use in the field, the writer had the base map photostated to twice the present scale, and the contacts and geologic locations were drawn upon this enlarged map. That accuracy of delimitation should suffer in the reduction to the normal scale of the map was unavoidable. It is to be regretted that the geology of such a complicated area as that covered by this report must be platted upon a base map of such small scale.

The following published geologic maps also represent conditions in different disconnected parts of the Roanoke area, and the data of these maps has been checked and assimilated into the present geologic map.

1. A geologic map of the middle and western states, James Hall, Geology of New York, Part IV, 1843.

2. Geologic map of the Virginias, W.B.Rogers, chiefly from the Virginia State Geological Survey of 1841, The Virginias, Vol. 1, No.1, 1880. Also in The Geology of the Virginias, edited by Jed Hotchkiss, 1884.

3. Geologic map of southwest Virginia, C.R.Boyd, Resources of southwest Virginia, New York, 1881.

4. Geologic map along the Richmond and Alleghany Railroad, Campbell, J.L., Geology and Mineral resources of the James River Valley, New York, 1882.

5. Geologic map of Virginia, Watson, T.L. Virginia Geological Survey, 1916.

6. Geologic map of western Virginia, compiled by G.W. Stose, Virginia Geological Survey Bull. 23, Plate IV, 1922.

7. Geologic map of the west foot of the Blue Ridge, G.W.Stose et al., Virginia Geological Survey Bull. 17, 1919.

8. Geologic map of the Valley coal fields, M.R.Campbell et al., Virginia Geological Survey Bull. 25, Plate I, 1925.

Previous geological work.

Numerous general and special publications have been issued within the past century and one quarter, sections and items of which deal with the geology of Roanoke County and the adjacent area. No previous attempt however, has been made to summarize the entire geology of the region nor to construct a complete geologic map of the area. The Roanoke region has been approached by geological reconnaisance from the northeast, southwest, and west. The present report connects these various reconnaisances and covers an area not heretofore described as a geologic unit.

The following list of references includes the most important published articles dealing with the larger problems of the local geology. This list does not include references to the mineral wealth of the region, and a list of those references will be found at the end of Chapter V. Taken together, the two lists comprise as full a bibliography of the Roanoke area as can be compiled fro research into available geological literature. The bibliography is undoubtedly incomplete and apology is offered to those authors whose publications may have been overlooked.

SELECTED REFERENCES ON THE GENERAL GEOLOGY OF THE ROANOKE AREA

1817. Maclure, William. Observations on the geology of the United States, Philadelphia, pages 37-8, 51, 58-9, 108.

1842-5. (published 1884). Rogers, W.B. Geology of the Virginias, Appleton and Co., New York.

1879. Campbell, J.L. Geology of Virginia, Amer. Journal of Sci., 3rd Series, Vol. 18, pp.16-30, 119-128, 435-446.

1880-5. Hotchkiss, Jed and others, The Virginias, Staunton Virginia, Vol. I - VI.

1881. Boyd, C.R. Resources of southwest Virginia, New York.

1882. Campbell, J.L. Geology and mineral resources of the James River Valley, Virginia U.S.A. New York.

1883. Fontaine, W.M. Notes on the geology and mineral resources of the Floyd Virginia Plateau. The Virginias, Vol. IV, pp. 167, 178-80, 185-92.

1884. ---------- Salem and the Roanoke Valley, The Times-Register Office, Salem Virginia.

1887. Stevenson, J.J. Notes on the surface geology of southwest Virginia. Am. Phil. Soc. Proceedings, Vol. 24, pp. 172-78.

1892. Darton, N.H. Notes on the stratigraphy of a portion of central Appalachian Virginia. Amer. Geol. Vol X, pp. 10-18.

1892. Walcott, C.D. Notes on the Cambrian rocks of Virginia and the southern Appalachians. Amer. Journal of Sci. 3rd Series, Vol 44, pp. 52-7.

1894. Campbell, M.R. Paleozoic overlaps in Montgomery and Pulaski counties, Virginia. Geol. Soc. Am., Vol. 5, pp. 171-90.

1894. Hayes, C.W. and Campbell, M.R. Geomorphology of the southern Appalachians. Nat. Geog. Mag., Vol. VI, pp. 63-126.

1895. Hayes, C.W. The southern Appalachians. Nat. Geog. Soc., Mon. 1, No. 10, pp. 305-336.

1895. Willis, Bailey. The northern Appalachians. Nat. Geog. Soc. Mon. 1, No. 6, pp.169-202.

1896. Campbell, M.R. Drainage modifications and their interpretations. Jour. Geol., Vol 4, pp. 567-81, 657-78.

1897. Watson, T.L. Bibliography of the geological, mineralogical and paleontological literature of the State of Virginia, Bull. Am. Paleontological Soc., Vol 2, No. 7.

1905. Campbell, H.D. The Cambro-Ordovician limestones of the middle portion of the Valley of Virginia. Amer. Journal of Sci. 4th Series, Vol 20, pp. 445-7.

1906. Grover N.C. and Bolster R.H. Hydrography of Virginia. Geol. Survey of Virginia, Bull III.

1907. Surface, G.T. Studies on the geography of Virginia. Geog. Soc. Philadelphia, Bull. Vol. 5, No. 4.

1907. Watson, T.L. Mineral resources of Virginia. Lynchburg, Virginia.

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

1912. Jack, G.S. History of Roanoke County, Roanoke Virginia.

1912. Kindle, E.M. The Onondaga fauna of the Alleghany region. U.S. Geol. Survey Bull. 508, pp. 46-7.

1915. Powell, S.L. Discovery of the Normanskill graptolite fauna in the Athens shale of southwest Virginia, Jour. Geol. Vol. 23, pp. 272-81.

1916. Stevens, G.C. Surface water supply of Virginia, Virginia Geol. Survey Bull. X,

1916. Raymond, P.E. Correlation of the Ordovician strata of the Baltic Basin with those of eastern America. Harvard Coll. Mus. Comp. Zool. Vol 56, No. 3, pp. 235-38.

1917. Moyer, G.E. The Cambro-Ordovician section in the vicinity of Salem, Virginia. Unpublished thesis, Roanoke College, Salem, Virginia.

1920. Raymond, P.E. Some new Ordovician trilobites, Harvard Coll. Mus. Comp. Zool. Vol 64, No. 2, pp. 273-96.

1923. Topham, A.J. The natural economic resources of Roanoke County, Virginia. Unpublished thesis, Roanoke College, Salem, Virginia.

1924. Hubbard G.D. and Croneis, C.G. Notes on the geology of Giles County, Virginia. Dennison Univ. Bull. Vol XX, pp. 307-377.

1924. Kinzer, C.W. A chemical interpretation of the limestones of the Roanoke and Catawba Valleys. Unpublished thesis, Roanoke College, Salem, Virginia.

1925. Campbell, M.R. and others. The Valley coal fields of Virginia. Virginia Geol. Survey Bull. 25, 1

1925. Raymond, P.E. Some trilobites of the lower middle Ordovician of eastern North America. Harvard Coll. Mus. Comp. Zool. Vol 67, No. 1,

1925. Wright, F.J. The physiography of the upper James River Basin in Virginia. Virginia Geol. Survey Bull. XI.

1926. Reger, D.B. Report on Mercer, Monroe, and Summers Counties. West Virginia Geol. Survey, County reports.

The following folios of the United States Geological Survey describe regions in the same province as the Roanoke area.

1894--- United States Geological Survey, geological folios Nos. 10, 12, 14, 16, 20, 26, 32, 44, 46, 59, 61, 90, 116, 118.

Acknowledgements.

For substantial assistance in the preparation of this report the writer is under obligations to various sources. Special thanks are due to Mr. Francis W. Collins of the Roanoke Water Works for permission to incorporate into the present report the results of a geologic investigation carried on in the interests of that company; to Mr. Charles Butts of the United States Geological Survey, who spent several days in the field with the writer and gave much valuable advice concerning the structure and stratigraphy of the area, especially in the selection of names for the units of mapping; and to Dr. Harry S. Ladd, who cooperated with the writer in the mapping of the region along the boundary between the Roanoke and Eagle Rock topographic quadrangles, and who made many valuable suggestions as to the geologic structure of that region.

To Professor Charles P. Berkey of Columbia University, the writer is deeply indebted for guidance and supervision during the field work of 1926 and through the preparation of the report. Professors Douglas Johnson, J.J.Galloway, and Roy. J. Colony of Columbia University have also criticized parts of the manuscript of this report and have offered many valuable suggestions thereupon. The writer has freely discussed many of the problems connected with this geologic study, and for criticisms and comments upon various parts of the report, he wishes to express his gratitude to Mr. George W. Stose, Mr. Marius R. Campbell, and Mr. Hugh Miser of the United States Geological Survey; to Professor Roy J. Holden of Virginia Polytechnic Institute; to Professor Harry I. Johnson of Roanoke College; to Professor Bailey Willis of Leland Stanford Jr.

University; to Mr. Samuel L. Powell of Blue Ridge Springs, Maryland; to Miss Anna I. Jonas of the Virginia Geological Survey; to Mr. David B. Reger of the West Virginia Geological Survey; and to Mr. Tarrant D. Guernsey of the Canadian Geological Survey.

Hearty cooperation was given to the writer by residents of the Roanoke area, and mention should be made of the aid furnished by Mr. Ben F. Moomaw, Secretary Roanoke Chamber of Commerce, Mr. J. Price Bowman, Dr. W.S.Sayers, Mr. Charles E. Moore, and Mr. N. Beck of Roanoke, and Mr. C. H. Hutchins of Vinton.

The writer has had the able assistance of his wife Harriette B. Woodward in the preparation of the manuscript, and especially in the preparation of the charts and figures which are entirely credited to her.

Finally, the writer wishes to express his sincerest thanks to Mr. Wilbur A. Nelson, State Geologist of Virginia, for the cooperation of the Virginia Geological Survey during the latter part of the preparation of the report, and for his personal advice and suggestions in both field and office work.

THE GEOLOGY OF ROANOKE COUNTY VIRGINIA AND VICINITY.

H. P. Woodward

Chapter 1.

Introductory Description.

CHAPTER I

INTRODUCTORY DESCRIPTION

Location.

Roanoke County is located in the west central part of the State of Virginia, about fifty miles from the West Virginia boundary. Roanoke, its chief city, is situated on the Roanoke River at about 80° West Longitude, and 37° 15' North Latitude. The county is roughly pentagonal in outline. Its greatest north-south dimension is about Seventeen miles, and its greatest east-west dimension is 20 miles. The area is 195,581 acres, or nearly 297 square miles. It is bounded by Botetourt, Craig, Montgomery, Floyd, Franklin, and Bedford Counties, and nearly all of its boundaries are crests of mountain ridges.

Relief and Drainage

Despite an open central valley area, the county may be said to be essentially mountainous. In the northern part, the mountains are typical Appalachian Ridges, parallel, even-crested, and extending along a northeast-southwest direction. South of the central lowland, the mountains are irregular in alignment, and form more massive uplands than to the north. Occassional independent mountain masses rise as prominent elevations within or at the edge of the valley floor, and are often without any marked ridge character. Coyners and Mills Mountains east of Cloverdale are of this type. (The latter hill which is labelled Mills Mountain on the topographic map is locally unknown by this name and is called Reeds Mountain. This local name is preferable to the printed name, since it avoids confusion with Mill Mountain which is south of Roanoke City). The southernmost knob of Tinker Mountain, constricting the Valley west of Cloverdale, is locally called Dead Mans Mountain from its outline along the horizon.

The highest point in the county is found in the extreme

Chapter I.

Insert near page 1 of mss.

Insert

PLATE I.

Plate I.

Outline map of Virginia showing location of area included in this report.

southwest where the central peak of the Poor Mountain mass, sises to 3960 feet in altidude. Other high individual summits are: Bent Mountain 3150 feet; Masons Knob 3217 feet: McAfees Knob 3210 feet, Twelve O'Clock Knob 2707 feet; and Stewarts Knob 2472 feet. More peaks reach high elevations in the western part of the county than in the eastern part, and they are more rugged in the southwest than to the northwest. The point where the Roanoke River leaves the county has the lowest elevation within the area, and the surface of the river is here about 880 feet above the sea. Thus the maximum relief of the county is 3100 feet. The level valley-floors average 1200 feet in altidude, above which the mountains rise 100 to 1800 feet more. The relief is primarily the result of differential erosion of hard and soft rock layers, and the hill crests are composed of resistant rock while the valleys have been carved out of weak rock. There are at least four separate ridge-makers in the geologic column, and the geological structure of the region is such that scarcely any two adjacent hills along the horizon are underlain by the same rock layer.

Seven-eighths of the county, (i.e. all the area south of Catawba Mountain,) drains into the Roanoke River, which cuts through a sag in the Blue Ridge at the eastern county-line and flows eastward to the sea. Farther east, this river is locally called the Staunton River. The area to the north of Catawba Mountain is drained by Catawba Creek into the James River, which roughly parallels the Roanoke, forty miles to the north. At Lafayette, a mile west of Roanoke County, the North and South Forks of the Roanoke converge to form the main river. These forks drain the dissected upland of eastern Montgomery County. Four large tributaries join the Roanoke within the county: Back Creek from the west and south; Tinker Creek and its large branch Carvins Creek, from the north; Glade Creek from the northeast; and Masons Creek from the northwest, which enters the Roanoke near Salem. The extreme southwestern upland is drained through Bottom Creek into the South Fork of the Roanoke, and Millers Cove in the extreme north west drains into the James through Craig Creek. There is evidence of

considerable underground circulation in the valley areas, and this phase of the drainage will be discussed in the chapter on Water Resources.

Descriptive Geography

Several geographic provinces or divisions may be recognized in the county. The most striking of these are the Blue Ridge, the Great Valley, and the Alleghany Ridges. Catawba Valley and Millers Cove are also geographic units, as is the open valley formed by the wide recesses of Masons, Carvins, and Bradshaws Coves. These divisions are in sharp contrast with adjoining areas, and their individual characteristics have affected the settlement and development of the county.

The Great Valley is constricted to a narrow width at the points where it enters and leaves Roanoke County, so that the Roanoke County lowland is somewhat separate from the rest of the Valley. This local division is called the Salem Valley from the town of Salem which is located near its center. The Salem Valley is separated from the Fincastle division of the Valley by the mass of Tinker Mountain, which projects far to the southeast and nearly meets the Blue Ridge above Cloverdale. A mile beyond the southwestern county-line, the Great Valley is further obstructed by the mass of the Pedlar Hills, which divides the Forks of the Roanoke River, and fills the area between Paris and Poor Mountains, separating the Salem from the Dublin Valley. The Salem Valley is thus about eight miles wide at its widest portion, and extends across the entire county for a distance of twenty miles. Its floor stands about 1000 feet above sealevel, although this level is broken by many small hills which rise to higher elevations. An extension of this valley to the northeast, lies between Porters Mountain and the masses of Mills and Coyners Mountains, and a southern extension projects between Mill and Sugar Loaf Mountains southwest of Roanoke City. The Salem Valley is drained entirely by the Roanoke and its tributaries, chief of which are Tinker and Glade Creeks.

In the southwestern part of the county, the Salem

narrows to a mile in width, and its floor is at a higher elevation, standing about 1200 to 1400 feet above sealevel. The main lines of travel pass through this lowland, and the larger cities and villages of the county are located in this province. The valley is open and rolling, and surrounded on all sides by mountains. It may be entered at five passes, two of which are at low elevations. The most open entrance to the Salem Valley is from the northeast along the length of the Great Valley, the pass at Cloverdale being only 100 feet above the level of Roanoke City. This gap is occupied by Tinker Creek, the Shanandoah Valley Division of the Norfolk and Western Railroad, and the Lee Highway. The northeastern extension of the Salem Valley along Glade Creek is occupied by the Lynchburg Division of the Norfolk and Western Railroad, and by the Roanoke-Lynchburg highway. These cross the Blue Ridge at Bufords Gap at an elevation of 1250 feet. Divisions of this railroad enter the valley from the south through Murrays and Maggotys Gaps, and from the west along the Roanoke River. A fifth entrance to the valley is along the Roanoke as it cuts through the Blue Ridge at the extreme eastern edge of the county. This pass however, is not utilized by any of the main lines of communication or travel.

The southern third of the county, south and east of the Salem Valley, is an upland area formed by the Blue Ridge and its lines of foothills. Between Buchanan and Roanoke, the Blue Ridge is composed of two parallel ridges, the northern one ending abruptly in Fullhardts Knob north of Cloverdale. The southern ridge continues into Roanoke County along its eastern boundary, with Yellow, Buck, and Mill Mountains as northern foothills. The southwestern upland has its surface at about 3000 feet, and forms the area composed of Poor and Bent Mountains. This is the most rugged part of the county, and is sparsely settled and poorly developed. The area is largely drained by Back Creek which flows parallel to the Roanoke and joins it near the gap through the Blue Ridge.

The northwestern third of the county consists of the parallel, northeast-southwest mountains of the Appalachian Ridges with

deep and narrow intermontane valleys between. The southernmost of these ridges, Fort Lewis Mountain, has been cut thru by two streams, Masons and Carvins Creeks. Both of these flow southward into the Roanoke and have opened wide recesses in the valley north of the mountain, which are called Masons and Carvins Coves respectively. The divide between the Roanoke and James Rivers is along the crest of Catawba Mountain, and the drainage to the north flows into the James through Catawba and Craig Creeks. The Catawba Valley connects the Fincastle Valley with the Dublin Valley which lies to the west and southwest of the Pedlar Hills. The Catawba Valley has by some been considered a part of the Great Valley of Virginia, but it is properly an intermontane valley within the Ridge region, although it is underlain by the Valley Limestone. The valley-floors in the northern third of the county are from 1500 to 2000 feet above sealevel, and the crests of the ridges reach elevations of about 3000 feet.

Soils.

The surface rocks of Roanoke County include all formations from the PreCambrian crystallines to the Lower Mississippian sandstones, each with its peculiar soil. By far the best type of soil is that found in the Salem and Catawba Valleys. This soil is the result of deep weathering of heavy limestones and it is especially productive. The soil is firm, deep-red, and of varying depths, often fifty to one hundred feet in thickness. Here and there it is very shallow, and fields may be obstructed with outcropping ledges or rows of residual boulders, which impair fertility and hinder cultivation. Cherty areas and siliceous streaks often render local areas better suited for pasturage than for agriculture. Such belts are developed upon cherty or sandy lenses within the Valley limestones and make up but a small part of the total valley floor. Wheat and corn thrive on the limestone soil, while grasses prosper best upon the shale soils adjacent to the lime soil belts.

The northern belt of the Salem Valley is covered with a lean brown soil which has developed from the weathering of the shales stratigraphically above the Valley limestone. This soil is less fertile than the red lime soil, and is often filled with tiny rock splinters which weather from the hackly shales below. The shale soils of the intermontane valleys of the Ridge region are unproductive, and give rise to the so-called "poor" valleys of this latter area.

The soil which develops from the weathering of the crystalline rocks is usually rather heavy, composed largely of clay, and of good fertility. Like the lime soils of the Valley, its prevailing color is deep-red and its depth is often great. The soil grades downward from a loam through a clayey subsoil into decomposed rock, which in turn grades into solid rock below. The soil is easily gullied by streams and rain-wash, and plowed earth is quickly removed during heavy showers.

The crests of many of the higher mountains are bald, and bare ledges are abundant. Boulders from these exposures are constantly being washed down to choke the stream-bottoms and contaminate the adjacent farm land. The mountains are generally composed of resistant sandstones or "freestone", and their soils are thin and siliceous. They are very loose, drain rapidly and will not retain manures, so that their main value is for orchards and pasturage. Where not cleared, they support growths of hardwoods and conifers.

By far the greater percentage of the area of the county is covered with residual soil, that is, soil which has developed from the decomposition and disintegration of the bed-rock directly beneath. Where the Roanoke and other large streams have developed floodplains, small isolated areas of silt or stream alluvium occur, but these are too scattered to modify the general lime nature of the Valley soils.

Climate

The county is favored with a pleasant climate well adapted for agriculture, despite a position along one of the main extratropical storm paths of the spring and autumn. The growing season lasts from 150 to 200 days, with the first killing frosts about the middle of October, and the last about the middle of April. The prevailing winds are from the southwest, and their average velocity is between eight and ten miles per hour. The average yearly temperature is 56 degrees, and the range of temperature extremes is from a few degrees below zero to several degrees above 100°. The average temperature for January is about 36 degrees, and for July about 78 degrees. The relative humidity averages about 80 percent.

The county receives 48 inches of rainfall yearly, in about 100 annual rainy days. The rainfall is evenly distributed throughout the year, although it is slightly greater in the summer and less in the autumn than in winter and spring. Thirty or forty days with thunderstorms are expectable during the summer months, and many of these storms are quite severe. Those storms which move down the Valley from the northeast and pass southwestward through the gap at Cloverdale seem to be more violent than those which move eastward, and the area around Cloverdale has a somewhat higher rainfall than the adjacent valley regions. Most of the storms follow the mountain ridges, so that the higher uplands have a greater rainfall than the lowlands. The first snows generally begin in late November, and there are often twenty or thirty days with thin snow covering the ground. The annual number of clear days is about 150; of cloudy days 100; of foggy days 25. The percentage of cloudiness is thus about 40 to 50 percent.

Vegetation

The Great Valley of Virginia has long been famous for its fertility and productiveness, and the Salem Valley is the center of much

agricultural activity. The Valley or Lee Highway is lined with fertile fields, prosperous farms, and productive orchards. The soil is firm and fat and excellent for wheat, so that the yield is often forty to fifty bushels to the acre. Corn, beans, tobacco, and clover thrive, and lead to an export of grain, cattle, and dairy products. The mountain slopes are well adapted for the production of apples, and many local varieties are exported in great numbers. Good pasturage is abundant, and stock of all kinds is raised. Nearly all of the area of the valley floors is in cultivation or in pasturage, although the higher rocky knobs of the lowlands are still forested. These stand out conspicuously among the well-kept farms of the valley bottom.

Most of the woods of central Virginia flourish in this area and good cheap lumber is abundant. A large proportion of the mountain ridges are timbered, although the forests have been cut over many times and have suffered severely from repeated forest fires. As a result, the forests are open and patchy, with many barren or bald areas between. The stand of the timber is better in the northwestern third of the county than in the southwestern part, mainly because of more productive and deeper soil, although much of the Poor Mountain upland is still densely forested. Lumbering is not an important industry, but most of the wood for local use is taken from within the county. Oak, chestnut, pine, hickory, cedar, and birch are the prevailing types, and the forests are chiefly of hardwoods with scattering conifers.

Development

The chief city is Roanoke, population 60,000, which is located in the east central part of the county in the Salem Valley along the Roanoke River. It is about 220 miles from Washington D.C., 200 miles from Richmond Virginia, and 260 miles from Norfolk Virginia. The nucleus of this city was Big Lick or Gainsborough, which was established in 1838 as a stage station on the old Lynchburg and Salem turnpike. The growth of

DEVELOPMENT

It is thought that the Roanoke Valley was first penetrated by white men in 1726, when two pioneers, Marlin and Salling, on an exploring expedition, were captured by Cherokee Indians, along the Roanoke River, supposedly near the present site of the city of Roanoke. The first land grants of this region were issued soon after, and from 1740 to 1760, large grants of land were made to McAfee, Carvin, Peters, Masons, Lewis, Poage, and others, whose names have been perpetuated in the geography of the area.

The first settlements in this area were made at about the same time in the Roanoke and Catawba Valleys, and in the valley of Back Creek, near Bent Mountain. Several main lines of Indian and early pioneer travel passed through the region. One great line traversed the Catawba Valley, and was the path of travel from Fincastle and points north to Smithfield (now Blacksburg) and the southwest country. The route of Indian travel along the great valley, known as the Great Path, passed through Roanoke County, near the present site of the Lee Highway, with a side trail extending through Buffords Gap near the site of the present Roanoke-Lynchburg road. Near the convergence of these two Indian trails was a free-flowing spring which naturally tended to make the spot a camping ground. Adjacent to this spring was a saline marsh to which deer and other animals came, and this was later called Big Lick The spring is now called the Franklin Mineral Spring, and is located at the present intersection of the Lynchburg and Hollins roads. The settlements of both the Roanoke and Catawba Valleys were driven out by an Indian raid in 1764, but were soon re-established.

Prior to 1730, all of western Virginia was called Orange County, but at that date, the county of Augusta was formed to include all the area west of the Blue Ridge to the Mississippi River within

Chapter I.

Insert near page 9 of mss.

Insert

PLATE II.

Plate I.

Figure A.

Aeroplane photograph of the Roanoke Valley, looking north along the Lee Highway. The folded ridges of the Appalachian Mountains are in the background. Note the well-kept farms of the fertile valley. The wooded patches represent uncleared areas of cherty or siliceous soils. Photograph by Underwood and Underwood.

Figure B.

Aeroplane photograph looking across the southern part of the city of Roanoke, showing Mill Mountain in center, and the Blue Ridge in the far background.
Photograph by Underwood and Underwood.

the latitude of Virginia. Thus at the time of Washington, Roanoke County was a part of West Augusta. In 1769, the county of Botetourt was formed, and then included much of central and southwestern Virginia. In 1772, the norther part of this county was identified as Fincastle County, but four years later, the area of Fincastle County was apportioned between Montgomery, Washington, and Kentuckie Counties, and only the name was retained for the county-seat of Botetourt County. On March 30, 1838, by an Act of the Virginia Legislature, Roanoke County was established from territory originally comprised in Botetourt County, and the town of Salem, then 35 years old, was chosen for the county-seat. The name Roanoke was taken from the Roanoke River, which in turn derives its name from an old Indian word, Roenoke or Rawrenoke, signifying shell money.

The town of Salem was laid out in 1802, and was established as a town by the State Legislature in 1806. It was incorporated in 1836, at which time its population was about 450 inhabitants, and it was the largest town of the region. The constriction of the Salem Valley a few miles west of Salem seems to have checked the early emigration of pioneers down the Great Valley, and it appears that the Valley was not settled by Virginians beyond Salem, until 1840 or later. In fact on the old maps, the Valley is represented as ending near Salem. Beyond this supposed mountain range which closed the Valley, pioneers passed through low gaps in the ridges into the uplands of southwestern Virginia and North Carolina. The present highway from Salem to Lafayette is said to have been surveyed by Washington.

In 1838, the Washington-Bristol turnpike was constructed through Roanoke County, and a village was established as a stage station near the present site of Roanoke. The village was first called Gainsborough but later became known as Big Lick, from the saline marsh already mentioned. The nucleus of this village was built around the stone house of

William Stover, built near the present ~~site~~ junction of Campbell and Henry Streets in about 1797. In 1856, the Virginia and Tennessee Railroad was constructed from Lynchburg to Bristol, and since Roanoke County refused to vote any bonds to help finance the railroad, the tracks were laid one mile distant from Salem and Big Lick, the two principal towns of the County. Gradually the business of Big Lick moved toward the railroad, and the former site of the town became known as Old Lick. In 1874, the town of Big Lick was incorporated with a population of about 450. In 1882 its official population was 600 inhabitants. During 1882, the Shenandoah Valley Railroad constructed its track from Hagerstown, Maryland, to Big Lick, at which point it joined the Norfolk and Western Railroad, which had formerly been the Virginia and Tennesee Railriad. From 1882 to 1884, the population of Big Lick greatly increased, so that in 1884, the settlement was incorporated as the city of Roanoke, its population being 5,276 people. The subsequent growth of this city has been remarkable, and has been in large part the result of development as a railroad center. The present population is in the vicinity of 60,000 inhabitants.

The population of Roanoke County at the time of formation was 5,497; in 1910, 54,457; and in 1927 about 72,000 people. Other settlements in the county are; Vinton, (known as Gish's Mill until 1884), population 3000; Cave Spring, population 200, Bonsacks, population 120; Starkey, population 50. Roanoke is the chief city, and is located in the east central part of the County along the Roanoke River. It is about 220 miles from Washington, D.C.; 200 miles from Richmond; and 260 miles from Norfolk. The seat of the county is Salem, present population 4,500.

Four divisions of two railroads meet at Roanoke City;- The Shenandoah, Norfolk, and Radford Divisions of the Norfolk and Western Railroad, and the Virginian Railroad. A short spur-line connects Salem with Catawba, and an electric line connects Roanoke and Salem. Five improved roads cross the county or meet at Roanoke. The best of these is the Lee Highway, which traverses the Great Valley from one

end of the State to the other and follows the valleys of Tinker Creek and the Roanoke River throughout much of this county. It is in first-class condition and carries much travel. Other improved roads lead from Roanoke to Lynchburg; from Roanoke to Rocky Mount; from Roanoke to Floyd Courthouse; and from Salem to New Castle. These mark the main lines of communication and travel. The majority of the other roads are unimproved dirt or sand-clay roads, and many of them are fairly good in the dry season. Some of the roads shown on the topographic map were originally old wagon roads, and are now impassible for modern vehicles; some of them are no longer traceable. Other roads, some now improved, have been made since the map was surveyed (1886-7) and are not shown on the map.

The valley regions of the county are well settled, and about 70 percent of the land area is in farms. The mountain slopes are generally rocky and untillable and in consequence are sparsely settled, so that considerable area, especially in the southwestern region, is very wild. The geographical location and railroad communication serve to make Roanoke the largest and most important inland city of Virginia. It is the southern gateway into the Great Valley, and the eastern gateway into southwestern Virginia.

THE GEOLOGY OF ROANOKE COUNTY VIRGINIA AND VICINITY

H. P. Woodward

Chapter II.

PHYSIOGRAPHY

Chapter II

PHYSIOGRAPHY.

General Statement

In studying the physiography of such an area as Roanoke County, the general effects of erosion and the factors influencing this erosion claim the most attention. So far as can be told, the chief agents of erosion in this area are, and have always been, streams. These have produced the present and past topographic forms as a result of four important factors; a. Inequalities of level upon the initial land surface; b. Differences of hardness in the underlying rocks; c. Variations in distance from the sea, and hence in local baselevels; d. Differential uplift or warping of the land surface. These factors have modified stream erosion to varying degrees in different erosion cycles, so that under the predominant influence of one or several of these factors, the surface of this county has passed through various stages of development, some of which may be recognized from the disposition of the present forms.

The most obvious result of these factors of erosion has been the production of similar land forms in districts where similar factors have been equally influential. This has had the effect of producing areas of provinces which as units have passed through similar physiographic history and which therefore, are now characterized by similar land forms. These are called physiographic provinces, and are readily apparent even to the layman, who easily distinguishes one from another.

The stages of the development of land forms may be considered in terms of epochs of erosion, or erosion cycles. An erosion cycle represents the evolution of the topography from any initial surface through the destruction of this surface by the agents of erosion to a resultant plane surface to which all elevations have been worn down. When this

plane has been perfected, the cycle is complete, and the resultant land form is then called a peneplane. The degree of perfection of the peneplane depends upon the nearness to completion of the cycle, so that if erosion is interrupted or incomplete, the topography may show any variation from the peneplane to a highly mountainous surface, depending upon the stage of erosion at the time of interruption. The completion of an erosion cycle. if uninterrupted, depends upon certain factors, chiefly, the speed of erosion, and the resistance of the rocks to this erosion. Under any condition however, the duration of an erosion cycle is very long, and a full cycle is seldom reached before some interruption occurs. This is generally an uplift of the land, which rejuvenates the streams and initiates a new epoch of erosion or lengthens the old epoch. The recognition of these completed or partially completed erosion planes is an important factor in interpreting the past physiography of a given area, so that the erosion levels in this county will be carefully described.

Attendant upon these changes in the land form are changes in the arrangement of the streams, and there is every reason to believe that the past drainage of Roanoke County was very different from that of the present; and it is possible to predict for the near geologic future other changes equally as radical. The following pages will therefore, be devoted to a study of the development of the topography of this area, in so far as this development may be determined from the present topography of the land.

The reader will find the following selected references valuable in understanding this development for the Appalachian Mountain region as a whole, and for other areas adjacent to Roanoke County.

Physiographic References

Campbell, Marius R., The Valley Coal Fields of Virginia, Va. Geol. Surv. Bull. No. XXV, pp.130-136, 1925.

Davis, William M., The geological dates of origin of certain topographic forms on the Atlantic Slope of the United States. Geol. Soc. Am. Bull. Vol. 2, pp.541-2; 545-86, 1891.

Hayes, C. Willard, The Southern Appalachians, Nat. Geog. Soc. Mon. Vol. 1, No. 10, pp.305-336, 1895.

Hayes, C.W. and Campbell, M.R., Geomorphology of the Southern Appalachians, Nat. Geog. Mag. Vol. VI, pp.63-126, 1894.

Stose, George W. et al, Manganese Deposits of Western Virginia, Va. Geol. Surv., Bull. No. XXIII, pp. 16-24, 1922.

Watson, Thos. L., and Cline, J.H., Drainage Changes in the Shenandoah Valley region of Virginia, Univ. of Va. Pub., Philos. Soc. Bull., Scientific Ser. Vol. 1, No. 17, pp. 349-363, 1913.

Willis, Bailey, The Northern Appalachians, Nat. Geog. Soc. Mon. Vol. 1, No. 6, pp. 169-202, 1895.

Wright, Frank J., The Physiography of the Upper James River Basin in Virginia, Va. Geol. Surv. Bull. No. XI, 1925.

Physiographic Provinces

The term physiographic province is applied to a unit of area which is characterized throughout by similar surface features, and which has developed this physical unity through a similar or closely related physiographic history for the whole area in question. In Roanoke County, three distinct physiographic provinces may be recognized, each sharply separated from the others, and each occupying roughly the same proportion of the area of the county. These are, from northwest to southeast, the Newer Appalachian Province, the Appalachian Valley Province, and the Blue Ridge Province. The Piedmont Upland Province lies just east of the Blue Ridge Province, but does not include any part of the area of the county.

The term Blue Ridge is applied to the narrow belt of contiguous mountains whose topography is developed upon hard rock of complicated structure, and which lies just east of the Great Valley. Throughout much of Virginia, this term is solely applied to the narrow mountain area underlain by crystalline rocks. This restricted usage of the term would be universally adopted except for the fact that in some places the term is also applied to the higher western foothills of the crystallines which are controlled by resistant sedimentary rocks. To restrict the term to the crystalline area would involve confusion of usage, expecially with the names printed on the topographic maps, so that it seems advisable to include within the Blue Ridge Province both the mountainous crystalline areas, and the contiguous foothill belt developed upon the sandstones of the earlier Cambrian. ~~This involves some difficulty of delimitation within Roanoke County in the case of Reeds and Coyners Mountains. On the geologic map of Virginia, published in 1916, these mountains were mapped as being underlain by Cambrian quartzites. They would thus be associated with the Blue Ridge Province as here defined. On the other hand, the rocks are now known to be Silurian in age, which would tend to associate them with the~~

~~Lower Appalachians. With the exception of this instance, the present usage of the term Blue Ridge involves no difficulty in central western Virginia, if indeed it does here.~~ In Roanoke County, the Blue Ridge is also called Porters Mountain, Stewarts Knob, Twelve O'Clock Knob, and Bent and Poor Mountains, while its larger foothills are called Mill, Yellow, and Buck Mountains.

The Blue Ridge Province contains maturely dissected mountains of crystalline and quartzose rocks, with disturbed structure and nearly accordant summits. Its drainage is dendritic save in some of the narrow valleys between the crystallines and the foothills. The texture of its topography is rather coarse. It has been eroded chiefly by stream erosion and this has served to bring out its relief by lowering the belts underlain by rocks of inferior hardness. The Roanoke is the only river to cross the ridge in this county, and it roughly divides the Blue Ridge Province into two sections; a northern narrow division composed mainly of crystallines, and a broad southern division containing areas of both crystallines and sandstones. In this county the two divisions are not strikingly different, although the Blue Ridge north of the Roanoke has no foothills, while to the south there are two ranges of sandstone foothills.

The Appalachian Valley Province, which is sometimes referred to as the Valley Province, lies immediately to the north and west of the Blue Ridge and its foothills. This province is developed upon a continuous belt of weak limestone and shales, and has an undulating surface at an elevation much lower than that of the Blue Ridge. It is in various stages of dissection in different parts of its extent, and its texture is also rather coarse. Most of its streams are subsequents, which have become adjusted to weak belts in the folded rocks beneath. ~~[Hills and Joyners Mountains may be said to rise from beneath the Valley, since the weak rock which controls the lowland development has been eroded from their summits.]~~ Many ~~other~~ hills rise from the surface of the Valley and are of different heights. In this county, the Valley Province is drained solely by the

Chapter II.

Insert near page 17 of mss.

Insert

PLATE III

Plate III.

Figure A.

View of Appalachian Ridges at northwestern edge of the Roanoke Valley. Tinker or Dead Mans Mountain at right, Smith Ridge at left, Carvins Creek gap in left center.

Figure B.

View looking north east across Roanoke. Dead Mans Mountain in left center, Mills or Reeds Mountain at right, Round Hill in center. The foreground shows the Roanoke Valley-floor peneplane, Round Hill rises to the Fincastle Valley-floor peneplane, and the higher mountains reach the Upland peneplane level.

Roanoke River and its tributaries.

The Newer Appalachian Province occupies the northwestern part of Roanoke County, and its mountains are often called the Alleghany or Appalachian Ridges. [~~and its southeastern boundary the Alleghany Front.~~] This province contains an area of mountains developed upon a folded series of resistant and non-resistant rocks, and the drainage is largely of the trellis pattern. The mountains are maturely dissected, and are in at least a second cycle of development, the whole area having been etched out by differential erosion from a plane surface of a previous erosion cycle. The even-crested ridges predominate over the valley belts, above which they rise about 1000 feet. The ridge-making formations are sandstones of Middle and Upper Paleozoic age, and the valleys have been worn upon shales. The province extends to the north of Roanoke County and adjoins the Alleghany Plateau Province in West Virginia, not far from the Virginia line.

Erosion Levels

General Statement.

Throughout much of the Appalachian region, two erosion levels or peneplanes have been prominently developed. These stand at different elevations, and make conspicuous surfaces of reference. Elevations above and below these planes can thus be readily located. On this basis, there are five physiographic levels; 1. Elevations above the upper peneplane; 2. the upper peneplane; 3. elevations between the two peneplanes; 4. the lower peneplane; 5. elevations below the lower peneplane. Each of these is recognizable in Roanoke County, and it is convenient to refer to them by name. The followings names will be used for the different levels;

1. The Summit Peneplane.
2. The Upland Peneplane.
3. Intermediate Levels.
4. The Valley-floor Peneplanes.
5. Trenches below the Valley-floor Peneplanes.

The Summit Peneplane.

The highest mountain area in this area lies in the southwestern corner of the county, partly in Montgomery County. This is the rugged mass of Poor Mountain which reaches a maximum elevation of 3960 feet. Viewed from the top of Bent Mountain, this mass rises nearly a thousand feet above the level rolling surface of the old Upland Peneplane which is well developed upon Bent Mountain. Above this peneplane, Poor Mountain rises as a prominent mountain front, and represents a region never reduced to the general upland level. Thus this area is a part of a land surface in exixtance before the beginning of the Upland cycle, and it is therefore much older than that peneplane. There is somewhat meagre evidence that this old surface was itself a peneplane with more or less degree of perfection. It will here be called the Summit Peneplane after Stose.[1] (~~45:20~~)

1) Stose, G.W. and Miser, H.D., Manganese Deposits of Western Virginia, Va. Geol. Surv. Bull XXIII, 1922 p.20

Its elevation in Roanoke County is about 3500 feet.

A few other peaks within the county reach nearly to this old surface. These are, Masons Knob, 3217 feet; McAfees Knob, 3201 feet; and Fort Lewis Mountain, 3328 feet. The summit of the Poor Mountain area is even-topped and shows evidence of benches at about the 3500 foot elevation In Giles County, this level (3600 feet A.T.) is very striking on Pearis Mountain and some of the other high peaks. The elevation is also reached by many of the mountain summits of the central Appalachians, and this level is taken to represent the somewhat even surface of the land at the close of the erosion cycle just prior to the development of the Upland Peneplane. It is the highest peneplane which can be definitely recognized in Roanoke County. Its average height is from 3500 to 4000 feet above sealevel. The surface has been also called the Pearis Peneplane from its development on Pearis Mountain in Giles County.[2] (~~[illegible]~~) Wright, in studying the physiography of the Upper James River basin found no evidence for a definite erosion surface in the Appalachian Ridge region older than the Upland Peneplane.[2] (~~[illegible]~~) However, he did not specially consider the area of the Blue Ridge, and it is probable that some remnants of this older surface might be

2) Hubbard, G.D. and Croneis C.G., Notes on the Geology of Giles Co., Virginia, Denison Univ. Bull. Vol. xx, 1924, p. 312.

3) Wright, Frank J., Physiography of the Upper James River Basin in Virginia, Va. Geol Surv. Bull. XI, 1925, p. 5

Chapter II.
Insert near page 19 of mss.

Insert

Figure 1.

Figure 1.

Generalized profile across the Valley of Virginia showing various levels described in this report. Folded Appalachians on left, Valley in center, Blue Ridge on right.

there found. Other remnants have been nearly entirely destroyed.

Because of its very old age, the Summit Peneplane has suffered more erosion and uplift than any subsequently formed land surface, so that its remnants are very rare and of small area. Those which remain, owe their existance to protected localities at the headwaters of streams, or to exceptionally durable rock, and are now coincident with the highest present mountain groups. There is little doubt that many of the elevations now standing near the 3000 foot level were remnants of the Summit Peneplane at the close of the Upland Peneplane cycle, but which have been reduced to lower levels since the latter cycle. To what extent the streams upon the Upland Peneplane owed their existance to a previous course upon the higher peneplane can not be determined, and it does not seem possible to trace the drainage patterns farther in the past than the middle of the Upland cycle. The age of the highest peneplane is thus indeterminate, but since it is known to antedate the Upland or "Cretaceous" level, it was possibly formed in late Jurassic or earliest Cretaceous time if the Upland Peneplanation is correctly dated. The records of the formation of the Summit Peneplane and of prior physiographic events are lost.

The Upland Peneplane.

The next highest physiographic level which is clearly discernable appears on the accordant summits and even crests of the mountains at a persistant elevation of about 3000 feet. A view from one of the highest mountains shows isolated remnants of an old erosion level to which many of the mountain summits now rise. Parts of this old level are preserved by broad shoulders near the crests of the higher ridges, and by the flat-topped summits of some of the mountain peaks. From the Valley, this erosion level is not conspicuous, but from a commanding elevation its remnants are quite prominent, and if one imagines the intervening valleys to be filled to the level of these remnants, the original flat nature of

Chapter II.

Insert near page 20 of mss.

Insert

PLATE IV.

Plate IV.

Figure A.

Tinker or Dead Mans Mountain underlain by Silurian quartzite rising from the level of the Roanoke Valley-floor peneplane.

Figure B.

View looking east across the Roanoke Valley toward the Blue Ridge.

the surface becomes very apparent.

This peneplane is well preserved on the summits of Bent Mountain about twelve miles southwest of Roanoke. Its surface is crossed by the Roanoke-Floyd Courthouse road which ascends the steep face of Bent Mountain from Poages Mill to reach the peneplane at Air Point. From the valley of Back Creek near the mill, Bent Mountain looms up as a steep mountain ridge, and one is surprised upon reaching the summit of its precipitous scarp to fine a plateau-like upland with gently rolling surface extending back from the very edge of the mountain face. The general elevation of this upland is about 3000 feet, and it is trenched with wide shallow valleys, between which rise low rounded hills. The surface is strikingly even, and slopes very gently to the southwest, being drained by the headwaters of Bottom Creek which flows into the South Fork of the Roanoke. To the south and west, the upland is bordered by higher ridges which stand from 500 to 1000 feet above the peneplane and represent remnants of the Summit Peneplane. From the present upland position of the remnants of the 3000-foot level, it is called the Upland Peneplane after Stose.[1] (~~[illegible]~~)

1) Stose, G.W. et al., Manganese Deposits of the West Foot of the Blue Ridge, Virginia, Va. Geol. Surv. Bull. XVII, 1919, p. 34.

It corresponds to the Cretaceous Peneplane as that term is commonly used throughout the Appalachian Region, and it is taken to be the equivalent of the highest peneplane in Maryland, Pennsylvania, and New Jersey, where the name Kittatiny Peneplane is used from its development upon Kittatiny Mountain. A similar level in Giles County has been called the Spruce Run Peneplane.[2] (~~[illegible]~~)

2) Hubbard, G.D. and Cronis, C.G. op. cit., p. 313

The Upland Peneplane is best developed in the southwestern part of Roanoke County, but isolated remnants occur in many other parts of the area. The crest of Fort Lewis Mountain extends for eleven miles at an elevation of about 3000 feet, and represents a remnant as yet unreduced from the Upland surface. Tinker Mountain, Masons Knob, and McAfees Knob have shoulders or benches at the 3000-foot level, and are relics of monadnocks which projected slightly above the Upland surface. The level summits of North, Cove, and Brushy Mountains have been but slightly reduced

from the Upland Peneplane. The surface is well preserved on the crests of ridges north and west of the county. The upland surface of Bent Mountain continues to the southwest into Floyd County, where much of that area lies near the level of the old plane. It is poorly preserved on the Blue Ridge north of Roanoke, if at all, for it is there very difficult to trace any accordant levels from summit to summit. The nature of this original surface has recently been studied by Doctor Frank J. Wright in Bulletin XI of the Virginia Geological Survey, The Physiography of the Upper James River Basin in Virginia. The area covered by this bulletin does not include any part of Roanoke County, but extends very near the northern boundary of the county.

At the end of the erosion cycle which produced the Upland Peneplane, the land was worn down to a featureless lowland of very slight relief, nearly at sealevel. This type of land form must have been developed upon an area possessing long-continued stability. The surface was not entirely devoid of relief, for monadnocks bearing remnants of the Summit Peneplane still persist. These represent areas of relatively more resistant rocks, or areas at the headwaters of streams where surface reduction had not reached completion. The peneplanation appears to have been more perfect in the central Appalachians than in Roanoke County.

Little can be told about the original drainage upon this part of the Upland Peneplane. It is probable that such master streams as the Roanoke, James and New developed their meandering courses upon the level surface of the Upland Peneplane, since their present courses are not primarily determined by the rock structures through which they now flow. In the area of the present Appalachian ridges, the effect of the alternating hard and soft rock layers was probably in evidence before the close of this cycle of erosion, with the production of parallel subsequent streams tributary to the master streams.

Since the formation of the Upland Peneplane, and causing the close of that period of erosion, gentle uplift of the whole area has

Chapter II.
Insert near page 23 of mss.

Insert

PLATE V.

Plate V.

Figure A.

The sandstone foothills of the Blue Ridge southwest of Salem, looking south.

Figure B.

View of the rugged sandstone foothils of the Blue Ridge south of Roanoke. Yellow Mountain at the left, view looking west.

elevated the land at least 2500 feet in the region near Roanoke, since the remnants of this peneplane now stand that much higher than the present streams. This uplift took place without folding of the rocks, but was no doubt accompanied by a differential tilting or warping which appears to have been more pronounced in the northern Appalachians than in the southern. This uplift and tilt caused pronounced rejuvenation of those streams whose gradients were increased, especially in the rivers now flowing eastward to the ocean. The New River which flows westward was less affected and possibly retarded by the uplift, for it has lagged far behind in the lowering of its valley. A later warping of the Upland Peneplane took place in Tertiary times.

This peneplane is now strongly dissected, and the softer rock belts have been eroded to depths of 2500 feet below the old surface. The remnants which are left are those which were distant from the base-level controlling the down-cutting, or which were upheld by especially resistant rock strata. The unreduced remnants of the peneplane still preserve the gently rolling surface upon which a few of the older monadnocks remain. The present elevation of this plane is about 3000 feet in Roanoke County. To the north where the peneplane has been studied under better conditions of preservation, the date of its formation has been determined as latest Jurassic or early Cretaceous, and the peneplane has thus been called the Cretaceous Peneplane. The accuracy of this date of formation is open to question, but so far as the writer is aware, the local area offers no solution to the problem.

Intermediate Levels.

Between the well-developed erosion surfaces of the Upland and Valley-floor Peneplanes occur slight benches which represent intermediate levels of erosion. Since these stand below the level of the Upland Peneplane and above the Valley-floor Peneplanes, they may be spoken

of as monadnocks on the valley floor. They are so called by Wright,[1] (~~[illegible]~~). Stose has identified a somewhat constant level at an altidude of 2250 feet, and has called it the Intermediate Peneplane.[2] (~~[illegible]~~) Hubbard and Croneis[3] (~~[illegible]~~) recognize in Giles County an intermediate peneplane which they have called the Buckeye Peneplane, altitude about 2500 feet. In Roanoke County there is very little evidence of a persistant wide-spread level between the two main peneplanes. Therefore any intermediate benches will be here called Intermediate Levels, and will be considered merely as phases of the general down-cutting which ensued during late Cretaceous and early Tertiary epochs.

1) Wright. Frank J. Physiography of the Upper James River Basin in Virginia, Va. Geol. Surv. Bull. XI, 1925, p 24.

2) - Stose, G.W. and Miser, H.D, Manganese Deposits of Western Virginia, Va. Geol. Surv. Bull. XXIII, 1922, p 21

3) - Hubbard G.D. and Croneis, C.G. Notes on the Geology of Giles Co, Virginia, Denison Univ. Bull. Vol XX, 1924 p. 313

In this area, two elevations between the upper and lower peneplanes show suggestions of benching; one at 1700 feet, and another at 2100 feet. These benches occur in the eastern half of the county, and are not to be confused with the 2300 foot plane of the Dublin Valley-floor of western Roanoke County, nor with the 1400 foot level of the Fincastle Valley in the eastern part. There is good evidence of these intermediate benches along Porters Mountain, and on Stewarts and Weavers Knobs. Similar levels also appear along the main Blue Ridge south of Roanoke City, and several of the wind-gaps in the Blue Ridge have their floors at about 1700 feet. Stose has recorded levels upon the even tops of the foothills of the Blue Ridge, and has noted an accordance of some of the low divides in these mountains. These represent his Intermediate Peneplane.[4] (~~[illegible]~~) He also notes that this level does not appear west of the Blue Ridge, nor south of the Potomac. He correlates this level with the Weverton Peneplane of 1400 feet elevation along the Potomac, and dates its age as late Cretaceous.

4) - Stose, G.W. and Miser, H.D. op. cit.

In Roanoke County, the crests of many parts of the Appalachian Ridges produce a somewhat even skyline at an elevation of about 2000 feet, which might be taken as an intermediate peneplane. On the other hand, these ridges are upheld by rock of uniform hardness, and where the dip of the rock is gentle and its outcrop broad, equal erosion

on both sides of a ridge previously peneplaned at a higher level will tend to lower the crest evenly, and thereby form a level summit without the intervention of a later peneplane. Where the ridge-maker is thin, the mountain crests are often irregular in outline. Thus the areas of regular summit at the 2000 foot level appear to be due to symmetrical erosion.

Three main types of monadnocks rise from the valley-floors. The most massive of these are the mountain ridges themselves, of which Catawba, Tinker, and Fort Lewis Mountains are typical examples. These are monoclinal or synclinal in structure and are composed of resistant rock of Paleozoic age. A second type of monadnock is represented by Mill, Reeds, and Coyners Mountains, which are likewise composed of hard sandstones, but possess complex structure. A third type includes the small and often linear ridges which rise but little from the floor of the Valley. They are the results of differential erosion upon harder members of the Valley limestones, and the adjoining shale belts. These are illustrated by the ridges in the northwestern part of Roanoke City, and by the low hills east of Salem . Their crests approach the level of the old Fincastle Valley, and are probably remnants of that floor now somewhat worn down.

The Valley-Floor Peneplanes.

The most striking physiographic feature of the whole Appalachian region is the long open valley which traverses the State from north to south along the northwestern edge of the Blue Ridge. The floor of this valley is an undulating surface sloping gradually to the bounding ridges which rise abruptly from the lowland. No single river drains this valley, but it lies within the drainage basins of four distinct master streams, and the intervening divides have been almost perfectly bevelled. In Roanoke County, the Great Valley is drained by the Roanoke River; to

the northeast it is drained by the James; to the southwest by the New. The Valley was never formed by one river's erosion, but consists of several wide benches or plane surfaces at different levels 100 to 400 feet apart. Each of these benches represents an erosion surface which was determined by the level of the master stream which drained that part of the Valley, and the series of these levels are called the Valley-floor Peneplanes after Stose.[1] (~~45:20~~)

1) Stose, G.W. and Miser, H.D. op. cit. p. 20

Authors use different terms to represent these lowland levels. Wright considers them all as forming a single peneplane which he calls the Valley Peneplane.[2] (~~50:11~~) Watson and Cline[3] (~~50:[illegible]~~) use the term Tertiary for the level crests of the ridges which rise from the valley floor, and Shenandoah for the Valley surface itself. Spencer[4] (~~49:6~~) in the area around Massanutten Mountain used the term Shenandoah for the hill-top level of the gently rolling country into which the lowland is dissected. Hubbard and Croneis[5] (~~46A:515~~) have adopted the term Pearisburg Baselevel for the Valley-floor in Giles County. M. R. Campbell[6] and others have called the Valley-floor peneplane the Blacksburg Peneplain from its good development near Blacksburg in Montgomery County. (~~47:155~~) North of the Potomac River, similar levels are called the Harrisburg and Somerville Peneplanes, while the general term Tertiary Peneplane has long been in use for any well developed erosion level below the so-called Cretaceous or Upland Peneplane.

2) Wright, Frank J. op. cit. p. 11

3) Watson, T.L. and Cline, J.H., Drainage Changes in the Shenandoah Valley of Virginia, Univ. of Va. Publication, Bull. Philos. Soc., Scientific Sec., Vol. 1, Nov. 1913. pp 357-8

4) Spencer, A.C., Geology of the Massanutten Mountains - Washington, 1897. p. 4.

5) Hubbard, G.D. and Croneis, C.G., op. cit. p. 313.

6) Campbell, M.R. et al. The Valley Coal Fields of Virginia, Va. Geol. Surv. Bull. XXV, 1925, p. 133

Three separate valley levels are determinable in and near Roanoke County; the Dublin Valley-floor, drained by the New River, with a present floor-level of from 2300 to 2500 feet; the Fincastle Valley-floor, once drained entirely by the James, with a present floor at 1400 to 1500 feet elevation; and the Salem Valley, now drained by the Roanoke, with its floor about 1000 feet above sealevel. Thus the area is interesting from a physiographic standpoint, in that it contains valley-floor levels at three different elevations, although all were apparently formed at the same time.

The triangular area defined by Cloverdale, Buchanan, and Fincastle shows the well-developed Fincastle Valley-floor at the 1400 foot level. This plane is one of the most striking of the lowland peneplanes, and extends northward to Eagle Rock and Balcony Falls as previously described by Wright.[1] (~~48:52~~) It has been relatively little dissected, and is remarkably even and undulating in appearance. The same plane may be traced into the eastern end of Catawba Valley. Levels, which are taken to be remnants of this plane, occur within the Salem Valley, where the tops of Round Hill, Smith Ridge, and the benches on Mills Mountain are levelled at an elevation of 1400 feet.

1) Wright, Frank. op.cit. p. 32

The Dublin Valley-floor ("Blacksburg Peneplain" of Campbell,[2] ~~47:151-5~~) was formed by the erosion of the New River and its tributaries, and its level floor is well developed east of Blacksburg and Christiansburg. Abundant traces of benches at this level (2300-2400 feet) may be found in the western end of Catawba Valley, and in the valleys between Paris and Fort Lewis Mountains. These valleys are now part of the Roanoke drainage basin, and their present floors are far below this higher level. The presence of these high benches could be explained by the capture by the Roanoke of drainage which was previously tributary to the New River. Immediately west of Lafayette, the summits of the Pedlar Hills are at the level of the Dublin Valley-floor, although this area is now greatly dissected and drains into the Roanoke. There are also levels in the western end of the Salem Valley which stand at an elevation of 2300 feet, although the evidence for correlation of these with the Dublin Valley-floor is far from clear.

2) Campbell, M.R. et al. opus cit. pp 131-5.

The Salem Valley-floor Peneplane with its elevation of 1000 feet now occupies the central part of the county. The level of this peneplane is considerably lower than that of the other Valley-floor planes and it would appear that the lower plane is somewhat younger than either of the other two.

The areal development of the Valley-floor Peneplanes is

by no means as complete as was that of the Upland Peneplane. The period of levelling was sufficient only for the removal of that part of the earlier surface which was underlain by weak rock, although this removal progressed well toward the heads of the larger streams. Only the limestones and softer shales were worn down during the Valley-floor peneplanation as compared with the almost complete surface reduction in the Upland cycle. In the Ridge region, the limestones and shales are much less perfectly bevelled than in the Valley itself where the broad outcrop of the Cambro-Ordovician limestones has furnished a greater single area of soft rock. Furthermore, the peneplanation has progressed along the strike of the soft rock outcrops, and the irregularities on the surface of the Valley are not especially apparent until one crosses the Valley at right angles to the "grain" of the topography.

Mention has been made of the monadnocks on the Valley-floor which reach the Intermediate Levels. Below these, there are lower monadnocks which rise 50 to 200 feet above the general lowland. These ridges are chiefly developed upon the cherty or siliceous layers in the Valley limestone, or upon harder members of the adjoining shale formations. They are generally parallel to the strike of the Valley, and are seldom more than a few hundred yards in length. Their surface is often rock-strewn or ledgy in marked contrast to the heavily soil-covered lowlands.

The lowland peneplanes have been considerably dissected since their formation, and the present streams are incised several hundreds of feet so that the nature of the planes has been greatly modified. The Roanoke and its tributaries are now incised at least 100 feet below the Salem Valley-floor; from 400 to 600 feet below the Fincastle Valley-floor; and from 700 to 1000 feet below the Dublin Valley-floor. The high elevation of the remnants of these lowland peneplanes is unusual for the Great Valley in northern and central Virginia. Considerable quantities of gravels and sands of fluviatile origin cover the various levels, and at the mouths of some of the narrow ravines in the Valley walls, small alluvial fans

have been built up slightly above the peneplanes. These are generally small with low-angle slopes, and are composed chiefly of quartzite pebbles and quartz sand. They are especially noticeable around the flanks of Mills or Reeds Mountain where they extend down nearly to Tinker Creek and effectively cover all exposures of bed-rock. Others appear southwest of Salem around the flanks of Twelve O'Clock Knob.

The Valley-floor Peneplanes were formed at the end of a period of land uplift, the total amount of which is closely approximated by the difference in present elevation between the Upland and Valley-floor Peneplanes. In Roanoke County this difference is about 2000 feet. Near Richmond, Virginia, the two peneplanes are nearly at the same elevation, and they closely approach each other to the west in West Virginia. The valley-floors have suffefed warping since the peneplanation, but the amount and distribution of the warping can not be accurately determined in this area. Since the base-levelling, the floors have been elevated some distance as is shown by the incision of the present streams, and the various planes are in all stages of dissection from early youth to full maturity.

The date of formation of the Valley-floor Peneplanes is somewhat in doubt, and there does not seem to be adequate data to determine this date in Roanoke County. In other regions where the evidence is fuller, the peneplanation has been tentatively assigned to the Tertiary Period, although this assignment is not without question.

Trenches Cut Below The Valley-floor Peneplanes

The recent uplifts of the area have increased stream gradients and closed the former cycles of valley-floor peneplanation. The rivers are again down-cutting, and a future base-levelled surface is now in process of formation. The elevation of the Roanoke River in its gap through the Blue Ridge is about 880 feet above sealevel. This elevation determines the present local baselevel for that river system north of the

Blue Ridge. The Roanoke is encroaching upon the drainage basin of the New River along the watershed at Christiansburg, and in the near geologic future will probably capture the headwaters of that stream. This will cause an attendant increase of volume for the Roanoke, and a lower local baselevel for the New, so that the whole drainage system of Roanoke and Montgomery Counties will be re-arranged. The Roanoke will more rapidly lower the elevation of its gap through the Blue Ridge, and the 900 foot plane which is now being formed will stand as a prominent bench or terrace into which the rejuvenated streams will entrench themselves.

The present streams are flowing in comparatively narrow valleys with floodplains of various widths. They have cut down farther below the Valley-floor Peneplane surface in the western part of the county than in the east, so that the Roanoke is 700 feet below the old valley bottom at Lafayette and only 50 feet below at Roanoke. The tributary streams are likewise entrenched to depths depending upon their distance from baselevel. As an average, the present valleys are from 50 to 100 below the Salem Valley-floor Peneplane. Many of the smaller streams are being temporarily upheld by resistant rock ledges in their channels. The vertical Silurian quartzite of Smith Ridge forming Carvins Falls acts as a control upon the headwaters of Carvins Creek, and, by its resistance to stream wear, is retarding the lowering of the cove floor. The Roanoke Water Works is making use of this geologic obstruction to help impound a reservoir in Carvins Cove for the water supply of the city of Roanoke.

The larger streams show many terraces along their courses. Some of these are floodplain terraces cut in alluvial material. Others are benches due to slight land uplift, and are well developed along the valleys of the Ridge region, where they are cut in the soft Ordovician and Devonian shales. For the most part the terraces are covered with gravels, and can not be correlated with each other or with terraces in adjacent areas. Except for the terrace areas, the surfaces of the Valley-floor Peneplanes are heavily covered with residual soils which have only

Chapter II

Insert near page 30 of mss.

Insert

PLATE VI

Plate VI.

Figure A.

The level Roanoke Valley-floor peneplane with the folded Appalachian Ridges in the background.

Figure B.

Looking north at Catawba Mountain whose level crest reaches the Upland Peneplane level.

been stripped away in the regions where active erosion has taken place since peneplanation. These soils and clays are of value for the clay industry, and in many places deposits of iron and manganese ore have accumulated during or after the period of peneplanation. The Valley lowlands have been etched out upon limestones of various kinds, and the residual soil is very fertile and abundant. The formation of the Valley-floor Peneplanes has resulted in the production of considerable areas of level land well suited for cultivation, and has had a large part in determining the present scenery and economic resources of the area.

Drainage Developments

Roanoke County is nearly equidistant from the master streams of the New and James systems. Its own river, the Roanoke, is the southernmost stream to cross the Blue Ridge in Virginia, so that the county lies very nearly along the divide between the Mississippian and Atlantic drainage basins. The present drainage of the county is largely through the Roanoke River; one-eighth of the area drains into the James River, and none of the area is within the basin of the New River.

It is difficult if not impossible to reconstruct the stages through which the present drainage of this county has developed. To some extent at least, the present arrangement of the larger streams was inherited from their arrangement at the close of the Upland Peneplane cycle. Since all of the master streams in this part of the Appalachians show incised meanders, it may reasonably be supposed that they developed their meandering courses in an earlier cycle than the present, and upon a peneplaned surface which was presumably the Upland Peneplane. There is also no reason to doubt that the tributary streams on that part of the Upland Peneplane now etched into the Appalachian Ridges, were partially adjusted to the underlying structure, and were already in parallel subsequent valleys before the close of that cycle. The period of Upland

peneplanation was terminated by an uplift of the whole Appalachian region which caused a disturbance of the pre-existing drainage. The uplift was accompanied by differential tilting of the peneplane surface, favoring an increase of slope for some streams, and lowering the slope for others, initiating a new cycle of erosion.

With the uplift and tilting, the streams rapidly began to incise themselves and to destroy the surface of the peneplane. As the streams cut into this surface which had been developed upon hard and soft rocks of complicated structure, the softer rocks were etched out of the folded area, and a series of subsequent streams became developed, tributary to the master streams. These tributaries began to lengthen themselves by headward erosion, so that by the time the master streams had become entrenched, their upper branches and tributaries were established in longitudinal valleys along the strike of the folded rocks. It is probable that these tributaries became involved in a series of stream captures, both among themselves, and with tributaries of other master streams, although the details of such captures have not been worked out. The presence of high-level terraces in the Catawba Valley, which slope gradually toward the New River, is highly suggestive that the present drainage of that valley has been diverted from the New into the James River at a fairly recent date. Furthermore, the presence of similar terraces in the eastern end of the Salem Valley sloping toward the Fincastle Valley-floor, may also be evidence that this part of the Salem Valley was once occupied by a branch of the James, which has recently been captured by the Roanoke.

An interesting example of recent stream capture may be seen in the southwestern corner of the county, where the headwaters of Back Creek are rapidly obliterating the upland surface of Bent Mountain and sapping the headwaters of the South Fork of the Roanoke. This is especially well shown near Air Point, where a sizable branch of Bottom Creek which formerly flowed southwestward on the old upland surface, has recently been diverted to the northeast into Back Creek.

The present divide between the Roanoke and the New Rivers is along the crest of a low ridge which extends south from Blacksburg to Christiansburg in Montgomery County. The elevation of the New River opposite this part of the divide is about 1750 feet. The elevation of theNorth Fork of the Roanoke at Trinity Crossroads, three miles from this point in the divide is 1450 feet, and the two rivers are less than ten miles apart. The divide is thus very unsymmetrical, and the difference in level very marked. There can be little doubt that the Roanoke is at present encroaching upon the basin of the New River. With the great difference in local baselevels, the watershed will eventually be worn down so far that the headwaters of the New will necessarily seek the lower level of the Roanoke, and will be diverted from the basin of the Mississippi River system into that of the eastern Atlantic Ocean. This capture will initiate a new cycle of erosion for much of this area, giving the Roanoke doubled volume, and the New headwaters a steeper gradient, thus rejuvenating the entire drainage systems.

General Summary of the Physiographic History

With the above discussion of the physiographic levels and drainage changes in mind, it is possible to summarize briefly the physiographic history of the county.

The last known marine sediments to be laid down in this area were Mississippian in age. Presumably from the Mississippian Period to the present, the area has been dry land, and hence subjected to the attack of agents of weathering and erosion. Sometime at about the close of the Paleozoic Era, this region was involved in folding and faulting which seriously disturbed the rock strata, and produced the complicated geologic structure which the county now possesses. What effect this folding had upon the land surface is highly conjectural. It is only known that the area was lifted far above sealevel, and that a cycle of

erosion was initiated in a region where marine deposition had long been taking place. Little is known about the results of this erosion through the Triassic and Jurassic Periods. The first record of physiographic history begins with the production of an erosion surface which approximated a peneplane. The degree of perfection of this peneplane can only be imagined, for the present remnants are poorly preserved and the record very unreliable. This land surface is called the Summit Peneplane, and little is known about it save its existance. It may have been formed during late Jurassic or early Cretaceous times.

After the reduction of the land to the Summit Peneplane a slight uplift of the whole region occurred, so that stream erosion again became active. The rivers cut into the Summit Peneplane and destroyed its level surface. This cycle of erosion finally came so near to completion that a second peneplane was formed about a thousand feet below the first plane. The second level is called the Upland Peneplane from the present position of its remnants. This peneplane was much more perfect than the first level, and in the process of its formation, nearly all trace of higher levels was obliterated. The second cycle of erosion took place during a long period of crustal stability, so that the streams upon its surface reached full maturity. It was terminated by a series of uplifts which renewed stream erosion in all parts of the area. The uplift was accompanied by warping of the peneplane, which gave favored streams an advantage over less favored streams, so that the master rivers became adversaries for possession of intervening areas. This advantage has continued to the present time, and the rivers to the north of Roanoke County are progressively more active than their southern neighbors. The date of this uplift was probably between the Mesozoic and Cenozoic Eras, so that the Upland Peneplane may have been the site of active erosion at the beginning of the Tertiary Period.

The uplift amounted to at least 2000 feet in Roanoke County before a period of rest occurred long enough for the production of

definite erosion levels. The various stages in the down-cutting of the streams into the Upland Peneplane left remnants at different elevations which have been called Intermediate Levels. So far as is known, none of these were extensively developed in this area. There was however, a pause in the uplifts which was sufficiently long for the production of a series of levels, bevelling the belts of soft rocks at an elevation of about 2500 feet below the Upland Peneplane. These levels were developed along several master streams, and are called the Valley-floor Peneplanes. They were all formed at about the same time, but were controlled by different local baselevels, so that they were developed at slightly different altitudes. This difference in levels caused a series of stream captures with the northern streams being more aggressive than the southern. Three of these Valley-floor Peneplanes were developed in Roanoke County; the Dublin Peneplane, elevation 2400 feet; the Fincastle Peneplane, elevation 1400 feet; and the Salem Peneplane, elevation 1000 feet.

Uplift and warping closed this erosion cycle, and started the present trenching in the floors of the older peneplanes. The conditions which had produced captures were continued and even augmented, so that drainage changes have occurred in the recent past, and may be imminent in the near future. The James River is apparently increasing its area at the expense of the Roanoke System, and the Roanoke is attacking the drainage basin of the New River. It may be safely prophesied that another geologic epoch will see the headwaters of the New River tributary to the Roanoke River system. This diversion will upset the present cycle of stream erosion in Roanoke County, and will again initiate a new cycle for the region. This area has thus passed through three distinct erosion cycles, and is at present in a fourth cycle, with prospects of an early change. The region has been more or less constantly in uplift from Mississippian times to the present, and especially so from the Cretaceous to the present. The uplifts are in part recorded by the depths of the valleys, and the periods of rest by the erosion terraces or peneplanes.

THE GEOLOGY OF ROANOKE COUNTY, VIRGINIA AND VICINITY

by

Herbert P. Woodward

CHAPTER V

MINERAL RESOURCES OF THE ROANOKE AREA

VIRGINIA DIVISION OF MINERAL RESOURCES
LIBRARY

CHAPTER V

MINERAL RESOURCES OF THE ROANOKE AREA

General Statement

Metals

- Iron and manganese
  - General Statement
  - Blue Ridge Hematite
    - Griffin specular mine
    - Mines near Blue Rudge Springs
      - Grubb specular mine
      - Edith mine
      - Lemon or St. Clair mine
      - Cundiff bank
      - Dewey mine
      - Ironville mine
  - Clinton hematite
  - Brown ores along the Blue Ridge
    - General statement
    - Mines south of Roanoke at the edge of the Roanoke Valley
      - Rorer mine
      - Gale mine
      - Griffin mine
      - Starkey mine
      - Castle Rock and Turner mine
      - Iron Bluff Farm prospect
      - Poor Mountain mines
  - Mines along the southeast side of the Blue Ridge in the Glade Creek Valley
      - Lynchburg or Grubb mines
      - Upland or Crozer mine
      - Buford bank

Mines along the northwest side of the Blue Ridge in the Fincastle Valley

Stoner mine
Murray bank
Gowan bank
Deal bank
White bank
Houston mines

Oriskany iron and manganese ores

Limestone magnetites

Titaniferous magnetites

Pyrite and pyrrhotite

Summary of iron and manganese deposits

Lead and zinc

General statement

Specific deposits

Martin and Wertz prospects
Bonsacks prospect
Langhorne and Wills prospects
Other lead and zinc prospects
Summary of lead and zinc deposits

Minor metalliferous occurrences

Gold

Silver

Copper

Arsenic

Nickel and cobalt

Fuels

Coal in Roanoke County

General statement

Brushy Mountain Belt

North Mountain belt

Fort Lewis Mountain belt

Summary of coal deposits

Oil and gas

Other non-metallic resources

Limes and cements

General statement

Cambrian limestones

Ozarkian and Canadian limestones

Ordovician limestones

Devonian limestones

Summary of cement deposits

Clays and shales

General statement

True sedimentary clays and shales

Watauga shales
Elbrook shales
Athens shales
Marcellus-Genesee shales
Mississippian shales

Residual clays from decomposition of bed rock

Residual clays of the crystalline area
Residual clays of the Shady dolomite
Residual clays of the Elbrook formation
Residual clays of the Copper Ridge formation
Residual clays of the Nittany dolomite

Transported clays of floodplain origin

Summary of clays and shales

Titanium and apatite (Nelsonite)

General statement

Description of deposits

Minor non-metallic resources

- Asbestos
- Barite
- Bentonite
- Construction stone and crushed rock
- Glass sand
- Graphite and talc
- Marl
- Millstones and buhrstones
- Ocher
- Sand and gravel

General summary of the mineral resources of the Roanoke area

Selected references on the mineral resources of the Roanoke area.

VIRGINIA DIVISION OF MINERAL RESOURCES LIBRARY

MINERAL RESOURCES OF THE ROANOKE AREA

GENERAL STATEMENT

The Roanoke area holds a variety of rock types many of which contain natural mineral products that are of economic value under favorable conditions of occurrence. Few of these products, however, are being mined at the present time in the district, and the mining industry is of little importance in Roanoke County.

Of the deposits which are being actively mined, clay, building and crushed stone, lime, nelsonite, and a very little iron ore are the most important, and the production of none of these is very large. Coal, iron and manganese ore, glass sand, barite, and cement rock may be added to the list of mineral reserves of possible economic value, but can be developed only under more favorable conditions than those of the present. There are some important branches of mining for which no substantial basis may be found within the limits of this area. One of the most essential commodities of modern industry, petroleum or rock oil, is not likely ever to be found here. The precious metals are likewise not present in the area in workable quantities. The occurrence of gold and possible silver near Roanoke is authentic, but the amounts are so limited as to be commercially negligible. Lead, zinc, copper and nickel have been discovered in this district but no known deposits have proven of actual value, and the main natural resources of the area are of non-metallic substances.

The development of the resources of the Roanoke area was started in the early eighties by the founding of Roanoke City. Prior to that time the mineral reserves were little known, and practically untouched.

During the period from 1880 to 1893 the population of the region greatly increased and the district was fairly well combed over in the effort to locate mineral deposits of commercial value. This mining boom was in part a reflection of a general interest in mining which at that time developed throughout the State of Virginia, and in part was the result of the opening of territory hitherto unsettled. No doubt the development of the city of Roanoke as a railroad town stimulated the mining industry, as did the meeting at Roanoke in 1883 of the American Institute of Mining Engineers. During the decade following 1883 most of the important mineral resources of the county were discovered and many of them were prospected and mined. The panic of 1893 forced the closure of most of these small mines and few operations were in progress by 1900. Since that time some new reserves have been discovered and a few of the old prospects have been re-opened, although at the present time mining is scarcely a prominent item in the general industry of the region.

It is thus necessary to refer to past discussions for data concerning many of the deposits, for most of them were then described in more detail than can be accomplished by examination of the present exposures. The descriptions of the prospects and mines of this county have been largely taken from earlier reports and in many cases little additional information has been furnished by the present survey.

Throughout this chapter all quotations and references will be referred to a bibliography which is appended at the end of the chapter. This system is adopted in order to allow a bibliography for each mine or prospect described without an excessive number of footnotes. So

far as the writer is aware, the list of references at the end of the chapter contains all mention in geologic literature of mineral occurrences in the Roanoke area.

The mineral resources will be discussed under three main headings:

A. Metals

B. Fuels

C. Other non-metallics

Chapter V, insert near page 210 of mss.

Insert

Figure 4.

Figure 4.

Map of the Roanoke area showing the location of the most important metallic mines or prospects.

Brown iron ore mines.

1. Gowan bank.
2. White bank.
3. Deal bank.
4. Houston mine.
5. Stoner mine.
6. Murray mine.
7. Buford bank.
8. Upland or Crozer mine.
9. Lynchburg or Grubb mine.
10. Rorer mine.
11. Griffin mine.
12. Gale mine.
13. Starkey mine.
14. Castle Rock mine.
15. Poor Mountain mines.

Blue Ridge hematite mines.

16. Lemon mine.
17. Edith mine.
18. Grubb specular mine.
19. Cundiff and Dewey mines.
20 Griffin specular mine.

Pyrite.

21. Bonsacks mine.

Lead and Zinc mines.

22. Bonsacks prospect.
23. Martin and Wertz prospects.
24. Langhorne and Wills prospects.

Nickel prospects.

25 and 26.

METALS

Iron and Manganese

That the presence of iron ore in this area has long been known is attested by the old Back Creek furnace which was washed away in 1813, and was located on Back Creek about six miles south of the city of Roanoke. The old Catawba furnace was built about 1820 near the present site of Haymakertown along Catawba Creek; and the Cloverdale furnace near that town was built about 1830 and abandoned in 1849. The accessibility of iron ores and ease of mining and smelting early led to operations on a small and crude scale. The discovery of higher grade ores elsewhere and the centralization of the iron industry have since made such small operations profitless, and the Roanoke iron ores are not being mined at the present time.

Some prospecting but very little serious mining was carried on in the region until the boom of the early eighties. The advent of the railroad and the mushroom development of Roanoke City induced local mining operations which were further encouraged by the meeting at Roanoke in 1883 of the American Institute of Mining Engineers. During the period from 1880 to 1905 many iron mines were opened up and abundant prospects were located, so that by 1905 three furnaces were in operation at Roanoke. Soon after this flurry, however, the mining became curtailed by economic pressure, and the workings were rapidly closed. Since 1920 no iron or manganese mine has been operated in the area around Roanoke except in the vicinity of Buchanan.

The iron and manganese ores of this district may be classified as follows:

A. Red hematite ores:

a. Blue Ridge "specular" hematite
b. Clinton "fossil" hematite

B. Brown ores of iron and manganese:

a. Cambrian ores along the Blue Ridge

1. Iron and manganese ores as pocket deposits in brown or variegated clays
2. Iron ores in dark-red ocherous clays at the edge of the Valley
3. Replacement deposits of stratified beds by iron and manganese ores

b. Oriskany iron and manganese ores

C. Magnetite ores

a. Limestone magnetites of the Valley

b. Titaniferous magnetites of the crystalline area

D. Pyrite and pyrrhotite

BLUE RIDGE HEMATITE

At or near the base of the Unicoi formation there occurs a ferruginous sandstone which is sometimes of sufficient quality to be locally mined as a siliceous iron ore. It is often called "mountain specular ore" from its occurrence high on the flanks of the Blue Ridge foothills. (Although this is called specular ore, it has no resemblance to true specularite.) It is very siliceous and of rather poor grade, having an average iron content of from 35 to 40 per cent, with 30 to 40 per cent of silica. The combined percentages of phosphorus and manganese seldom exceed one per cent. In Roanoke County this ore has been mined only on Buck Mountain. Several other mines and prospects have been opened along the southwestern flank of the Blue Ridge

near Blue Ridge Springs.

The Blue Ridge hematite consists of a bedded deposit of quartz sandstone and conglomerate which has been partly replaced by hematite. The ore is dense and hard and generally deep-bluish-green in color when encountered at depths, with the hematite giving little color to the containing rocks. Near and at the surface the ore is much weathered, and takes on a dark-red color due to the oxidation of the iron content. Where long exposed, much of the hematite alters to soft limonite with traces of manganese oxides as incrustations. The siliceous nature of the ore is due to the presence of unreplaced sand grains and quartz pebbles which are very abundant along some of the bedding planes. Small gray or reddish clay lumps are found in the ore and thin lenses of shale often occur in the poorer masses. The hematite is associated with the sandstones, quartzites and shales of the Unicoi formation, and possesses the same strike and dip as the containing rocks. The rocks have been much fractured and deformed and generally stand at high angles. In the belt north of Blue Ridge Springs the ore is persistent along the strike for over three miles, although interrupted by ravines. The bedded nature of the ore shows an original deposition probably very similar to the deposition of the Clinton ore. The containing rocks are unfossiliferous but are probably of marine origin. Only one bed of ore is known in the Roanoke area, and this is from 4 to 12 feet thick near Blue Ridge Springs, and 2 feet thick on Buck Mountain. The ore is mined both from open cuts and by deep mining along the dip. The highly siliceous nature of the Blue Ridge hematite greatly impairs the value of this type of iron ore, and it is not probable that these workings will ever be economically important.

The Griffin Specular Mine.

This prospect is located on the north slope of Buck Mountain along the Indian Grave road about six miles southwest of Roanoke. This is the southernmost working of the Blue Ridge hematite. The orebed is about 2 feet thick and is interstratified with the Unicoi sandstones and sandy shales. The beds strike nearly east and west and dip to the south. The ore is a fissured and veined quartzose sandstone partly replaced by hematite. The rock is fractured and shows large areas of slickensides. Near the surface it is weathered to soft hematite and limonite. An analysis of a mine sample by R. J. Holden showed 40.97 per cent of metallic iron and 31.16 per cent silica. (Holden 15, p. 447).[1]

---

1. The number refers to the bibliography of references which is given at the end of this chapter.

Some ore was mined in this area from open cuts, but was never shipped and is still piled in dumps along the side of the road. The prospect has not been operated since 1908.

Three-quarters of a mile south of the Griffin specular mine the orebed is again exposed about a half-mile above Back Creek at the head of a small ravine. The ore at this exposure is the same as that already described and the prospect has never been opened.

Blue Ridge Hematite near Blue Ridge Springs.

Several mines have been opened in this ore along the southeast flank of the Blue Ridge, north and west of Blue Ridge Springs. The ore outcrops at an elevation of about 1800 feet, and is traceable for over

three miles, striking N 60° E. There is only one orebed which is about six feet in thickness and dips to the northwest at an angle of 50 degrees. The containing rocks are sandstones and sandy shales, much fractured above the ore and massive below. The rocks are dark green below the weathered surface and iron stained above. On the opposite side of the Blue Ridge these ores also occur and have been mined from a series of small workings which lie outside the area covered by this report.

The Grubb Specular Mine.

This mine (Holden 15, p. 447; Harder 11, p. 225) is located about three miles northwest of Blue Ridge Springs and is connected with the Norfolk and Western Railroad by a short spur line. The property belongs to the Virginia Iron, Coal and Coke Company and was in operation as late as 1920. Since that time the mines have been closed, and the property and machinery are rapidly deteriorating. Both open pit and shaft mining were carried on, and a shaft nearly 1300 feet was sunk into the hillside. The ore was of fair grade but very siliceous, and its quality was injured by the quantity of blue quartzite or "blue-rock" which was extracted with the ore. A crusher and washer were located at this mine.

The Edith Mine.

The old working of the Edith mine (Holden 15, p. 444; Harder 11, p. 227) lies about 500 feet above the Grubb specular mine and is about a half-mile farther to the northeast. It is connected with the Grubb

mine by a narrow-gauge railroad and an incline. The early operations were from open stopes and trenches, but later a shaft was opened up cross-cutting the orebed. The ore is typical Blue Ridge hematite and is much faulted below the surface. An analysis from the Virginia Iron, Coal and Coke Company showed the following composition:

Metallic iron....	37.09
Silica.....	36.91
Phosphorus.....	0.37
Manganese.....	0.27 (Holden 15, p. 444)

The Lemon or St. Clair mine.

This mine (Holden 15, p. 445) is located a short distance southwest of the Grubb Specular mine in the same ore bed. It was operated on a small scale in 1907 by R. P. St. Clair and the ore was hauled in wagons to the Grubb tipple. A few prospects were also opened up at this locality in the limonite ores which occur a short distance from the slope, where the iron content is said to have been 57.817 per cent. (Hotchkiss 19, p. 19.)

The Cundiff bank.

In Bedford County about three miles from Blue Ridge Springs, a small working was opened in 1883 by the Crozer Steel and Iron Company on the Edith Iron property (McCreath 24, pp. 54-5). This mine was adjacent to the Upland mine in the Blue Ridge limonite. An analysis of the red hematite furnished by Captain Le Warne the mine superintendent in 1883 showed the following content:

Metallic iron.....	46.70
Phosphorus	0.666
Silica	24.75
Phosphorus per 100 parts iron...	1.426 (McCreath 24, p. 55)

The Dewey mine.

The same ore bed which occurs at the Edith mine was worked about three miles to the east near Montvale (Holden 15, p. 472; Harder 11, p. 227). The ore here has the same strike as at Edith and dips nearly vertically. The main workings are drifts along the ore bed at various levels from the surface downward for possibly 1200 feet. The ore bed is said to be from 3 to 12 feet thick and to have been somewhat folded and faulted. A spur line connects with the tipple at Montvale three miles away. An analysis of the ore ran as follows:

Metallic iron	36.90
Manganese	0.23
Phosphorus.....	0.28
Silica	34.85 (Holden 15, p. 472)

The Ironville mine.

This mine (Holden 15, p. 472; Harder 11, p. 227) is located about one-half mile north of Ironville immediately southwest of the Dewey. It was first opened up in 1879 and was worked at intervals up to 1910. The ore was hauled in wagons to Ironville. The workings extended for several hundred feet along the strike of the ore bed which was worked in depth to 200 feet. The ore bed is vertical and the general conditions are as at Dewey. It is said that the underground workings of these two mines connect. An analysis of the ore furnished by the Virginia Iron, Coal and Coke Company then operating the mine is as follows:

Metallic iron	34.66
Manganese	0.15
Phosphorus	0.39
Silica	39.06 (Holden 15, p. 472)

None of these mines on the southwest slope of the Blue Ridge is in operation at the present time, and the mining equipment is rapidly deteriorating. Of the workings on the northwest side of the ridge, only the "Spec" mine east of Nace is now active.

Clinton Hematite

Bedded deposits of hematite are associated with the Clinton formation or its equivalent from New York State to Alabama, but few workable deposits of this ore occur in Virginia and none near Roanoke County. Some Clinton ore is mined in the Oriskany district of Alleghany and Botetourt Counties, in Giles County, and in Lee and Wise Counties. The formation is present in Roanoke County and carries a little hematite which is not only too thin but also of too low grade to be of economic value.

The Clinton formation outcrops along the southeastern face of Catawba Mountain. The formation here consists of sandstones and shales with a few thin interbedded limestones. Well toward the base of the formation occurs a very thin bed of red fossil ore a few inches thick and traceable for ten or twelve miles east of Catawba Sanatorium along the strike of the formation. This lens is interbedded between green shales and its sedimentary character points toward deposition as a marine sediment. The ore breaks with a blocky fracture and represents material laid down at the same time as the enclosing rocks. The

Clinton is seldom deformed but generally dips at rather high angles. The red iron stain is washed down the exposure for several feet, so that the actual thickness of the iron horizon is often exaggerated. The ore is called fossil ore since it is composed of an aggregate of tiny shells of brachiopods, crinoid stems, and bryozoa, whose original calcium carbonate has been replaced by ferric oxide. In some places the ore is granular and consists of tiny rounded quartz grains which have been coated with hematite. This type of Clinton ore is called flaxseed ore.

Analyses of the Catawba ores were made in 1884 by Mr. Henry Froehlings as follows:

	1.	2.	3.	4.
Metallic iron ...	55.490 ...	66.375 ...	51.970 ...	40.672
Phosphorus	0.034 ...	0.014 ...	0.176 ...	0.156
Manganese	0.000 ...	0.000 ...	0.000 ...	0.383

(Hotchkiss 20, p. 107.)

1. Hematite from Beard's on Catawba Creek, from middle range of Catawba Mountain

2. From Captain Jas. Peak's on Catawba Creek, same ridge, six miles from specimen 1

3. From Captain W. W. Beard's on Catawba Creek, from the continuation of Catawba furnace ore beds in North or Catawba Mountain

4. From David Barnett's land on the side of Catawba Mountain

Blocks of this ore have been found on Little Brushy and Mills Mountains, but no ore in place was observed.

Brown Ores Along the Blue Ridge

This name is used to include all brown ores of iron and manganese oxides which occur at the foot or along the slope of the Blue Ridge. The deposits include several types of ore bodies which have heretofore been given a different name. For convenience of treatment these are all grouped under the above term. They include the so called "mountain brown ores"; the "limestone limonite" or "Valley brown ores", and the deposits of manganiferous iron or purer manganese at the west foot of the Blue Ridge. The known deposits occur in small scattered groups from Front Royal to the southwestern limit of Roanoke County. For the most part they are situated on gravel-covered benches of the various Valley-floor Peneplane remnants on the west slopes of the sandstone foothills of the true Blue Ridge. The ore belt is not far west of the contact of the pre-Cambrian crystallines and the Paleozoics. The ores are either associated with the Erwin quartzite and the beds of the shady dolomite directly above, or with the residual clays resulting from the weathering of these formations. The deposits are seldom large, but are numerous and some have been worked for over 150 years. There is a marked grouping of the workings, and this report will deal with four separate groups: those surrounding the Rorer mine five miles south of Roanoke; those surrounding the Grubb or Lynchburg mine near Blue Ridge Springs in Botetourt County; those on the slopes of Poor Mountain, and those mines on the northwest slopes of the Blue Ridge near the Houston mine.

The brown iron and manganese ores are nearly always at the base of the shady dolomite at or near the contact with the Erwin quartzite.

A few additional deposits are known from the Watauga shales; in the brecciated zones of the Erwin; in pocket deposits of residual clays from the Elbrook formation; or in stream and channel gravels of fluvial origin derived from the erosion of the ore-bearing formations. All of the deposits have had the same general history, and the different types of deposits represent different stages in the same processes of ore formation. These ores may be classified as follows:

1. Irregular concentrations in brown or variegated clays
   a. Pocket deposits along or upon quartzite foothills
      1. In residual Shady clays along slopes of monoclinally dipping Erwin quartzite
      2. In synclinal basins upon a floor of Erwin quartzite
   b. Pocket deposits in transported fluvial clays in the Valley
   c. Irregular masses along faults in clays of the lower Shady

2. Concentrations in dark-red ocherous clays at edge of Valley
   a. Pocket deposits in residual clays above the Shady or Elbrook formations

3. Replacement deposits of stratified beds along slope of foothills
   a. Along faults and brecciated zones of the upper Erwin
   b. In sandstones or shales of the lower Shady or of Erwin quartzite
   c. Along seams and fractures in shales

The most common type of deposit is that occuring in brown or variegated clays as irregular concentrations which were produced by downward moving meteoric waters. This ore occurs as lumps, grains, and shapeless masses ranging from a small nodule to masses up to 1000 tons in size. The deposits are generally located on one of the remnants of the old Valley-floor Peneplanes, a few hundred feet above the

present drainage levels. The deposits along the quartzite foothills of the Blue Ridge are most abundant, and occur in irregular broken masses in the residual clays of the lower 300 feet of the Shady dolomite, concentrated against the impervious beds of the Erwin. They are especially rich where the Erwin dips monoclinally toward the Valley. In this type the ore deposits are more or less linear with their long axis parallel to the hill slope and often dip with high angles. The erosion benches truncate the beds, and the ore has been accumulated along the surface of these benches in the shales below the surface. Much float ore occurs and the orebodies are often very large. The ore itself is generally mammilary and occurs in the bright-colored clays resulting from the decomposition of the basal Shady beds. Sometimes in the larger masses of ore an unreplaced limestone nucleus may be found showing that the ore is replacing original calcareous material. In a few cases the ore occurs well toward the top of the foothills in troughs or gentle swales on the surface of the Erwin quartzite. Here the deposits are small and the quartzite itself may be in part replaced by ore. Farther out in the Valley, where erosion has transported the weathered clays, scattered deposits of ore may accumulate or be concentrated from the fluvial clays. These are also small and the ore is often contorted from the slumping of the clay masses. At other places faults parallel or transverse to the strike of the beds cut the basal Shady, and accumulation of ore may occur. This type of deposit is uncommon and no representatives are known in the Roanoke area.

On the lower levels of the Valley but near the line of the Blue Ridge occur irregular deposits of brown ore as lumps and masses in

dark-red limestone clays above the Shady and Elbrook limestones. This ore is shallow but somewhat richer than the ore associated with the quartzite. The deposits are of the same general nature as those on the foothill slopes but the ore has not yet been carried down to the quartzite basement. These deposits are invariably associated with dark-red clays, and the bright-colored or variegated clays are conspicuously absent. Many masses of residual undecomposed limestone occur as "horses" in the ore bodies. This type of deposit is much more important in southwestern Virginia than along the Blue Ridge.

A small number of deposits represent replacements of stratified beds, and have not been decomposed by weathering to any extent. In places the Erwin quartzite is crushed and brecciated and ore sometimes replaces the broken sandstones or fills the crevices of the crushed zones. Some brown ore is also found along bedding planes. In other places the sandy members of the lower Shady and sometimes of the upper Erwin have been replaced with ore to give a mass of sandstone highly impregnated with iron. This ore is free from clay but is very sandy and therefore of poor grade. The sandstones are replaced to varying degrees and range from highly ferruginous sandstones to quartzites barely stained with iron. In favorable locations, limy members of the Watauga and Lower Cambrian shales have been replaced with iron to give a low-grade brown ore which alternates with thin seams of shale. No deposits of this kind are known in Roanoke County.

The brown ores along the Blue Ridge consist of impure hydrated oxides of iron, often so intimately intermixed with manganese oxides that it is impossible to determine in the field of what minerals an

ore sample may be composed. The iron oxides range from limonite to goethite and carry from 35 to 45 per cent metallic iron. The manganese oxides are of four kinds: psilomelane, pyrolusite, magnetite, and wad. Thus the brown ores are of three general classes: relatively pure iron ore; manganiferous iron ore, and relatively pure manganese ore. All of the ore is non-Bessemer, and the more highly manganiferous ore is unsuited for steel but is used for ferromanganese. The grade of the ore determines the manner of mining, and the ore as mined runs about one car of ore to from 5 to 25 cars of clay. The ores around Roanoke are high in phosphorus. The most common ore is a brown earthy amorphous mixture of oxides containing considerable clay. This ore is purer and darker where it is associated with limestones, and becomes lighter and poorer where mixed with sand and clay. The so called "valley ore" is purer than the "mountain ore" and contains less manganese. Some ore is black, glossy and hard and breaks with a conchoidal fracture to show an amorphous structure. This type occurs as fillings and replacements and is less common in the clay pockets. It is sometimes mammilary with a high percentage of manganese. With it occurs needle ore which is found as cavity fillings and in the clay pockets. This is dark brown in color and very pure but with much manganese.

The following analyses show the average metallic content of the three general types of brown ore:

	1.	2.	3.	4.
Metallic iron	41.99	41.22	47.15	12.32
Metallic manganese	0.81	0.90	7.27	44.31
Phosphorus	0.25	0.93	0.06	0.10
Alumina	1.91	.....	.....	.....
Silica	16.17	20.61	8.03	5.47

1. Valley limonite, average of 21 mines in the New River-Cripple Creek district (Holden 15, p. 414).
2. Mountain limonite, average composition. (Holden 15, p.416.)
3. Manganiferous iron ore from Houston mine. (McCreath 24,p.51.)
4. Manganese ore from Houston mine. (McCreath 24, p. 51.)

The iron and manganese of these ores was originally derived from the Piedmont crystallines and deposited in the limestones and shales at the time of their deposition. The metallics were probably widely disseminated through the rocks and combined with either carbonic acid, sulphur, or some form of silicic acid. The present undecomposed shales and limestones carry ferrous silicate minerals and pyrite, and the Shady dolomite contains nodules or concretions of mixed lime, iron, and manganese carbonates. Under the influence of descending oxidizing meteoric waters, and in part through the agency of organic acids, the carbonates were altered to hydrates and the metallic contents were transported along favorable channels and redeposited as oxides by replacement of calcareous matter in the clays. The localization of the oxides was favored by the impervious basement of quartzite and by the cracks and fissures along brecciated zones. The amount of concentration was governed by the abundance of the original metallic minerals in the overlying beds. This accounts for the scattered nature of the deposits and for the grouping of the workings.

This process of concentration would operate most favorably upon an area of low relief under a warm moist climate, and the epoch of Valley-floor peneplanation when deep rock-decay was taking place seems to have been suitable for the ore accumulation. Some ore had no doubt

been formed before the Valley-floor erosion, but has been eroded away. The process is still continuing, and some ore is found in association with Tertiary deposits of gravel. The present deposits of this brown ore are all located upon the benches along the valley except the ore bodies in the fluvial clays which have been derived from higher deposits by erosion. The former is the most important type of iron deposit in Roanoke County, and the chief workings were the Rorer, Gale and Starkey mines. The presence of the ore has been proven in the area of the foothills south of Roanoke and also along Poor Mountain. If any iron ores are mined in the future from the Roanoke area, the workings will be in the brown ores along the Blue Ridge.

Mines south of Roanoke at the Edge of the Roanoke Valley.

The Rorer mine.

The Rorer mine[1] were opened up about 1880 on the property of

---

1. Hotchkiss 19, pp. 6, 63, 120; Hotchkiss 20, pp. 106, 152, 191; Hotchkiss 21, pp. 62, 147; Holden 15, p. 446; McCreath 24, p. 55; Ries and Somers 28, p. 36; Harder 11, p. 240.

McLanahan, Rorer, and Chapman about three miles south of Roanoke on the western slope of a southern extension of Mill Mountain. These mines were the most extensive mining operations near Roanoke. The operating company organized in Roanoke in 1882 as the Rorer Iron Company and at that time controller over 5000 acres along the belt of strike of the ore. By August 1883 the company had shipped to Ironton, Ohio over 2500 tons of high grade limonite and their daily capacity was about 150 tons of ore. The company was reorganized June 25, 1884,

and by 1885 had 12,000 tons of brown ore stocked and ready for shipment. The production was nearly constant from 1880 to 1910 when the mines were closed. They are at present owned by the Virginia Iron, Coal and Coke Company but are not in operation. A steel-rail narrow-gauge railway connects with the Norfolk and Western Railroad and crosses the Roanoke River near the old Rorer quarry. The mining has been largely from open cuts by steam shovel.

The first opening was on the south slope of Mill Mountain and consisted of a long open cut known as No. 2 Cut. Along the face of this opening is exposed about fourteen feet of a somewhat porous, yellowish-brown limonite dipping at a high angle. Nearby openings show the same general character of ore. A sample of 83 pieces was analyzed by A. S. McCreath in 1883. The sample was collected from the ore pile at the mouth of the cut, and showed the following composition:

Metallic iron	52.425	(McCreath 24, p. 55)
Phosphorus	0.493	
Siliceous matter	9.610	
Phosphorus per 100 parts iron ...	0.940	

Another large cut was made on the top of the ridge and about 250 yards from No. 2. This cut showed a nearly solid face of ore which was much more compact than at No. 2. The ore was darker and in places almost black. A sample of 96 pieces was analyzed by McCreath as follows:

Metallic iron	55.350	
Phosphorus	1.260	
Siliceous matter	3.870	(McCreath 24, p. 55)
Phosphorus per 100 parts iron ...	2.276	

The ore deposits occur in steeply dipping shales or clays of the basal Shady dolomite not far above the Erwin quartzite which lies to the east. The limonite is associated with iron-stained clays and sandy beds, and there are streaks of gray clays sometimes six feet in diameter. The ore on the dump along the narrow-gauge railway is porous, rusty-brown in color, and shows traces of manganese stains on the surface. The pits are over fifty feet deep and partially filled with water at the present time, so that it was not possible to make closer examination of the ore exposed.

An analysis of ore from this mine was furnished Holden by the Virginia Iron, Coal and Coke Company and ran as follows:

Metallic iron	38.38	
Metallic manganese	1.20	
Phosphorus	1.14	(Holden 15, p. 446)
Silica	20.91	

South of the Rorer mine along the Roanoke-Rocky Mount highway, the ore bed crosses the road and was mined here on a small scale from open cuts. These pits are grown over at present but masses of nodular brown ore are piled nearby.

The Gale mine.

The Gale mine[1] is located about a mile southwest of the Rorer

---

1. Hotchkiss 19, pp. 2, 6, 19, 68, 81; Hotchkiss 20, pp. 106, 191; Holden 15, p. 446.

---

and about three and one-half miles southwest of Roanoke. It lies about a half-mile south of the junction of the Starkey and Rocky Mount roads. This mine was opened up by Rorer and Chapman in 1882 on the old Gale farm and was controlled by the Rorer Iron Company. By 1884

this company had built some fifteen buildings at the mine, forming a settlement which was called Gale, and was the headquarters for the operations of that company. It has not been in operation since 1907.

The first openings, known as the Old Gale or No. 1 Cut, were along the eastern face of the ridge which extends north from Buck Mountain. Some ten feet of stratified limonite was uncovered, more or less mixed with clay and siliceous material. The strike of the beds is northeast-southwest with a gentle dip toward the northwest. In 1882 A. S. McCreath took a sample of 75 pieces from the ore in place across the face of this cut "to represent the clean ore". This sample he analyzed as follows:

Metallic iron	56.550	(Hotchkiss 19, p. 2,6)
Phosphorus	0.178	
Siliceous matter	5.710	

The phosphorus content of this ore is very low as thus analyzed, and McCreath admitted having checked this point separately. Later in the same year another analysis from the same beds by Mr. Henry Froehling showed:

Metallic iron	61.246	(Hotchkiss 19, p. 19)
Phosphorus	0.943	
Silica	1.606	

Some of the ores occur in a shallow syncline on the top of the Erwin quartzite, and in 1884 were being mined from a breast of solid ore "75 feet long and 50 feet high, one of the finest displays of stratified iron ore in the country" (Hotchkiss 20, p. 106). This same year the mine had on hand 3000 tons of lump ore, and 4000 tons of washed ore. The ore bed is also exposed in the nearby open fields, and one bed of several feet thickness occurs. The mines along the Rocky

Mount road are in this bed.

The Griffin mine.

This prospect (Holden 15, p. 446; Hotchkiss 19, p. 81) is located a short distance southwest of the Rorer mine along the strike of the same ore bed. The geologic conditions are the same as at the Gale mine, and the ore is of the same general quality. This prospect was worked in a small way in 1903 by the West End Furnace Company and the ore was used by their furnace at Roanoke.

The Starkey mine.

The Starkey mine[1] is located about five miles southwest of Roanoke, three-quarters of a mile from Starkey and a mile and one-half from the narrow-gauge railway. It is about two miles south of the Gale mine. The occurrence of the ore in this locality has long been known, and it was mined in a very crude way in the early part of the mineteenth century. In 1884 an old miner's sledge was found in the Starkey mine, which had lain there since 1813 when the old Back Creek furnace was washed away. This furnace was erected to smelt the Starkey ore. The ore outcrops in a belt several feet wide, and is a massive black limonite with patches of cellular light-brown ore. The mine was operated as late as 1902 by the Pulaski Iron Company but is now abandoned. The mining was all from open trenches and the ore was hauled in wagons to the Norfolk and Western Railroad at Starkey.

---

1. Hotchkiss 19, p. 68, 81; Hotchkiss 20, p. 139-40; Holden 15, p. 447.

The Castle Rock and Turner mines.

These prospects[1] are located about six miles southwest of Roan-

---

1. Hotchkiss 19, p. 19, 81; Holden 15, p. 446.

---

oke and two miles northwest of Cave Springs. They are along a gravel-coveredbbench near Sugar Loaf Hill on the old Turner farm. An analysis of the ore in 1883 by Dr. Henry Froehling of Richmond is as follows:

Metallic iron	56.107	(Hotchkiss 19, p. 19)
Metallic manganese	0.337	
Phosphorus	0.5167	
Silica	9.910	

The mines were operated by the Rorer Iron Company, and the Castle Rock mine was connected with the Roanoke and Southern Railroad by a narrow-gauge spur line. The mine was last operated in 1895.

The Iron Bluff Farm prospect.

Blue Ridge limonite has been reported (Hotchkiss 20, p. 140) from the Iron Bluff Farm, located about three miles from the Rorer Iron Company narrow-gauge railway, and about four miles from the Norfolk and Western Railroad. The exact location of this occurrence is not known to the writer.

--- o ---

The above group of mines and prospects lie along a narrow belt just north of the quartzite foothills which close the Salem Valley at the south. The occurrence of the brown ores is always at the base of the Shady dolomite, and the ores are of about the same quality. The

amount of phosphorus in these ores is uniformly high, so that any use of the ores is handicapped by present metallurgical requirements. Another exposure of the brown ores is found on Poor Mountain.

The Poor Mountain mines. (Bott and Chapman Prospects.)

This occurrence of the brown ores of the Blue Ridge area was discovered by Rorer and Chapman in 1882 on the Bott, Hall, and Thomas farms along the western slopes of Poor Mountain between Salem and Elliston. (Hotchkiss 19, pp. 2, 68, 81; Hotchkiss 20, pp. 44, 102, 139.) The exposures are about 13 miles southwest of Roanoke and about one mile from the old Owens tank of the Norfolk and Western Railroad. The ore is very similar to that of the Gale and Rorer, and consists of cellular limonite which is sometimes massive and often very clayey. The original description of these prospects announced

> "a solid dtratum of ore 150 feet long, from 20 to 50 feet wide, and with a thickness that can only be determined by blasting." (Hotchkiss 19, p. 2.)

Analyses in 1883 by Dr. Henry Froehling showed the following composition:

	Bott ore	Hall ore
Metallic iron	55.140 ...	57.521
Metallic manganese ...	1.444 ...	1.360
Phosphorus	0.4 ...	0.821
Silica	8.120 ...	6.030 (Hotchkiss 19, p. 2)

The Bott property contained 2000 acres of land along the base and northwest side of Poor Mountain from a point opposite Elliston eastward for several miles. In 1884, Mr. J. B. Gifford of Philadelphia, "an expert in iron matters", and somewhat of an optimist, reported to

Messrs. Rorer and Chapman that -

> "...there are stratified seams of shales and hematite (?) ores extending through the entire length of the property aggregating from 50 to 60 feet in thickness, and extending down to an unknown depth, which in my opinion is very valuable, not only on account of the millions of tons of ore it contains, but the superior quality of iron that a mixture of these ores will produce.
>
> The ore belts are one mile from the Norfolk and Western Railroad, and run parallel with the road the entire length of the Survey . . . from 150 to 200 feet above water level."
>
> (Hotchkiss 20, p. 44.)

In 1884 the owners were taking out ore and piling it up beside the railroad, and the "show of ore was remarkable". Several masses of brown ores were uncovered by stripping, and from the Poor Mountain mine No. 1 over 3000 tons of brown lump ore was piled near the railroad. Much of this ore still remains in the old dumps near the tracks. Analyses of ore from the Chapman mine along the Norfolk and Western Railroad were made in 1884 by Mr. P. Salom, chemist for the Crozer Iron Company. These analyses were as follows:

	1.	2.	3.	
Metallic iron	43.22 ...	45.30 ...	51.84	
Insoluble residue .	26.39 ...	21.14 ...	13.34	
Phosphorus	1.11 ...	0.82 ...	1.36	(Hotchkiss 20,p.102)

1. Upper or eastern cut

2. Middle cut

3. Western or field cut

A hasty examination of these prospects in 1926 showed that the earlier reports were highly exaggerated, and that the show of ore is much the same as at the Gale or Rorer workings, if as extended.

Mines along the Southeast side of the Blue Ridge in the Glade Creek Valley.

The Lynchburg or Grubb mine.

This mine[1] lies immediately south of the Grubb Specular mine,

---

1. Holden 15, p. 444, Plate LXV, fig. 2; Harder 11, p. 236, 240; Stose et al 30, p. 124; Ries and Somers 28, p. 47.

---

and was operated by the same company, the Virginia Iron, Coal and Coke Company. The mine is about two and three-quarters miles northwest of Blue Ridge Springs and eleven miles northeast of Roanoke. A short spur line connects with the Norfolk and Western Railroad. The mines were first opened in 1882, and have been closed since 1920. The ore body is located in residual variegated clays resulting from the decomposition of underlying limestone, and is immediately south of a fault which brings the Elbrook formation against the Unicoi formation. Limestone fragments occur in the ore body, and are occasionally found in the unaltered interior of large ore fragments. The lime content of the ore greatly impairs their value. The deposit is an irregular replacement of large size in a pocket deposit in residual clays.

The ore body is forty feet thick, and dips with the bedding of the clays toward the Blue Ridge. It is surrounded by a reddish residual clay through which are scattered pockets of very fine dense clays having a porcellaneous lustre. This clay was tested for use as brick-clay but the attempts were unsuccessful.

An analysis of the ore furnished in 1907 by the operators is as follows:

Metallic iron	41.20	(Holden 15, p. 444)
Metallic manganese	1.13	
Phosphorus	1.23	
Silica	14.08	

For this type of ore the limonite has a high percentage of silica and phosphorus. Very meagre quantities of manganese oxides are associated with the brown ores. A shaft has been opened to a depth of 200 feet.

Stose, Miser and others (Stose et al. 30, p. 124) have described the main structural features of this mine, but have concluded that the limestone from which the ore was derived and which is the bed rock of the area south of the fault is the Shady dolomite. The writer has gone over this ground, but was unable to find undoubted exposures of the Shady dolomite near the mine. It is his interpretation that the limestone near this mine belongs to the Elbrook formation which is abundantly exposed a few hundred feet south of the fault about one mile farther north. Mr. Charles Butts and Doctor Henry S. Ladd both concur with the writer in this interpretation, and with him were unable to find exposures of Shady near the mine.

The writer also interprets the limestone near the Crozer mine as belonging to the Elbrook formation.

The Upland or Crozer mine.

This mine[1] was opened in 1883 about a mile and one-half northeast

---

1. Hotchkiss 19, pp. 19, 66-8; Hotchkiss 21, p. 62; Catlett 6, pp. 315-16; Holden 15, p. 444.

---

of the Grubb mines. It was originally owned by the Edith Iron Compa-

ny, later by the Crozer Iron Company, and at present is controlled by the Virginia Iron, Coal and Coke Company. The workings consist of several open cuts of large size from which have been taken over 700,000 tons of brown ores. The ore bed is quite thick although much broken and displaced. The ore body occurs in residual clays and shales directly above the Erwin quartzite which dips southeastward at rather high angles. The ore is good, but contains much clay which increases the amount of material to be handled. The phosphorus content is high, the iron runs from 42 to 43 per cent, and the ores are sometimes highly manganiferous. Limonite from this mine, analyzed in 1884, showed the following composition:

Metallic iron	54.60	(Hotchkiss 21, p. 62)
Metallic manganese	3.38	
Phosphorus	0.353	
Sulphur	0.15	
Insoluble residue	5.33	

Ore from the Cundiff bank of the Upland mine was analyzed in 1883 as follows:

Metallic iron	54.60	(McCreath 24, p. 54)
Phosphorus	0.59	
Siliceous matter	5.57	

The Buford bank.

A few miles farther northeast in Bedford County the Crozer Steel and Iron Company opened several trenches in 1883 on the Edith Iron property. The ore from this exposure showed the following composition:

Metallic iron	52.880	
Phosphorus	0.568	
Siliceous matter	88.390	(McCreath 24, pp. 54-5)

None of the above workings are in operation at the present time.

Mines along the Northwest side of the Blue Ridge

in the Fincastle Valley

The Stoner mine.

This mine[1] is located about one mile northeast of Troutville, on

---

1. Weeks 40, p. 321; Watson 35, p. 252; Harder 13, p. 65; Stose et al. 30, p. 123-4.

---

the northern slope of the valley of Stony Battle Run, along a low ridge and about 1550 feet above sea-level. This hill reaches to the old Fincastle Valley-floor Peneplane, and adjoins and parallels the steep slopes of the main Blue Ridge.

The beds strike nearly east and west and dip steeply to the north. There is a small quartzite hill west of the creek which appears to be an anticlinal nose plunging steeply to the west. The workings consist of several old pits and a shaft which was sunk about 20 years ago. In 1917 several more prospect pits were made. All of the workings are from 10 to 100 feet above the creek level, and it is probable that the limestone in this tract is decomposed to or nearly to the creek level. The surface of the ridge is covered with coarse quartzite debris and sand up to seven or eight feet. Below this is a variegated clay containing chert fragments. This clay is derived from the weathering of the Shady dolomite and contains abundant small nodules of hard black psilomelane, minutely botryoidal in shape. Some of the chert fragments are partly replaced by manganese oxide. The psilomelane appears to be in the clay in a ratio of about 1 to 10. The extent of manganiferous ground is at least 1200 feet by 150 feet, and probably at least 10 feet deep on the average.

An analysis from the Chapman property ran:

Metallic manganese	45.80	(Weeks 40, p. 321)
Metallic iron	3.06	
Phosphorus	0.169	

The Murray bank.

This is located near Troutville and is a mile and a half from the railroad. It was owned in 1883 by the Crozer Steel and Iron Company. This prospect consisted of an open cut, from which a sample of 25 pieces was analyzed by McCreath as follows:

Metallic iron	53.050	(McCreath 24, p. 52)
Phosphorus	1.266	
Siliceous material	6.630	
Phosphorus per 100% Fe....	2.386	

On J. G. Layman's farm, once part of the old Cloverdale Furnace estate, one-quarter mile from the railroad at Troutville, considerable show of ore was found, and the orebed was proven in an ENE direction for one-quarter mile. The main cut was in the face of the ridge about 300 yards south of the old Cloverdale or Fincastle road. The ore occurred in variegated clays near the surface. Occasional masses of rich ore were found in the cuts. A sample of 150 pieces was analyzed as follows:

Metallic iron	42.750	(McCreath 24, p. 52)
Phosphorus	0.76	
Siliceous matter	25.000	
Phosphorus per 100% Fe....	0.177	

Another opening was made about one-quarter mile southeast of Troutville in an open cut. Here the ore occurs in loose granular red clay with rich wash ore. It is sometimes a brown, rich-looking hema-

tite, with but little flint, although it is sometimes sandy. 200 pieces from the south face of cut were analyzed as follows:

Metallic iron	49.575	(McCreath 24, p. 52)
Phosphorus	0.167	
Siliceous matter	14.920	
Phosphorus per 100% iron....	0.336	

The ore occurs as pocket deposits in residual clays, with angular fragments of various sizes, and replacements along seams in variegated clays.

The Gowan bank.

This prospect[1] is located two miles south of Lithia and three

---

1. Harder 11, p. 262; Harder 13, p. 65; Stose et al. 30, pp. 119-20.

---

miles east of Nace. It is connected with the Norfolk and Western Railroad by an abandoned tramway which followed East Hollow to the railroad three miles northeast of Nace where an old furnace was located. The mine was operated for iron during the Civil War and has been prospected for manganese by various lessees. Some ore may have been shipped. The mine is located along the west base of the Blue Ridge at elevations of about 1500 to 1650 feet. Several cuts, small adits, and a shaft comprise the old workings and all were caved in in 1917. The workings are in the basal beds of the Shady, which is cherty and contains one or more beds of coarse calcareous and ferruginous grit or fine conglomerate. The chert is cavernous or drusy, brown and sandy. In the pits may be seen red and ocherous clays with chert nodules and abundant lumps of more or less siliceous limonite. The Erwin here

strikes N 50° E and dips 50° NW. The gritty sandstones of the Shady have been slightly faulted, and dip northwest and southwest with low angles.

The old ore on the dumps shown iron ore from the siliceous grit ved, and brown ores with manganese and chert from the residual clays. The latter often contain small lumps of hard rich psilomelane and some soft blue ore also occurs. The dumps have been picked over by prospectors and hence may not be representative of the ore.

The Deal bank.

This mine (Harder 13, p. 65; Stose et al. 30, p. 121) is located about one mile south-southeast of Nace at the northwest base of the Blue Ridge on the land of the Pulaski Irom Company. It was worked originally as an iron mine, but some manganese ore was also shipped. It has been closed since 1910. Several open pits and cuts are located in the variegated residual clays of the Shady at elevations of about 1570 feet. The Shady appears to dip nearly vertical and to strike N 70° W. The Erwin occurs in the ridge just to the south. Some massive brown chert containing angular cavities occurs. Most of the ore is brown iron ore, with some psilomelane and magnetite which are intermixed in the same specimens.

The White bank.

This mine[1] is situated on the northwest slope of a low northeast-

---

1. Harder 11, p. 262; Harder 13, p. 65; Stose et al. 30, p. 120.

---

ward trending hill about three and one-half miles east of Nace south-

east of Lithia. The property belongs to the Pulaski Iron Company. It was worked in 1907 as an iron mine, although little of the ore was shipped. A number of cuts and pits have been developed along the ridge for over a fourth of a mile at elevations of about 1500 to 1600 feet. Mixed manganese and iron ores occur in the variegated clays of the basal beds of the weathered Shady dolomite. Brown ore in considerable quantity is found at some of the openings. Large porous masses of yellow and brown chert occur with the ore. Psilomelane occurs in concretionary masses up to one or two pounds. This ore is largely blue granular pyrolusite. Where the iron is most abundant no manganese masses occur.

The Houston mines.

This mine[1] is located about two miles northwest of the Grubb

---

1. Hotchkiss 19, p. 68, 119; Hotchkiss 20, p. 62,135; McCreath 24, p. 49; Watson 35, p. 251-2; Holden 15, p. 444; Harder 12, p. 262; Harder 13, p. 65; Stose et al. 30, p. 121-2; Ries and Somers 28, p. 45.

---

mines on the opposite side of the Blue Ridge. The mines are situated well up on the northwest slope of the Blue Ridge, about 400 feet above the drainage level, and a mile and one-half south of Houston or Nace. There are two large banks about three-eighths of a mile apart, and the ore was formerly taken from a number of cuts and tunnels. The manganese ores are found over a distance of a mile in a N 35° E direction. A small spur line formerly connected with the Norfolk and Western Railroad at Nace but has been abandoned. The mines were operated

in the eighties and were the principal Virginian producers of manganiferous iron ore. In 1884 and 1885 the mine was producing and shipping daily to Pittsburgh over 40 tons of manganiferous iron ore suitable for spiegel. It is said to have contained about 30 per cent of metallic manganese (Hotchkiss 30, p. 135). The limonite was sent to Crozer furnace at Roanoke. The mines were first worked for manganiferous iron ore but later for purer manganese ore. Some of this was used for chemical work but most of it was used for steel.

The ore is found in the variegated (white, red, yellow and brown) clays of the highly weathered Shady dolomite, and in places this clay is over 100 feet thick. Some of the clay is very tough. In other places it contains white altered chert. Again, there often occur ledges of brown, fine-grained gritty sandstones in the clay. These have been called horses. ~~(37:55)~~. In the abandoned ore pits of No. 4 mine of the Houston Iron Company deposits of bauxite occur with the clay. This is the only known occurrence of this mineral in Virginia. The bauxite is pisolitic, red and cream-colored, and contains cavities which are coated with fine crystals of gibbsite. The bauxite was observed only a few feet below the surface of the red clay in masses up to 40 pounds in weight. The bauxite is found only in the west bank and 8 cars of this material are said to have been mined and shipped in 1915 (Stose et al. 30, p. 121). The mines are developed on the Fincastle Valley-floor peneplane at an elevation of about 1750 feet. The clay is underlain by the Erwin quartzite which outcrops immediately to the south, and dips at an angle of about 75° to the northwest toward the Valley.

Both manganese iron and pure manganese ores occur in close association and the manganese ore occurs as nests and pockets often yielding 100 to 150 tons of clean high-grade ore. Brown iron ore and small masses of manganese ore occur as concretions in the brown clays and as replacements in the ledges of brown sandstone grit. Sometimes pockets of manganese are found next to the iron ore. Most of the manganese ore occurs as seams and replacements in the lower brown sandstone horses and clays. The ore is generally in irregular masses and much unreplaced material is often associated with the ore or grades into it. Most of the ore is a steel-blue psilomelane and the rest is manganite in small needle-like crystals. The ore is soft and friable, blue and granular. The granular ore is a replacement and the needles fill the cavities.

115 Samples were analyzed as follows:

	1.	2.	3.	4.
Metallic manganese	7.277	44.312	59.870	39.00
Metallic iron	47.150	12.325	0.500	12.00
Phosphorus	0.061	0.101	0.049	
Siliceous material	8.030	5.470	2.300	

1. Iron ore. 2. Manganese ore. 3. Selected manganese ore. 4. Average run of mine, 1883-5. (McCreath 24, p. 50-51.)

Limonite ore from this mine ran:

Metallic iron	56.19	(Hotchkiss 20, p. 62)
Metallic manganese	3.01	
Phosphorus	0.047	
Sulphur	tr.	
Insol. residue	11.59	

The ores have slid down the slopes with the residual clays to give

contorted folds within the ore-beds. There occur occasional rich lumps called bombshell ore. The ores average 44% iron.

The production of manganese ore from this mine 1883-5 was as follows:

1883	2,900 long tons of ore	
1884	828	
1885	1,082	(Watson 35, p. 252.)

ORISKANY IRON AND MANGANESE ORES

In Roanoke County the Oriskany horizon is represented by a sandstone at the top of the Giles formation which lies directly below the black Genesee-Marcellus shales. In Botetourt and Craig Counties this sandstone and the underlying limestone carry important brown ores of iron and manganese. In the area under consideration no mines or prospects have been opened up at this horizon, and the sandstone does not carry ore of commercial value.

In the adjacent counties beds of dark-brown limonite high in silica and manganese occur as irregular masses which are sometimes hard and solid but often cellular. The ore is found at the base of the sandstone or replacing the cherty limestone below. The beds are not deformed and usually carry much clay and sand with the ore masses. The horizon outcrops along the lower slopes of the Appalachian ridges at one of the Valley-floor erosion levels, a few hundred feet above the present stream channels. The ore often continues along the strike

for some distance with fairly constant thickness and high dips. The iron and manganese have evidently been leached from higher levels by descending surface waters, and have been deposited near the bottom of the zone of surface weathering on the floor of the peneplanes. Subsequent uplift of the land has enabled the streams to cut into this floor so that the deposits as now found lie along the mountain slopes on distinct benches. The ores have been additionally enriched by deposition subsequent to the uplift of the original peneplane. The source of the ore was probably the overlying Devonian black shales which carry 4 to 5 per cent of iron. It is possible that the sandstone itself is a source for the iron. This has been suggested by Kemp (Kemp 22, p. 764) and Weld (Weld 41, pp. 416-17). The outcrops of the sandstone are often discolored with manganese oxide stains which also occur along bedding and joint planes.

Disseminated masses of brown ores occur in the Oriskany member in Roanoke County. These may be seen along the outcrop of the Giles formation on Tinker, Dead Mans, and Catawba Mountains. The sandstone is yellowish, coarse and friable, and the oxides occur in fissures, pockets and as disseminations. At no place, however, were deposits noted of such size or commercial value. In Craig Creek Valley, a few miles beyond the Roanoke County line, several workings have been opened about 12 miles southwest of Newcastle. These were operated on a small scale during the war, but have been closed down since 1920. The ore was psilomelane and manganite with brown limonite. The iron content was about 27 per cent, and the manganese content from 37 to 43 per cent. (Stose and Miser 31, p. 115-19.)

According to report (Campbell, M. R. et al 4, p. 21) Oriskany brown ore outcrops in some quantity on the south slope of Cove Mountain. This exposure was not visited by the writer.

Numerous reports of cellular brown ores have been described from the "Hudson River shales, Formation III of Rogers" of the Roanoke and adjacent areas.[1] The present author agrees with E. J. Holden that -

---

1. Rogers 29, 220; Campbell, J. L. 3, 57; Pechin 26, p. 1024; Hotchkiss 19, pp. 68, 81; Hotchkiss 20, pp. 43, 139, 169.

> "...such deposits have either not been seen by the writer, or, if seen, have not been confirmed as belonging to this formation."

The formation III of Rogers is now called the Martinsburg shales, and no brown ores are known from this horizon. It is possible that the reported occurrences belong to the Oriskany brown ores.

Limestone Magnetites

In a few localities in Virginia very small isolated occurrences of magnetite have been reported from the clays of the Valley limestone. The magnetite is associated with iron carbonate and hematite, and occurs either in beds within the limestone or near the base of the residual clays above. It is generally of very high grade but in quantities too small for economic use. The magnetite is thought to be a secondary concentration from the overlying shales.

A single occurrence of specular magnetite has been reported from Roanoke County (Hotchkiss 19, p. 19). This was from the Simmons beds of Mr. F. H. Rorer, near the Rorer Mines. An analysis in 1883 by

Henry Froehling is given:

Metallic iron	61.246
Phosphorus	0.943
Silica	1.606

No ore of this kind was found by the writer, and the location of the Simmons beds is indefinite. It is supposed that the magnetite probably came from the Shady dolomite rather than from the Elbrook formation. If this is the case, the occurrence is unusual for no magnetite has heretofore been recorded from the Shady.

Titaniferous Magnetite or Ilmenite

Important deposits of nelsonite, a mixture of apatite and ilmenite occur in the crystalline rocks east of Vinton. These will be described under Titanium and Apatite.

Pyrite and Pyrrhotite

Pyrite.

An occurrence of pyrite with associated galena and sphalerite has been described from the Martin and Wertz properties two and three-quarter miles south of Roanoke (Watson 34, p. 71). The minerals occur in one of the limestone members in the Watauga shale, and have been prospected for lead and zinc, under which head the occurrence will be more fully described. A similar occurrence of these minerals is found near the Norfolk and Western Railroad about one mile north of Roanoke, Botetourt County.

Pyrrhotite.

Deposits of pyrrhotite are known in Floyd County and are described under Nickel.

Summary of Iron and Manganese Deposits

The early descriptions of the iron resources of Roanoke County were drawn with a lavish hand, and the reports of forty years ago were very glowing. At present no iron or manganese ore is being mined in the county, and no new prospects have been opened up within the last twenty years. It is barely possible that operations will begin again sometime in the future, if the ores can be mined at a profit. The Clinton hematite exposures show too meagre quantities of ore for exploitation. There is no data to warrant prospecting for the limestone magnetite, pyrite or pyrrhotite occurrences. Unless more Oriskany ore is discovered, no serious operations can be expected from this type of ore in Roanoke County. From the available information, only the limonite and hematite ores along the Blue Ridge belt hold out promise of future value, and even with these the outlook is very uncertain.

The Blue Ridge hematite is known to occur on Buck Mountain, and may occur in the Poor Mountain area. The ore is very thin and of poor grade. An average of these ores in the area shows the following content:

Chapter V
Insert near page 248 of mss

Insert

PLATE XXXI

Plate

Fig. A.

The abandoned stack of the old Catawba Furnace, located along Catawba Creek north of Haymakertown, Botetourt County. This furnace was abandoned about the time of the Civil War.

Fig. B.

Abandoned open-pit working of residual brown iron ores of the lower Shady dolomite, five miles south of Roanoke along the Rocky Mount highway.

Metallic iron.....	38.84
Silica	33.89
Phosphorus	0.43
Metallic manganese	0.22

If this ore is ever used it will be under very different metallurgical methods from those in use at the present time, and it is highly probable that the need for iron ore will never become so urgent as to require use of ore of this type. It is possible that this ore may again be mined on a commercial basis from those deposits along the Blue Ridge in Botetourt County, especially along the northwestern slopes where the ore is of better grade and in more abundance, but the small known quantity in Roanoke County is scarcely to be considered as an economic reserve.

The greatest supply of iron in the Roanoke area is the brown ore along the Blue Ridge belt. The presence of this ore has been proven in the area south of Roanoke and along Poor Mountain. There are still considerable quantities of the ore which have not been mined although few new prospects will be discovered. The greatest drawback to the present use of this ore is the high phosphorus content and the general avoidance by the iron industry of medium or low grade limonites. The Roanoke ores have a fair composition for this type of iron ore, their average composition being as follows:

Metallic iron	52.24
Metallic manganese	1.36
Phosphorus	0.80
Silica	8.20

These iron ores may become useful under two conditions: (a) an increase in the price of pig iron which will bring the lower grades of

ore into the market; and (b) metallurgical improvements which will make possible the economical production of pig iron from low-grade ores. Until these conditions obtain the ores of Roanoke County will probably lie idle.

There seems to be no outlook for the mining of manganese ore in this area. No known deposits in Roanoke County have a sufficient percentage of this metal to approach the requirements of successful production. Even the fairly rich ores of the Blue Ridge in Botetourt County are not now being mined and will not again be mined except under the stress of unusual conditions.

Lead and Zinc

This region has been prospected in the past for lead and zinc at five separate localities, but at none of these was ore found in workable quantities and no serious mining was undertaken at any of the prospects. The minerals which attracted attention were galena and sphalerite closely associated with pyrite, chalcopyrite, and calcite. They occur well toward the base of the Watauga formation in one of the interbedded dolomites of that formation. It is not possible to determine whether the same dolomite always carries the ore minerals, for the localities are widely separated and the individual beds cannot be traced from one exposure to another. In each case the dolomite lies between red, purplish and gray shales, and the whole series has been highly folded, broken and brecciated. Both the shales and the dolomites are veined with calcites and rocks are often faulted.

The metallic minerals are closely associated and follow the brecciated zones of the dolomite as irregular lumps and stringers. The deposits appear to be disseminated cavity fillings which have been introduced and localized by cold meteoric waters. The intimate relations of the sulphides show that they were all introduced at about the same time. The minerals are little altered and no secondary minerals were observed. The iron sulphides are often decomposed by weathering subsequent to their extraction, and readily crumble upon the old ore dumps. Sphalerite is present at each of the five prospects, and galena at all save the Bonsacks prospect. Slight traces of gold and silver have been reported from the galena at two of the localities. It is supposed that the metals were originally contained in the dolomites and shales in finely disseminated form, and have since been concentrated by meteoric waters along lines of structural weaknesses. The minerals were probably transported as sulphates and reduced to sulphides by the organic material of the enclosing rocks. There is little or no replacement of the surrounding wall-rocks. The actual date of formation of the ore minerals is unknown, but must have succeeded the period of deformation in which the country rocks were folded and crushed.

None of these prospects is now being worked, and there is little possibility that they will ever be of economic value.

The Martin and Wertz prospect.

These prospects[1] are located about two miles southwest of Roanoke

---

1. Watson 34, p. 71; Watson 35, p. 530; Anonymous 43, p. 291; 309, 433; 42, p. 462; 44, p. 159; 45, p. 159.

---

on the old farm of William H. Martin, A small opening was also made on the adjoining Wertz property. The minerals are galena, sphalerite and pyrite, which occur in close association in one of the dolomitic members of the Watauga shale. The occurrence has been known for a long time and is reported to have been prospected about 1840. It was again opened up in 1885 and 1886, when the Roanoke Zinc and Silver Mining Company was organized in Roanoke with a capital of $600,000. This company made several small openings, but sold out within a year to J. H. Bartlett of London. A few years later the Washington Zinc Company was organized in Roanoke to investigate the Martins and Bonsacks prospects. The Pennsylvania Zinc and Iron Company was also interested in the properties, and made plans for the location of a furnace west of Roanoke to use these ores. The investigations of the area showed ore but in very disappointing quantities and the prospects have long since been abandoned. The dump piles have been leveled off and the pits are grown over and filled with water.

During the boom of the eighties, several openings were made along a small branch over about three acres of land. All of these openings exposed a dolomite interbedded with the Watauga shales. The ore-bearing dolomite was crystalline and much fractured with the veins filled with white calcite. The rock is dark gray to black and very dense, and interbedded with reddish and purplish shales which dip about 30° to the southeast. The strike of the rocks is about N 40°E. The shales have also been fractured and are likewise calcite-veined.

They show two sets of joints which intersect at an angle of about 35 degrees. The ore consists of crystalline galena and sphalerite, with much pyrite or marcasite which has been decomposed to a white crumbly mass. No ore was observed in place and little can now be found on the dumps. The ore was reported to be very rich, running 57 per cent zinc, $24 silver, and $4.20 gold to the ton (Anonymous 43, p. 291). There is no present surface indication of ore of any economic value, either in place or on the old dumps.

The Bonsacks prospect.

This prospect[1] is located along the Norfolk and Western Railroad

---

1. Watson 34, p. 72; Watson 35, p. 530; Anonymous 45, p. 463.

---

about one-half mile northeast of Bonsacks in Botetourt County. It is about seven miles northeast of Roanoke and within a mile of the Roanoke County line. The old workings were situated along the railroad in a small cut through the Watauga shale. Little mining has been done at this locality which was prospected in 1889 by the Washington Zinc Company of Roanoke. The ore was sent to a furnace at West Lynchburg. A shaft was sunk about 90 feet below the surface, at which depth a body of sphalerite was reported some twenty feet in length. The mine dump shows pyrite, chalcopyrite and sphalerite, and some ore was visible in place near the opening of the shaft. No galena was observed at this locality. The ore was disseminated in the limestone as at the Martin prospect, with the pyrite occurring as irregular stringers and masses through the rock. The limestone is nearly black, crystalline, and

veined with white calcite. The pyrite has been considerably oxidized on the dumps. Nearby occur the purple and variegated shales of the Watauga formation, and the ore-bearing dolomite is one of the members of that formation. The zinc is said to have assayed from 30 to 40 per cent zinc. The prospect is now abandoned.

The Langhorne and Wills prospects.

Some prospecting for lead and zinc has been carried on from time to time on the property of Colonel Langhorne and the adjacent land of the Wills estate along Bonys Run, about two and one-half miles south of Crockettsville or Alleghany Springs in Montgomery County.[1] The

---

1. Boyd 2, p. 6-8; Hotchkiss 16, p. 133; Fontaine 10, p. 190-1; Watson 34, p. 73-4.

---

prospects lie along the west foot of Poor Mountain in rather rugged country whose average elevation is about 2250 feet above sea-level.

The minerals of this locality are galena, sphalerite and calcite which occur intermixed in masses of well-developed crystals. The sphalerite is low in iron and is very translucent and resinous. These minerals are found in one of the dolomitic members of the Watauga shale and are scattered through this member in irregular masses and lumps. The dolomite is coarsely crystalline, generally quite compact but sometimes very porous and spongy. It has suffered considerable dynamic metamorphism and is veined and brecciated. The nearby shales are purplish, gray and black in alternating series, and dip at angles of about 65° to the southeast. The whole sedimentary series strikes about N 30° E. The limestone which contains the minerals is 12 feet

in thickness, and in the early reports was improperly called a "vein". The minerals, of which galena predominates, occur irregularly impregnating the dolomite in lumps, along crevices and cracks, and as stringers in the brecciated rock. It is said (Fontaine 10, p. 190-1) that the galena contains 16 ounces of silver to the ton. The quantity of the minerals is so small that the occurrence is not of commercial value, although the dolomite has been prospected at scattered localities from Calfee's on Little Silver to a point opposite Shawsville on the Roanoke. Beyond Shawsville to the north the minerals appear to be absent.

The prospects were opened up by Colonel Langhorne in the early eighties and several open cuts were made. No ore was mined, but a few samples were shipped for examination. Two new openings were made in 1905 on the adjacent Wills land, but all prospecting was soon abandoned. The openings have all caved in, and it is difficult at the present time to see much of the original "ore" in place.

Other Lead and Zinc prospects.

In 1880 a sixty-foot shaft was opened on Pilot or Abners Knob southeast of Christiansburg in Montgomery County. Galena, sphalerite and chalcopyrite were discovered as impregnations in a dolomite under conditions very similar to those on the Langhorne prospect. The quantities of the minerals were too small to mine. (Hotchkiss 16, p. 88; Fontaine 10, p. 190.)

Some good specimens of galena and pyrite were found along Brush Creek about a mile below the Brush Creek gold-field on the farms of Graham and Walter. These were never seriously prospected.

Summary of Lead and Zinc Deposits

As above described the lead and zinc deposits of the Roanoke area occur in one of the calcareous members of the Watauga shale. The minerals are found at several localities but at no place in quantities of commercial value, and there is no prospect of these deposits being developed. The search for lead and zinc in this region has been generally abandoned, although during the summer of 1927 a professional prospector, Mr. Holland, was examining some of the old mines and was making additional search for these ores.

Minor Metalliferous Occurrences

Small quantities of gold, silver, copper, nickel, cobalt and arsenic have been reported at various places in the Roanoke area, and small mining prospects have been opened in a few scattered localities. Most of these occurrences are in the rugged Blue Ridge Plateau area of Floyd-Franklin-Montgomery Counties, a short distance southwest of Roanoke County. A description of the more important occurrences will be given, although the interest in these prospects is largely historical.

Gold.

A small amount of placer gold was panned from the gravels of Laurel and Brush Creeks and their tributaries in Montgomery and Floyd counties in the early eighties. The gold was discovered by J. M. Thomas,

and the chief washings were limited to a small branch of Brush Creek on the lands of John Walters, about 12 miles southeast of Christiansburg and three miles east of the old Pilot House on Pilot Mountain. The gold-bearing area is on the west side of the Blue Ridge along the southeastern base of Pilot Mountain chiefly in Montgomery County. It is about four miles wide and twenty miles long.

The country rock is a series of schists and gneisses of metamorphic character and includes many rock types. Talcose, quartzose, chloritic, and mica schists are common, interbedded with and intruded by igneous masses which have suffered metamorphism to varying degrees. The surface of the rocks has been deeply weathered and there is considerable residual soil in addition to the stream gravels. The soil is deep red over the gneisses, and gray or yellow with quartz fragments over the schists. The whole series is cut by many heavy veins of white and mottled quartz carrying pyrite with traces of gold. The gold-bearing veins and stringers are largely in the gneisses. Some of the gold has been reported from the gneiss and schists themselves. The veins are often large, one being from 8 to 10 feet in thickness. They trend in general along a northeast-southwest direction, and the dip of the schistosity of the containing rocks is toward the north. The gold was found chiefly in the surface washings and in the gravels along the creek bottoms.

The first report of the gold recorded about 25 to 75 cents of gold per bushel of dirt, and that two men with a tin pan washed out $100 of gold in five days. It is reported that $2500 was discovered in two and one-half months, and that 12,130 pennyweights of gold were washed out of two acres of pay dirt less than six inches in average

depth. The gold field was thought to be a "bonanza" and in 1885 Professor Davis of Virginia Agricultural and Mechanical College estimated with his eye that the dirt would run between $1500 and $1900 per ton. (Hotchkiss 21, p. 65.) One assay is reported to have yielded as much as $94 of gold and $3 of silver to the ton. (Waters 35, p. 564.) A few nuggets were found which sold for $1 to $2 each. Most of the gold was in very small particles, and the methods of panning were very primitive. According to Fontaine (Hotchkiss 18, p. 155) the average yield for the best dirt in 1882 was 5.5 grains of gold per pan of 25 pounds. In other places the gold ran about 33 pennyweights per day by hand in rude sluice boxes. The gold was bright yellow and in pieces of all shapes. Its specific gravity was about 15.5. Some of the gold contained as much as 32 per cent of silver. In the veins the gold ran about 64.6 grains per ton, of which 27.1 grains were silver (Watson 35, p. 564). In the gneisses the combined gold and silver was about 6 grains per ton of rock.

An analysis of the gold from Montgomery County ran as follows, Porcher analyst:

Gold (by cupellation and parting) ...	65.31	
Silver (by cupellation and difference) ...	34.01	(Watson 35, p. 564)
Copper	0.14	
Iron	0.20	
Quartz	0.34	
	100.00	

The interest in this area soon waned, and little trace of activity is now apparent. No mining has been carried on in the district for several years.

With the exception of the Brush Creek gold area, no other gold-bearing rocks occur within the vicinity of Roanoke County. Traces of

gold were reported from the galena and pyrite on the Martin lead and zinc prospect three miles southwest of Roanoke. The galena was said to contain $4.20 of gold per ton. (Anonymous 43, p. 241.) Gold has also been reported from the Roanoke River gravels near Roanoke. (anonymous 42, p. 156.) There is no geologic reason to expect gold in the rocks of the Roanoke area.

Silver.

Very meagre traces of silver have been reported from a few localities near Roanoke. In each case the silver occurs as a very minor constituent of either gold, galena or arsenopyrite, which are themselves of rare occurrence.

The galena from the Martin lead and zinc prospect southwest of Roanoke was assayed to contain $24 of silver to the ton, and largely upon this assay (Anonymous 43, p. 291) the Roanoke Zinc and Silver Mining Company was organized at Roanoke in 1886. Neither zinc nor silver were found in paying quantities. The galena on Colonel Langhorne's estate near Shawsville was reported to carry 16 ounces of silver to the ton (Fontaine 10, p. 191). The arsenopyrite at Rewald P. O. (Boyd 2, p. 263) in Floyd County was said to carry from 18 to 34 ounces of silver to the ton, and the Brush Creek gold of Montgomery County contained 32 per cent silver by one assay (Watson 35, p. 564).

Copper.

Professor Wm. M. Fontaine (Fontaine 10, p. 191) reported in 1884 that copper minerals were occasionally found in the Poor Mountain area,

and recorded a specimen of chalcocite from these mountains.

Mr. Hutchins of Vinton informed the writer that prospecting had been carried on for copper in the crystalline rocks northwest of Sugar Loaf Hill, and that several occurrences of copper minerals had been found in that vicinity. An old copper prospect is reported along the Roanoke-Lynchburg highway about a mile and one-half northeast of Coyners. Copper minerals, chiefly chalcopyrite, have been found near Copper Hill, just south of the Roanoke-Flpyd County boundary. None of these occurrences was verified by the writer, nor were any copper minerals observed in the area.

Arsenic.

Several occurrences of arsenic are known in Floyd County, and the largest is located near Rewald P. O. about eight miles southwest of the corner of Roanoke County and two miles southeast of Huffville, Floyd County. This mine has been operated by the United States Arsenic Mines Company of Pittsburgh since 1903 and is on the old farm of Major William Guerrant. Several lenses of arsenopyrite occur within quartz-sericite schists, and appear to be replacements of some of the schistose beds. The chief ore-body is a lens which is about 4 feet in thickness at the surface and which expands to 14 feet at a depth of 120 feet. A shaft some 90 feet deep was sunk with an adit of 215 feet, and considerable ore was taken out. The ore ran about 25 per cent arsenic, and carried from 18 to 34 ounces of silver per ton in the richest part. (Watson 35, p. 211.)

Other nearby occurrences of arsenopyrite are reported, but are

of too small quantity for economic use.[1]

---

1. Boyd 2, p. 263; Fontaine 10, p. 190; Hotchkiss 21, p. 65; Watson 35, p. 211; Watson 36, p. 687.

Nickel and Cobalt.

The Lick Creek Nickel mine[1] is located in Floyd County along Lick

---

1. Boyd 2, p. 262-3; Fontaine 10, p. 190; Watson 35, p. 578; Watson 36, pp. 683-97; Weld 41, p. 756-7.

Creek near its intersection with Flat Run to form the South Fork of the Roanoke River. The mine lies about seven miles southeast of Alleghany Springs or Crockettsville, and is within four miles of the Roanoke County line on the old John Light farm. The occurrence has long been known and was mined for copperas during the Civil War. Considerable prospecting has been done, and some attempt has been made to mine on a larger scale, although mining is very difficult and expensive because of the toughness of the containing rocks.

The ore minerals are sulphides, chiefly pyrrhotite and finely-disseminated chalcopyrite, and they are widely distributed in the ore-bearing rocks which carry 15 per cent of pyrrhotite by bulk (Weld 41, p. 156-7). The workings are aligned in a northeast-southwest direction for about four miles over an area of crystalline and metamorphic rocks with rather high surface relief. The surface elevation is about 2000 feet, and the local relief about 1200 feet. The country rocks comprise a series of micaceous schists and gneisses of varying compo-

sitions derived in part from old sediments and in part from igneous rocks. The ore-bearing rocks are of igneous origin, and are intrusive into the metamorphic series. These igneous rocks are of three kinds and all have been subjected to dyhamic strain since their intrusions. The largest of the intrusives is a hypersthene syenite very similar to that which is found near Vinton in Roanoke County. This has been cut in places by dikes of gabbro and diabase. The ore is associated with the gabbro dike which is about 20 feet wide where exposed in the mine. This is in contact with the syenite on the footwall of the dike. The ore rock is fine grained and massive, and the sulphides are finely disseminated throughout, especially along the weaknesses in the silicate minerals with considerable replacement of them.

Watson concludes that the sulphides are secondary, and were formed after the metamorphism of the rocks. They replace and include the rock minerals, the whole being fine grained and massive with no banding. The nickel-bearing mineral has not been determined, and it is not known whether the nickel occurs in the pyrrhotite or as separate unobserved minerals. In 1907, the average ore on the dump was said to contain 1.75 per cent of nickel, and a fraction of 1 per cent of copper, and some of the ore was reported to run from 3 to 5 per cent nickel (Watson 36, p.686). As much as 0.4 per cent cobalt is reported. The dike strikes about N 45° E and its inclination is toward the southeast at an angle of about 45°. The pyrrhotite is strongly magnetic.

F U E L S

Coal in Roanoke County

A recent publication (Bulletin XXV, 1925) of the Virginia Geological Survey, The Valley Coal Fields of Virginia, by Marius R. Campbell and others, deals adequately with the occurrence of coal in the Roanoke area and the present discussion is larkely taken from that bulletin.

The counties adjacent to Roanoke County have been coal-producers of note. The Catawba field of Botetourt County, and the Brushy Mountain and Price Mountain fields of Montgomery County have furnished coal in considerable quantities. In Roanoke County, although the coal-bearing series is present, important seams of coal are either absent or inaccessible, so that the local production has been very meagre and the future possibilities are very discouraging. The paucity of coal beds in this county is largely the result of the complex geologic structure of the coal-bearing formation, although the formation outcrops over discontinuous belts totaling at least twenty miles in extent within the limits of the county. This formation is the Price sandstone of Lower Mississippian age, and consists of a series of bluish-white sandstones and conglomerates with a thickness of about 1700 feet. It contains a few scattered coal seams toward the middle of the series, of which the Merrimac seam is the most important. This is now being mined at several places in Montgomery County near Blacksburg. The formation outcrops in Roanoke County in three disconnected belts under very similar conditions; along Brushy Mountain near the northwestern

border of the county; along North Mountain from Moomaw Gap to the northern limit of the county; and along Fort Lewis Mountain from the Montgomery County line to a point north of Salem. Each of these belts is along the southeastern flank of a high mountain, and each lies near or is terminated at the southeast by a great thrust fault which brings Cambro-Ordovician rocks upon the higher members of the coal series. These three outcrops of the Price formation are entirely separate from each other, and each lies within a different member of the series of great open folds which characterize the Appalachian Ridge region. No other occurrences of the coal formation are known within the county, ahd these three belts will be discussed separately.

The Brushy Mountain Belt.

This outcrop of the Price formation is a continuation into Roanoke County of the coal-bearing rocks of the Brushy Mountain field of Montgomery County. The formation is exposed along the southeastern slopes of Brushy Mountain, and dips about 30 degrees, S 25° E. The outcrop is cut off at the base of the mountain by the Miller Fault which has overthrust the Cambro-Ordovician formations upon the Lower Mississippian series. The overthrust limestones cover the exposure of the upper part of the Price formation, and since few coal seams are found above the line of the fault, it is supposed that the important coal beds if present lie beneath the limestones and shales. In the exposed Price formation along Brushy Mountain no good evidence of coal was observed, either in Roanoke County or within two miles of the Roanoke County line, and this belt may be considered unfavorable

for any development of coal on a commercial scale. It has been reported (Campbell, M. R. et al 4, p. 281) that coal was once prospected in Millers Cove, but no trace of these prospects has been found. Most of the coal specimens reported from this belt have been of black carbonaceous shales of no economic value.

Under the supposition that the important seams are buried beneath the Cambro-Ordovician rocks, the question of their accessibility arises, and particularly the possibility of reaching them by deep mining below the overthrust rocks. Campbell (Campbell, M. R. et al 4, p. 138, 150) has considered this point, and has concluded from the probable thickness of the overlying fault block -

> ". . . that it is hopeless to expect coal at depth south of a line extending from Blacksburg to the point of Cove Mountain, and that even along this line the coal may be too deep for economic mining." (Campbell, M. R. et al 4, 158.)

Considering the uncertainty of reaching any coal below the thrust block, and the scarcity of obtainable data from the exposed beds, the probability of success in such an undertaking is very doubtful, and operations are not recommended without more information than is available at present.

The North Mountain Belt.

From Moomaw Gap northwestward into Botetourt County the Price sandstone outcrops in a narrow belt along the southeastern slope of North Mountain. The beds strike about N 50° E, and dip to the southeast at angles of about 60 degrees. The great Pulaski Fault at the base of the Mountain has overthrust the Cambro-Ordovician rocks upon the upper part of the coal series, and like the Miller Fault in the

Brushy Mountain belt, lies so near the mountain that the upper coal seams are either cut out or concealed. M. R. Campbell who has studied this area concludes that the important Merrimac or Langhorne seam of Montgomery County is covered by the fault block of the Cambro-Ordovician series (Campbell, M. R. et al 4, p. 281).

Above the fault, however, and well up the slopes of the mountain, are exposed several thin seams of coal which have been prospected at several localities, chiefly by T. G. Chapman, about three-quarters of a mile northeast of Catawba Sanatorium. The coal seams are found a short distance down the slope of the mountain from the exposure of the Ingles conglomerate and are thus near the base of the Price formation. The coal occurs in several very small and lenticular seams which are badly shattered and displaced, with many angular fragments intermixed with the coal. In the largest and best prospect, two small seams are exposed along a drift 15 feet long. These are about twenty inches thick and are about 30 feet apart in the section. They are both interbedded with thin shales and enclosed between sandstones. The containing rocks are faulted and broken, indicating that much movement has taken place. The strike is here N 53° E and the dip 78 degrees to the southeast. The seams become thinner with depth, so that further prospecting and mining has been abandoned. (Campbell, M. R. et al 4, pp. 279-81.) Hotchkiss (Hotchkiss 19, p. 81) has recorded that beds of "anthracite" coal in the Price formation have been worked for local use along North Mountain. The Chapman property, however, has the best showing of any prospect visited.

At several points along the mountain coal "blossom" was observed, but this has largely resulted from the weathering of black carbonaceous

shales with only small fragments of true coal present. The known quantity of coal along North Mountain is so small as to discourage further prospecting.

The Fort Lewis Mountain Belt.

Along the southeastern slopes of Fort Lewis Mountain the Price formation outcrops from the western limit of Roanoke County to a point north of Salem. This belt is not known to contain workable beds of coal, although fragments of coal have been found in these rocks. Holden (Campbell, M. R. et al 4, p. 281) reports that the best occurrence he discovered in this area was

> ". . . a highly pyritiferous coal bed about 8 inches thick."

It was reported to the writer in 1926 that some small-scale prospecting had recently been done and that more was being considered, but this report was not verified.

Considering the good development of coal in the Price formation of Brushy Mountain in Montgomery County within twenty miles of the Fort Lewis belt, it seems unusual that Fort Lewis Mountain contains no workable beds. M. R. Campbell (Campbell, M. R. et al 4, p. 281) has explained this inequality by the presence between the two areas of the great Pulaski Fault. The coal series on Fort Lewis Mountain is in the Catawba Syncline which has been thrust many miles northwestward from its original position. It is quite possible that in that part of the geosyncline in which the Catawba Syncline rocks were deposited the Price formation carried no coals at all. Thus the Fort Lewis belt may represent coal-less Price sandstones overthrust very near coal-

bearing Price sandstones. This would readily account for the inequality of development of the coal seams in the two belts which are now so close together.

Summary of Coal Prospects in Roanoke County

The coal that is found in Roanoke County is very splintery and largely mixed with bone, and as now exposed has been too badly weathered for careful examination as to composition and fuel ratio. It is obvious from this discussion that the coal seams of the county can never be considered a substantial economic reserve - if they can ever be more fully prospected. The nature and geologic structure of the coal-bearing formation hinders profitable mining in this county. For discussion of the North Mountain belt, and the Brushy Mountain belt beyond Roanoke County, the reader is referred to Bulletin XXV of the Virginia Geological Survey.

Oil and Gas

Within the last two years there has been considerable speculation concerning the possibility of obtaining oil or natural gas from the rocks of Roanoke County. Added interest has arisen because of the so called "gas-well" on the Williamson Road.

This well is located about a mile and one-half northeast of Ro-

anoke on that part of the Lee Highway which is known as the Williamson Road. The well is situated on the northeast side of the road just south of the entrance to the new "Upson" real-estate addition. The well is 119 feet deep and its flow of water is maintained by pumping. The water has a sour taste, and presence of contained gas is noticed soon after drinking. Small quantities of has accumulate in the vacuum tank of the pump and at favorable times issue from the water taps in sufficient volume to burn for a few moments with a blue flame. It is said that upon analysis the gas proves to be "natural gas", but this report was not verified by the writer. The presence of the gas in this well is unique in the vicinity, and other wells of equal or greater depth within a few hundred feet of this well have no sign of gas. It was reported to the writer that gas was found in another well about a quarter of a mile to the northeast, but this report was not verified after inquiry in that vicinity. Reports of gas from Moomaw Springs northwest of Roanoke were also not substantiated.

The well in question is located about a half mile north of the southern outcrop of the Elbrook formation, and the presence of this limestone on all sides is known. The well is about four hundred yards due east of the crest of Round Hill which is considered to be a fenster of sandstone projecting through the overthrust mass of the Salem fault block (see page). No outcrops of sandstone were visible on the hilltop, but the abundance and angularity of the sandstone boulders or "river-jacks" indicates sandstone as bed rock immediately below the soil cover.

Provided that the gas which issues from this well is natural gas,

there are at least two possible explanations of its presence. The gas may be derived from the decomposition of organic matter in a small pocket in the Elbrook formation. Such occurrences under similar conditions are known in other regions and pockets of gas are often found in the Onondaga limestone of western New York State. This would explain the isolated occurrence and limited quantity of the gas. As an alternate explanation, the gas may be derived from Devonian shales below the Salem thrust block, and may have seeped upward along fissures in the overthrust limestone and thus be tapped by this particular well. The presence of the sandstone on Round Hill, which is taken to be the Clinch sandstone of Silurian age, would tend to show that such conditions might obtain. In neither case is there any possibility of procuring gas in commercial quantity.

This gas-well is located beneath a gasoline filling station, and the presence of the gas was not discovered until after the station had been established. There is thus a possibility that the gas is not natural but is due to gasoline leakage. Some effort has been made to organize a company to investigate the oil possibilities of the region around the gas-well, and several leases have been procured for this purpose.

The rocks of the Roanoke area have been intensely folded and faulted and subsequent erosion has deeply dissected the region. It is highly improbable that rocks of this nature would now contain either oil or gas, for these very volatile substances have had ample opportunity to escape during the deformation of the rocks, if indeed they were ever present. There does not seem to be the slightest rea-

Chapter V
Insert near page 270 of mss.

Insert

Figure 5.

Figure 5.

Map of the Roanoke area showing location of quarries and workings in the non-metallic reserves.

Coal.

1. Chapman prospect.

Limestone quarries.

2. Blue Ridge Springs quarry.
3. Mundy quarry.
4. Roanoke city quarry.
5. Salem city quarry.

Clay deposits and brick yards.

6. Webster Brick Company.
7. Adam, Payne, and Gleaves Company.
8. Salem Brick Works.

Barite.

9. Reeds quarry.

Glass sand.

10. Salem Glass Works quarry.

Marl.

11. Daleville opening.

som to believe that petroleum or rock-oil will ever be discovered in Roanoke County, and it is very improbable that natural gas will be found in quantity to warrant even local development. To discourage any attempts at exploitation of these substances would seem in keeping with the facts now known.

OTHER NON-METALLIC RESOURCES

Limes and Cements

A comprehensive discussion of the Cement Resources of Virginia west of the Blue Ridge by Ray S. Bassler was published in 1909 as Bulletin II-A of the Virginia Geological Survey. This bulletin contains a discussion of the limes and cements of the Great Valley and the Appalachian Ridges, but offers little data concerning the occurrences of these materials in the Roanoke area. The reader is referred to this report for information about the nature and use of limes and cements in general, and concerning the possibility of their development in adjacent areas.

The rocks used by the lime and cement industry are chiefly limestones, dolomites and shales of various compositions. The term limestone is theoretically restricted by this industry to a highly calcareous rock which contains less than 5 per cent of magnesia oxide. The relative amount of magnesia below this figure determines whether the

limestone is less or more pure. A limestone which contains from 5 to 45 per cent of magnesia may be called a dolomite, and is less or more pure as the amount of magnesia varies between 5 and 45 per cent. The term shale is loosely used to represent any fine-grained argillaceous sedimentary rock which is fissile or shaly. Limestones and dolomites are the main sources of limes and cements, and shales are mixed in finely ground form with the calcareous rocks to add alumina. Hence this discussion will deal chiefly with limestones.

Limestones are used for the following purposes:

1. Crushed stone, building stone, road metal etc.
2. As a source of lime or quick-lime
3. For the making of cement -
    a. Natural cement
    b. Portland cement

The use of limestones for building stone, road construction and similar purposes will be discussed later in this chapter. The uses of limestones for lime-burning and for cement manufacture are so similar that they may be discussed together.

Not all limestones are suitable for the cement industry. Usable rock must maintain a purity which depends upon the particular purpose for which the limestone is to be used. For lime-burning, the rock should have a low percentage of magnesia and should be as free from argillaceous material as possible, since these impurities retard slaking of the lime. Almost any relatively pure limestone may be burned for lime, and rocks of this kind are common in the Roanoke area. On the other hand, the cement industry requires such a rigid standard of

purity that good cement rocks are rare. The ideal cement rock should contain 75 per cent of calcium carbonate and 20 per cent of clayey material. So few rocks reach this ideal standard that limestones of inferior quality are often used, and the needed constituents are later added in the process of cement manufacture. Generally these constituents may be supplied from shales of different kinds.

Cement rocks are of two main kinds: those used as natural cement, and those used for making Portland cement. Natural cements are limestones which will produce a cement directly upon burning without previous grinding or mixing. They contain from 13 to 35 per cent of clayey material, of which from 10 to 20 per cent is silica. The alumina and iron together make up from 3 to 15 per cent of the rock. They are thus argillaceous limestones. When burned at low temperatures they do not slake, but form a cement which will set under water more rapidly than will Portland cement, although it possesses less strength. Natural cement rocks are rare and seldom occur in abundance. Portland cement is an artificial mixture of lime, silica, alumina and iron oxide. This mixture is burned at a high temperature to a clinker, which is finely ground to form the Portland cement. Rocks suitable for this use are more abundant than for natural cement, but less abundant than those suitable for lime-burning.

Several formations in the Roanoke area are sufficiently calcareous to be considered as possible sources of rock for lime or cement. The most convenient method of discussing these rocks is to consider them according to their age, and they may be grouped as follows:

A. Cambrian limestones

B. Ozarkian and Canadian limestones

C. Ordovician limestones

D. Devonian limestones

Cambrian limestones.

The limestones of the Shady and Watauga formations are extensively quarried for lime and crushed stone, but have not been worked for cement rock. In general these limestones are too dolomitic for use in the manufacture of Portland cement, and no exposures of the rocks were observed to show material sufficiently pure for use as natural cement. The most easily accessible outcrop of the Shady dolomite is along the Blue Ridge from Troutville to Buchanan. Here the outcrop of the dolomite parallels the Norfolk and Western Railroad, and is less than a mile from the tracks. If cement rock could be developed from the Shady, this belt would offer good transportation facilities. Exposures of the Watauga occur along the railroad from Troutville to Buchanan and in the Roanoke Valley at Roanoke. An analysis of limestone from each of these formations is given in Table . The high percentage of magnesia greatly impairs their value as cement rocks.

The Elbrook formation of Upper Cambrian age contains an abundance od limestones but the beds are very shaly and argillaceous. The formation as a whole lacks pure limestones of the quality necessary for cement rock. Elbrook limestones are quarried in many places throughout the Roanoke area, but the rock is used mainly for road material. Analyses of typical limestones of the Elbrook formation are given in

Table , analyses 3-7. Samples 3-5 were chosen as representing the purest members of the Elbrook exposed near Salem and near Glenvar.

Ozarkian and Canadian limestones.

The combined thickness of the Copper Ridge formation (Ozarkian) and the Nittany dolomite (Canadian) is over 2500 feet, and the greater part of this thickness is represented by limestones and dolomites. None of these beds, however, are known to be of a quality suitable for cement rock. The dolomites contain too much magnesia for Portland cement, and the limestones are insufficiently pure for natural cements. It is somewhat surprising that so extensive a series of calcareous beds should contain no workable cement rocks in the Roanoke area. This characteristic, however, obtains in these rocks throughout Virginia, and at very few localities are cement rocks obtainable from the Ozarkian or Canadian formations. Analyses of limestones from these formations in the Roanoke area are given in Table . The limestones have been extensively quarried for furnace flux, lime burning, and for road material, and are entirely suitable for these purposes.

Ordovician limestones.

The purest limestone of this area is the Mosheim member of the Chazy group, at the base of the Ordovician and immediately below the black Athens shale. This is the Stones River formation of Bassler. This formation is a pure fine-grained blue or dove limestone containing about 95 per cent $CaCO_3$. The color and composition are remark-

References to table of limestone analyses.

1. Limestone from quarry southeast of Buchanan,
P. Salom analyst, (Hotchkiss 19, page 62)

2. Massive limestone, 2 3/4 miles southeast of Roanoke,
W.E.Barlow analyst, (Watson 34, page 72)

3. Gray massive limestone, Salem city quarry,
C.W.Kinzer analyst, (Kinzer 23, page 13)

4. Massive gray limestone, 2 miles east of Salem,
C.W.Kinzer analyst, (Kinzer 23, page 13)

5. Gray limestone, Cavern Hill near Glenvar,
C.W.Kinzer analyst, (Kinzer 23, page 13)

6. Limestone, Blue Ridge Springs quarry,
P. Salom analyst, (Hotchkiss 19, page 62)

7. Limestone, Catawba creek near Stone Coal Gap,
W.B.Rogers analyst, (Rogers 29, page 344)

8. Limestone, near Blacksburg,
W.B.Rogers analyst, (Rogers 29, page 170)

9. Limestone, Davidson farm 1 mile east of Blacksburg,
J.R.Eoff Jr. analyst, (Watson 34, page 74)

10. Limestone, Bell quarry, 3 miles southwest of Blacksburg,
J.R.Eoff Jr. analyst, (Watson 34, page 74)

11. Dove limestone, 1 mile east of Catawba Sanatorium,
C.W.Kinzer analyst, (Kinzer 23, page 13)

12. Dove limestone, near Keslers Mill, 2 miles east of Salem,
C&W.Kinzer analyst, (Kinzer 23, page 13)

13. Slaty limestone, 3 miles north of Roanoke,
W.B.Rogers, analyst (Rogers 29, page 393)

14. Limy shale, Catawba Valley near Catawba P.O.,
W.M.Thornton, (Bassler 1, page 136)

Horizon	Shady	Watauga	Elbrook					Copper Ridge	Nittany		Mosheim		Athens	
No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$CaCO_3$	51.34	–	51.91	63.12	53.44	54.16	44.64	52.50	46.46	66.43	94.48	95.36	46.20	67.03
CaO	–	30.06	29.4	35.68	30.26	–	–	–	–	–	53.5	53.5	–	37.54
CaO_2	–	43.98	35.92	41.0	44.86	–	–	–	–	–	42.2	41.9	–	–
$MgCO_3$	46.02	–	27.93	23.79	39.83	39.86	37.53	34.34	37.38	24.21	2.32	0.21	34.16	1.85
MgO	–	18.41	13.36	10.90	19.05	–	–	–	–	–	1.11	0.1	–	0.88
SiO_2	6.45	trace	16.2	6.13	1.17	4.24	14.36	–	–	–	1.37	2.49	12.68	23.56
Al_2O_3	1.05	0.43	3.71	3.39	2.63	1.12	2.48	0.84	1.33	0.88	1.51	2.17	4.00	5.48
Fe_2O_3	–	0.93	2.77	2.14	1.15									
Na_2O	–	0.21	–	–	–	–	–	–	–	–	–	–	–	–
K_2O	–	0.24	–	–	–	0.10	–	–	–	–	–	–	–	–
P	0.01	–	–	–	–	–	–	–	–	–	–	–	–	–
S	0.14	–	–	–	–	0.11	–	–	–	–	–	–	0.93	–
H_2O		3.30	–	–	–	–	1.00	–	–	–	–	–	2.00	–
Insol. Res.		2.90	–	–	–	–	–	3.48	14.93	8.18	–	–	–	–
Total	107.01	100.47	101.36	99.95	99.32	95.69	100.01	91.16	100.12	100.70	99.69	100.69	99.97	97.92
Sp. Gr.			2.70	2.82	2.66						2.76	2.87		

ably uniform wherever the limestone is exposed. Its thickness in the Catawba Valley is about 30 feet. The lower seven feet, however, are conglomeratic, so that the pure limestone is about 23 feet in thickness. The formation outcrops in a narrow belt along the Catawba Valley just south of the Catawba Sanatorium, and may be traced along the strike for several miles. The thickness increases toward the west and thins toward the east. The formation is present south of the Salem Fault and is exposed near Keslers Mill on Masons Creek northeast of Salem. This southern exposure of the Mosheim is very limited and the bed is cut out by faulting.

Analyses of this rock from the Catawba Valley and from Keslers Mill are given in Table . The lime content is very high and little silica or magnesia are present in the rock. It is entirely suitable for Portland cement. It is impossible to tell from the analysis of a rock whether it is suited for the manufacture of natural cement. It is probable, however, that the Mosheim limestone is not sufficiently argillaceous for this purpose, but with admixture of clayey material from the nearby shales it might prove satisfactory. The outcrops of this formation are not far from the Salem-Catawba Railroad, and could be quarried advantageously in the Catawba Valley. This formation may be safely considered a suitable source of material for Portland cement. It has not been quarried for this purpose in 1927.

The Athens shale of the Catawba Valley outcrops adjacent to the Mosheim limestone. The shales themselves are not suited for use as cement rocks, but could be used with the purer Mosheim in the manufac-

ture of natural cement material. Analyses of these shales from outcrops near the exposures of the Mosheim limestone are given in Table , samples 13 and 14.

Devonian limestones.

The Giles formation which overlies the Clinton sandstones contains a thin limestone member at the base of the formation. This is exposed about one mile south of Newcastle, Craig County. This limestone or its equivalent is used for cement rock in Alleghany County near Clifton Forge. No test was made of this rock in the Roanoke area, but it does not possess any of the megascopic characters essential to cement rocks. No quarries are known in this formation within the area under consideration, and the limestone appears to be too variable and inaccessible in occurrence for economic use.

Summary

The Roanoke area is fortunate in containing a supply of material which can be used for cement and lime. The writer is prepared to recommend that the Mosheim limestone be worked for Portland cement and that a good locality to develop this formation for this purpose would be in the Salem Valley near Keslers Mill on Masons Creek northeast of Salem. A better exposure of this formation occurs in the Catawba Valley near the Catawba Sanatorium. This locality is not as advantageously situated with reference to transportation as is the occurrence at Keslers Mill. It is entirely possible that good cement material occurs in the Shady and Elbrook formations, and prospecting in

these formations might yield favorable results. The limestones of the Watauga, Copper Ridge, and Nittany formations seem less likely of promise than do those of the Mosheim, Shady, and Elbrook.

Clays and Shales

The following discussion of clays and shales is based upon a recent bulletin of the Virginia Geological Survey by Heinrich Ries and R. E. Somers, on the Clays and Shales of Virginia West of the Blue Ridge (Virginia Geol. Surv. Bull. XX, 1920). To this bulletin the reader is referred for a description of the character of clays in general and for an account of their occurrence in adjacent counties. All tests of the Roanoke County clays which are herein mentioned were made by Ries and Somers.

The clays of this area are used chiefly for the manufacture of common brick and tiles, and such usage demands that they conform to a standard set of physical characteristics. Among these necessary characteristics is plasticity, or the ability to be molded into a desired shape when wet. Any additional water which is required to render a clay plastic is called water of plasticity, and its amount varies with different clays although it must range between certain maximum and minimum limits. Another property of considerable importance is shrinkage, of which there are two kinds - air shrinkage and fire shrinkage. Air shrinkage takes place as the clays are dried, and clays which possess high air shrinkage are undesirable because of the tendency to

warp and crack. Fire shrinkage is the contraction of the clay mass during firing, and a high fire shrinkage in clays is likewise undesirable. The color of the fired clay is of importance and depends largely upon contained impurities. The color of the original clay is but little index to the color of the final brick. Transverse and tensile strength are of importance as are the fineness and hardness of the ultimate clay products. A discussion of the importance of these characteristics for clays in general may be found in Bulletin XX above mentioned, or in one of the textbooks on economic geology.

The fusing points of clays is one of the features governing their desirability and, in describing the various clays of Virginia, Ries and Somers give the fusing points in terms of Seger Cones which are used in the clay industry for testing the fusibility of clay products. These cones are made of clays and fluxes artificially mixed in regular proportion and graded to represent a series of known fusing points each but a few degrees higher than the next. The cones are composed of kaolin, feldspar, quartz, marble, and pure ferric oxide. They are placed in a kiln out of reach of the actual flames, and because of their known fusing points can be used to register the temperature of that kiln. As they become heated the tip of the cone becomes soft, and at the fusing point bends over until it touches the base of the cone. They may be observed through peep-holes in the kiln walls. The temperatures of the fusing points of the commonly used cones are as follows;

Cones	Fusing Points			
Cone 010	1,742 degrees F. or		950 degrees C	
Cone 05	1,922	"	1,050	"
Cone 03	1,944	"	1,090	"
Cone 1	2,102	"	1,150	"
Cone 3	2,174	"	1,190	"
Cone 5	2,256	"	1,250	"
Cone 9	2,390	"	1,310	"

The clays of the Roanoke area may be classified as follows (modified after Ries and Somers):

A. True sedimentary clays or shales

a. Watauga shales
b. Elbrook shales
c. Athens shales
d. Marcellus-Genesee shales
e. Mississippian shales

B. Residual clays from decomposition of bed rock

a. Residual clays of the crystalline area
b. Residual clays of the Shady dolomite
c. Residual clays of the Elbrook formation
d. Residual clays of the Copper Ridge formation
e. Residual clays of the Nittany dolomite

C. Transported clays of floodplain origin

True Sedimentary Clays or Shales

Some shales are usable for the manufacture of clay products and hence may be considered as clays. Shales are transported clays of different kinds which have been deposited in beds chiefly as marine sediments. Consolidation has temporarily destroyed the original property of plasticity, but the shales may regain this property when

very finely ground and mixed with water. Shales are of much greater extent than most surface clays, but the difficulties of working often offset this advantage. Where these shales are weathered the clayey nature becomes partially restored, and the amount of weathering is thus an important factor in the usability of shales for the manufacture of clay products. Often they may be ground and used with true residual clays to good advantage. When the shales contain thin lenses of limestones and sandstones which cannot be thrown out during mining, the cost of handling as compared with that for residual clays is much greater, and generally prevents the economic use of this type of clay-shale. Furthermore, many shale beds are very gritty or calcareous and these characteristics impair their quality.

Watauga shales.

The Watauga shale has a wide area of outcrop and its beds are in many places of sufficient quality to serve as clays. The chief disadvantage to the use of the Watauga shales is the alternating nature of its lithology. Thick beds of good shale are seldom found without interbedded limestones and gritty members which make clay operations very difficult.

The Watauga shales are worked in several places near Roanoke for clays. The Adams, Payne and Gleaves Company are operating a brickyard east of Roanoke between Roanoke River and Tinker Creek. The shales are here very argillaceous, brick-red, and dip eastward at steep angles. They are artificially mixed with floodplain clays taken from the adjacent river deposits, and are used at the nearby kilns of this company.

The red shales lie on the southeast side of a small thrust fault which is visible in the cliff along the railroad. The company has opened a cut into the hill, and has followed the shales for about fifty feet in a large pit which they are operating by steam-shovel. Calcareous layers a foot or so in thickness occur with the soft shales, but these can be avoided in the working. The clay burns red, and is used for the manufacture of common brick.

Ries and Somers record the occurrence of workable shales east of Bonsacks just north of the Roanoke line. About one-quarter of a mile east of Bonsacks are numerous outcrops of the red, yellow and grayish shales of the Watauga formation. These shales will not grind up to a plastic mass when fresh, but when weathered form a yellowish and gray smooth clay of good plasticity. The clay requires about 40 per cent water of plasticity and has 8.6 per cent air shrinkage. At Cone 010 the clay shows no fire shrinkage but has a high absorption of 25.3 per cent. At Cone 05 it gives a good brick with 6.4 per cent fire shrinkage and 14.3 per cent absorption. The clay fires red and can be used for common brick. Only six feet of thickness was observed for the clay of workable grade. (Ries and Somers 28, p. 61.)

At a locality along the Lynchburg Highway and midway between Coyners and Blue Ridge Springs, the Webster Brick Company is working clay shales of the upper Watauga. This is the most extensive clay working in this area, and the plant manufactures ordinary brick which is used for building in Roanoke. The shales dip steeply to the southeast and strike N 80° E. The fresh shale is less satisfactory than slightly weathered rock, and a mixture of both is used. The brickyard lies a

Chapter V

Insert near page 283 of mss.

Insert

PLATE XXXII

Plate

Fig. A.

Clay pit in weathered Watauga shales, Webster Brick Company, Webster, Botetourt County.

Fig. B.

Brick kilns of the Webster Brick Company, Webster, Botetourt County.

short distance from the Norfolk and Western Railroad, and is connected with it by a short railway. A chemical analysis of the clay shale from Webster is given by Ries and Somers (Ries and Somers 28, p. 59):

SiO_2	51.08
Al_2O_3	22.05
Fe_2O_3	10.43
CaO	none
MgO	2.28
K_2O	5.92
Na_2O	0.20
Loss on ignition	7.36
	99.32

Watauga shales suitable for brick clays occur along the wagon road near Lithia in Botetourt County. The shale requires 18 per cent water of plasticity, and the air shrinkage is low. The clay has a rather short heat range, but burns to a hard brick of low absorption at Cone 05. The color after burning is red. (Ries and Somers 28, p. 30.)

Elbrook shales.

The lower beds of the Elbrook limestone contain shaly members which might be used for brick clay. The formation is extensively exposed in a wide belt across the area, but the greater part of the outcrops are of the limestone members. Ries and Somers examined shales from this formation about two miles north-northwest of Blacksburg, and found them to be of fair quality. The shale if mixed with the residual clay from the nearby limestone areas could be used for brick if properly fired. The Elbrook is not a promising source of clay shales.

Athens Shales.

The Athens shale is conspicuously exposed in this area, but the beds are of poor quality for clay products. The shales outcrop in a belt along the Catawba Valley from Ironto, Montgomery County to Tinker, Botetourt County, but in this belt are too gritty and calcareous for use. An outcrop of this shale east of Fincastle shows clay shale

of fair grade but lacking sufficient plasticity even when ground. Its residual soil, however, is satisfactory and the fresh shale might be mixed with the residual clay.

An outcrop of these shales near Cloverdale is described by Ries And Somers (Ries and Somers 28, p. 56). The shales outcrop along the west side of the Norfolk and Western Railroad just north of Cloverdale station. When fresh they are grayish-brown, fine-grained, rather soft, but very splintery, and there is a long exposure of the shales and the overlying residual clays. This residual material is very tough and plastic and can be easily molded. If the prospect is to be used, it would be possible to mix the fresh shale and residual clay in the proportions of 1/4 shale and 3/4 clay, in order to eke out the smaller quantity of the true clay. Such a mixture was worked up by Ries and Somers with 31 per cent water and became highly plastic, having an air shrinkage of 5.4 per cent. Its tensile strength averaged 35 pounds to the square inch. Firing tests gave the following results:

Cone	Fire-Shrinkage	Absorption
010	0.0%	24.5%
05	3.0	19.3
1	5.4	12.3
5	8.7	2.0

The brick was too porous at Cone 010, but at Cone 05 was steel-hard and made a good brick; ir became nearly vitrified at Cone 5. The mixture could be used satisfactorily for common brick and might be worked with a stiff-mud machine.

Marcellus-Genesee shales.

Certain types of Devonian shales may be ground and worked with water to form clays of good quality. They can seldom be used in fresh condition. Many of them are highly carbonaceous and hence not usable although some of the softer shales may be very favorable. The Marcellus-Genesee shales outcrop in the Roanoke area on the slopes and floors of Carvins, Masons and Bradshaws Coves, and also along the northern slopes of Coyners and Little Brushy Mountains. In general they are dark colored with smooth feel and weather to a clayey mass. They are often too carbonaceous for clay purposes. Shales of this age are being worked from a cut at the western end of Little Brushy Mountain. The shales have been highly deformed and are much crushed and broken. Their color is much lighter than is usual for the formation, and the shales are often colored brick red on their surface exposures. The material has been used by the Salem Brick Company since 1922 for sommon and face bricks. It burns at Cone 02 or 2, and the total shrinkage is 10 per cent. The shales as used are mixed with either floodplain or residual clays which are found nearby.

Mississippian shales.

It has been reported that good fire clays occur with the coal beds along North Mountain near the old Catawba furnace, and that these clays are favorable for use in manufacturing fire brick, stove linings, pipes, tiles etc. (Hotchkiss 19, p. 161.)

Shales of the Maccrady formation are utilized for brick manufacture in Montgomery County and are worked between Blacksburg and Chris-

tiansburg. No occurrence of these shales is known in the present area.

Residual Clays from Decomposition of Bedrock

Much of the surface of the Roanoke region is covered with a mantle of residual soil and clay which has resulted from the decay of rocks directly below the surface. The thickness of this type of soil varies greatly but often reaches one hundred feet. The nature of the soil depends largely upon the kind of rocks from which the soil has been derived as a result of decomposition and decay. The residual clays of the Roanoke area may be divided into two major divisions: the clays of the crystalline area; and those of the sedimentary area. Of the latter division there are several minor groups which are of economic value in this region and which will be discussed in detail below.

Residual Clays of the Crystalline Area.

The various crystalline rocks which lie to the east and south of the Blue Ridge Fault have been deeply weathered to form a heavy blanket of residual clays. These clays are generally quite thick, deep-red, and extremely ferruginous. The high percentage of iron renders them unfit for the manufacture of most clay products, and none of these clays is at present being worked in Roanoke County. In other regions these clays sometimes contain white streaks of nearly pure high-grade kaolin, but occurrences of this kind have not been observed in the present area.

Residual Clays of the Shady Dolomite.

The lower three or four hundred feet of the Shady dolomite, where exposed at or near the surface, weathers to a fat, heavy clay which is often highly ferruginous. This is the horizon of one of the Blue Ridge limonites and these clays therefore occur near iron mines and prospects. The clays are generally brown with iron stain, or variegated with bright colors. The deep-red colors of the crystalline residuals are lacking. The clays contain little lime and their ferruginous nature makes them red-burning. They are patchy in occurrence and the change to bedrock is often sudden with many pillars or "horses" of unweathered bedrock contaminating the clays.

A small deposit of residual Shady clays occurs at the old Rorer limonite mines south of Roanoke. The clay is brown, iron stained, and had pockets and streaks of gray clays which are plastic and buff-burning. There is scarcely enough of the good clay to warrant operation of the deposit, but if more clay was found and the area seriously prospected, the clay might be sold to steel works or used in saggers. (Ries and Somers 28, p. 36.)

A considerable quantity of this type of clay occurs in the abandoned ore pits at No. 4 mine of the Houston Iron Company one mile southeast of Nace, Botetourt County. The ferruginous clays are here associated with a gray mottled clay (which is locally called "fire clay"), and with small deposits of pisolitic bauxite. These clays were tested by Ries and Somers (Ries and Somers 28, p. 46), but it is questionable whether they could be used alone for clay products. There is not enough of either type of clay to warrant establishing a plant at the

mine, and the main use for them would be as an ingredient of porous shapes of semi-refractory character.

Residual clays of the Elbrook formation.

This formation is widely distributed in the Roanoke area and disintegration of its members often furnishes clays of good grade. Ries and Somers have described a deposit of residual clay at the old Lynchburg or Grubb iron mines (Ries and Somers 28, p. 47). At these mines (see page) the ore is surrounded by a reddish residual clay through which are scattered streaks and patches of white and gray clay of very fine dense texture, and with a porcellaneous lustre. Some of these pockets are ten to fifteen feet in diameter, and the contacts with the reddish clays are very sharp. A chemical analysis of this material, given by Ries and Somers, is as follows:

SiO_2	43.18%	
Al_2O_3	39.21	
Fe_2O_3	0.15	
MgO	tr	(Ries and Somers 28, page 47)
NaO	0.08	
H_2O above 108°C.	14.23	
H_2O below 108°C.	3.39	
	100.24%	
Specific gravity....	2.46	

On the basis of the above analysis, the mineral somewhat resembles halloysite of Dana, but has a higher alumina-silica ratio than

does the halloysite of commonly accepted composition. The writer was informed in 1926 by the superintendent of the Webster brickyards that an attempt had been made to use this material for the manufacture of brick. It was reported that the clay made a satisfactory brick and fired red. The more ferruginous clays in which the iron is found are very plastic, and after firing give a curious ringing sound. At Cone 010 the absorption was 28.4 per cent. At Cone 05 the material showed the high fire shrinkage of 10.3 per cent, although the absorption had dropped to 9.4 per cent. The clays are not being worked at the present time.

Along the road from Lithia to Fincastle, and for a distance of two or three miles west from Mill Creek, there is an abundance of residual clay derived largely from the Elbrook formation. The clay is deep-red and very plastic when wet. If it were used for brick manufacture it could be hauled to the railroad at Lithia. It might be advantageously used with the clay shales of the Athens which are exposed about one mile east of Fincastle.

A small deposit of residual clay from the Elbrook is being worked about two miles southwest of Salem where it occurs in a low ridge along the Salem-Christiansburg road. The deposit is about 15 feet thick where exposed and is covered with stream gravels and sands. The clays are both red and yellow, but the red varieties are too sticky for use. The residual clay is hand-mixed with the floodplain clays which occur nearby, and is used for the manufacture of soft-mud brick. It has been worked by the Salem Brick Works. The pits were temporarily abandoned in 1922 in favor of the Devonian clay shales which occur about a mile

and one-half to the north.

About one-half mile south of Ellett on the Virginian Railroad in Montgomery County there is a considerable area of residual clay derived from the Elbrook limestone. This material was mixed with clay shales from the Athens which outcrops a short distance to the north. The mixture was examined by Ries and Somers (Ries and Somers 28, p. 63) and found suitable for brick manufacture, although they do not recommend its commercial development.

Professor Harry I. Johnson of Roanoke College, Salem, has furnished the writer with the following analysis of residual clay from the Elbrook formation. This clay was taken from the subsoil on High Street, Salem.

SiO_2	55-70%	
Al_2O_3	20-35	
Fe_2O_3	10	
MgO	5.4	H. I. Johnson, analyst
CaO	tr	
K_2O	2.4	
Na_2O	3.3	

Residual Clays of the Copper Ridge formation.

The Copper Ridge formation directly overlies the Elbrook formation, and weathers to a deep-red soil of irregular thickness. Ries and Somers (Ries and Somers 28, p. 48) mention the occurrence in these residuals of workable clays near Cloverdale, west of Hollins Station,

and between Hollins and Cloverdale. From Christiansburg to Blacksburg, except for a small area around Merrimac, the country is underlain by the Copper Ridge formation, which at many places shows banks of residual clays formed by weathering. The clay is plastic and red-burning. Two miles east of Christiansburg on the north side of the Lee highway there is a clay deposit which is sandy and gray. This material was tested by Ries and Somers (Ries and Somers 28, p. 76). It could be utilized in the manufacture of buff-burning face brick, terra cotta, and low-grade fire brick. The deposit lies within a mile of the railroad, and is well worth development. There is not less than 20 acres underlain by this material.

Residual clays of the Nittany dolomite.

The clays of this formation are well distributed over its area of outcrop, and are exposed at several places in quantity sufficient for clay production.

Immediately west of Daleville there is a good exposure of a smooth red residual clay of good plasticity (Ries and Somers 28, p. 46). It is derived from the weathering of a hard blue-gray limestone. Ries and Somers mixed this clay with 33 per cent water and the resulting material had 9 per cent air shrinkage and burned red. It was steel-hard at Cone 05. At Cone 010 its fire shrinkage was 1.3 per cent and its absorption was 24.1 per cent; at Cone 05 the fire shrinkage was 9.3 per cent and the absorption was 9.6 per cent. This strong increase of shrinkage is characteristic of many residual clays of limestone origin. The clay would be good for common brick or tile.

Ries and Somers report a long cut in these clays about one-eighth of a mile west of Hollins Station along the Norfolk and Western Railroad. Here the clay is very plastic, yellow and red in color, and contains considerable chert. It has 37 per cent water of plasticity and its air shrinkage is 7.5 per cent. Its fire shrinkage at Cone 010 was zero, and its absorption was 24.1 per cent which is too high for general use. At Cone 05 the clay fired red and was steel-hard. Its fire shrinkage at this cone was 3.3 per cent and its absorption was 17.5 per cent. The clay could be used for common brick but should be dired above Cone 010.

Transported Clays of Floodplain Origin

Clays of this type occur in scattered areas in the Valley lowlands along the floodplains of the larger streams. The clays are seldom very extensive in outcrop and the material is greatly contaminated with river debris which is often interlayered to such an extent that handling of the clays is very difficult. The clay is more plastic and possesses a higher tensile strength than do the residual clays but is sometimes very sandy and gritty. The floodplain clays can be used to good advantage with clays of other kinds, and the mixture is excellent for brick and drain-tile. Two deposits of this kind are being worked in Roanoke County for the manufacture of common and soft-mud brick.

The Adams, Payne and Gleaves Company operated a brickyard along

the floodplain of the Roanoke River near Tinker Creek east of Roanoke. Open excavations with steam shovels have exposed a blue sandy, very plastic clay which fires red and gives brick with 11 per cent absorption. At the end of the pits near the kilns but away from the river occurs a very sticky clay which has not as yet been used. The clays are worked in a stiff-mud machine. Physical tests upon the clays were made at the Blacksburg Experimental Station, and the breaking load of the fired clay was determined at 1190 pounds, with a modulus of rupture of 507 pounds. The crushing strength per square inch was 4072 pounds. (Topham 33, p. 17.)

The Salem Brick Works have been using a floodplain clay which occurs along the Roanoke River about two miles west of Salem. The clay was mixed with a limestone residual for the manufacture of soft-mud and common brick. It was not being worked in 1927.

Summary.

The production of clay and shale for brick manufacture is an important industry in the Roanoke area, and at least three large brickyards are in operation at the present time. Deposits of workable clays have been proven at a number of additional localities in the region, and could be operated with every prospect of an adequate supply of good material. Transportation facilities are available for many of the known deposits, and the distribution of the finished products could be readily handled. The demand for such products should be the controlling factor in the duture development of clays.

There are no known deposits of high-grade kaolins for porcelain manufacture within this area, and the writer does not anticipate their discovery.

Titanium and Apatite

Roanoke County contains valuable deposits of ilmenite and apatite which offer promise of considerable economic value as sources of titanium and phosphates. The deposits have been described by Watson and Taber in 1913 in Bulletin III-A of the Virginia Geological Survey, pages 235-247, and the present discussion is largely taken from this bulletin.

The deposits are found about two miles east of Vinton, and four miles east of Roanoke City at the foot of the Blue Ridge which is here very low and without pronounced ridge character. The minerals occur within the area of the crystalline rocks along the valley of Wolf Creek near the main road leading east from Vinton. The crystallines represent a part of a great thrust block which has been faulted from the east upon the Cambro-Ordovician rocks of the Valley. The trace of this fault passes in a north-south direction about two and one-quarter miles west of the deposits. The occurrence of these minerals was first observed in 1890 by local parties, and some shallow openings were made from which ore was shipped to the furnaces at Roanoke. This material was rejected by the furnaces because of the high phosphorus and low iron content. The area was later prospected by Mr. H. M. Engle of Roanoke in about 1905. Watson and Taber examined the region in 1910 and this examination formed the basis for the report above mentioned. In 1926 the area was being worked from a single open cut by Mr. Hutchins of Vinton. The earlier shafts, pits, and open cuts were abandoned and grown over with brush.

The ore consists of an igneous rock high in titanium and phosphorus

which has been called nelsonite by Watson from Nelson County, Virginia, where a larger occurrence is known (Watson 35, p. 300). Nelsonite consists of an intimate association of apatite with either ilmenite or rutile, or both. The Roanoke County nelsonite is an ilmenite-nelsonite containing little or no rutile. The rock is very dark, blue-gray, fine-grained to porphyritic in texture, and generally shows foliation due to metamorphism. The ground mass consists of very fine grains of ilmenite, and the phenocrysts are of apatite which is sometimes developed in good hexagonal crystals up to five centimeters in diameter. The ratio of ilmenite to apatite is variable, and the two minerals are often equally abundant in a single specimen. A few silicate minerals occur as accessories, chief of which are biotite, unstriated feldspar, occasional quartz, hornblende, and pyroxene. Epidote is a common accessory and appears to be of secondary origin. The intimate relations of the ore minerals suggest contemporaneous formation, for each shows inclusions of the other. The outlines of the apatite crystals are somewhat stronger than those of the ilmenite, suggesting that the apatite crystallized slightly earlier than the ilmenite. The rock is generally much weathered and its surface is pitted with depressions caused by the removal of the apatite phenocrysts. The ilmenite alters to limonite and masses of relatively pure limonite occur in the residual material. A composite analysis of nelsonite from Nelson County is here given:

TiO_2	39.74%
P_2O_5	10.01
Fe_2O_3	8.43
FeO	26.79
CaO	12.44
MgO	0.71
MnO	0.21
SiO_2	0.73
H_2O-	0.20
H_2O+	0.51
F	0.60
Cl	tr
CO_2	tr
S	0.61
	101.13%
Less O	0.40
	100.73% Sp.gr. 4.073

Average of four samples of ilmenite-nelsonite from Nelson County, Va., Wm. M. Thornton, analyst. (Watson & Taber 39, p. 109.)

The nelsonite appears to be developed in numerous dike-like bodies in a hypersthene-quartz syenite, although the exact contacts of the nelsonite and the syenite were not observed because of the deep residual soil which covers the area. The ore bodies strike N 65° E and may be traced by float in the soil covering. Some of them have

been followed for upwards of a quarter of a mile, and one was observed to be at least 50 feet wide. The country rock is a greenish-gray, coarse-grained to porphyritic syenite which is strongly gneissoid in structure. It is deeply weathered and exposures are very unsatisfactory. Where fresh the rock may be seen to carry both orthoclase and plagioclase feldspars, pyroxene, a little biotite and garnet, and a small amount of quartz. The phenocrysts consist of orthoclase crystals and are sometimes several centimeters in length. Under the microscope the rock is seen to carry apatite, pyrite, ilmenite, and titanite as accessories. The syenite has been strongly metamorphosed and the gneissoid structure is pronounced. Associated with the syenite occurs a coarsely crystalline pegmatite rock composed of bright green epidote, pink feldspar, and clear white quartz. This rock is also much weathered and the feldspar is partly kaolinized. In this section apatite, titanite, biotite, and pyrite occur as accessory minerals. The quartz and feldspar are intergrown and the quartz is often strained. A single diabase dike heavily weathered was observed by Watson along the road near the Hutchins farmhouse.

The igneous and metamorphic series is pre-Cambrian in age, and belongs to the crystalline area of the Blue Ridge Province. Since the actual contact of the nelsonite and the enclosing rock was not observed, it is impossible to determine whether the ore occurs as segregations within the syenite or in dikes of later age. By comparison with the larger and better known deposits of the Amherst-Nelson area, Watson considers the Roanoke County nelsonite to be a magnetic segregation similar to the segregations of titaniferous magnetites in gabbros. (Watson and Taber 39, p. 246-7.)

Description of Deposits

Five occurrences of nelsonite have been described by Watson and Taber from the Vinton area. In each case the ore appears in dike-like form in the area of the hypersthene syenite.

The largest of these occurrences is found on the Bush farm about a mile and one-half east of Vinton. Several pits were opened in 1902 on this farm along a belt of nelsonite which is conspicuous by the presence of much float in the residual soil. The ore occurs just south of the road and in 1926 was being mined from an open cut at the base of a low hill. The float occurs for a distance of 250 yards along a N 60° E direction roughly parallel to the road. The nelsonite is porphyritic and foliated, with phenocrysts of white apatite in a fine-grained, blue-gray ground mass of ilmenite. The two minerals are strongly intergrown, and the apatite contains skeletal crystals of ilmenite inclusions. The phenocrysts are sometimes prismatic with good crystal forms, but are often highly weathered so that the apatite is soft and crumbly. Secondary greenish-brown epidote together with biotite and orthoclase are minor constituents. Upon exposure the rock weathers readily, and the ilmenite alters to brown limonite. The rock is conspicuously heavy and when fresh is very dense and difficult to extract. This prospect is being operated by Mr. Hutchins of Vinton.

A quarter of a mile to the southeast are two or more dikes of nelsonite, one of which was traced by Watson for 400 yards in a N 60° E direction. Where exposed by one of the surface cuts this dike was at least 50 feet in width. The rock is dark gray and fine-grained with considerable apatite, some chlorite, and a little ilmenite. A smaller

dike parallels this to the south.

Across the road from the Bush prospect and parallel to it, occurs a similar dike which is exposed in the steep cliff below the north side of the road. A few openings have been made along this belt and show a width of at least 30 feet for the nelsonite. The ore resembles that from the Bush prospect and contains hornblende, pyroxene, biotite and pyrite in addition to the apatite and ilmenite.

A quarter of a mile to the northeast is another short dike at least 200 yards long and striking N 67° E. Here the ore is exposed by several surface openings and is of the same general character as at the other prospects. The apatite is greatly altered.

A short distance farther north on Mr. Hutchins' farm, much nelsonite float is visible in the residual soil, and some has been gathered up to make stone fences. Watson has noted that this occurrence more nearly resembles a segregation in the syenite than a dike deposit.

The above descriptions have been taken from Bulletin III-A of the Virginia Geological Survey, pages 237-247.

At the present time the ore is sent to the furnace of the Virginia Iron, Coal and Coke Company, where it is used in the manufacture of high-speed steels because of its high titanium content. Mr. Hutchins informed the writer that he was conducting experiments with finely ground ore for use as fertilizers, and that the material in this capacity was proving highly efficacious. The nelsonite is being mined from open pits by steam shovels. A car of ore is shipped every two days. The cost of extracting the ore is relatively small, so that these operations are very profitable. There is no reason why additional operations could not be developed in the Vinton area.

Minor Non-Metallic Resources

Asbestos

The name asbestos is applied to any one of several silicate minerals which are characterized by fibrous structure. The asbestos of commerce is generally derived from one of the fibrous varieties of amphibole. Serpentine or chrysotile asbestos is also used in industry. The most common occurrence of asbestos minerals is in igneous and metamorphic rocks, and in the Roanoke area in the Blue Ridge crystallines.

Asbestos was formerly mined by the American Asbestos Company about 12 miles south of Bedford and 25 miles east of Roanoke. The mines have been closed for over fifteen years. Asbestos of two varieties was mined from vertical dike-like masses that were parallel to the schistosity of the containing metamorphic rocks. The masses were very irregular in occurrence, and the asbestos occurred in fibers up to eighteen inches in length.

A small amount of tremolite asbestos has been mined about two miles east of Rocky Mount in Franklin County. The asbestos occurs in slabs along shear planes in an amphibolite, and is sometimes called slip-fibre. It was mined in depth to over 40 feet, but the mining has been abandoned.

Amphibole asbestos has been reported from Roanoke County, but not in commercial quantities. The writer has observed small masses of asbestos or slip-fibre along planes of shearing in the crystalline rocks of the Blue Ridge, but the occurrences were all very limited. Small masses of mineral fibres occur along bedding-planes and fault-planes

in the limestones of the area. These may be observed in the Salem City quarry. This material attracts the interest of the quarryman, but is of no commercial value.

Merrill[1] reports the following analysis of amphibole asbestos from Roanoke County, the original locality being unknown to the writer.

SiO_2	55.81	
Al_2O_3	1.66	
FeO	6.81	R. L. Packard, analyst
CaO	12.74	
MgO	21.09	
Ignition	1.81	
	99.92	

1. Merrill, G. P. The Non-Metallic Minerals. New York, 1904, page 186.

Barite

Barite (heavy spar, baryta, or barytes) is barium sulphate ($BaSO_4$), and is a heavy, white mineral with glistening cleavage. It is commonly found in granular, earthy, or porous masses, generally intimately associated with the country rock in which it occurs. It is found in the Roanoke area under two widely different conditions: (a) in fractures in metamorphosed crystalline rocks of the Piedmont area; and (b) as replacements in the Valley limestone or in its residual

clays. Deposits of the first type occur about 15 miles to the east of Roanoke County in Bedford County. Deposits of the second type have been prospected along Tinker Creek about two miles north of Roanoke City.

In Bedford County the barite occurs in a figsure in a schistose granite-porphyry, about three miles northwest of Thaxton and 14 miles east-northeast of Bonsacks. The deposit lies at the southwestern base of Taylors Mountain in the Piedmont Crystallines, the locality was prospected on a small scale as early as 1866, and was re-opened along a small cut in 1906. This open cut was about 20 feet deep, and extended for 450 feet along the strike of the fissure. The barite is crystalline, white to blue-gray, and carries small grains of galena and sphalerite. Watson considers the barium to have been derived from the feldspar of the granite-porphyry. (Watson 37, p. 724.) No other occurrence of this type is known near Roanoke County.

Deposits of barite are found in the surface exposures of the Elbrook formation about two miles north-northeast of Roanoke, and have been worked in a small way on Frank Reed's farm along the old Franklin road just east of Tinker Creek. A small prospect was also opened on the west bank of Tinker Creek along the Hollins road near the old tollgate. On the Reed farm open cuts were made several years ago near the large barn and some barite was shipped for the sugar industry. The barite occurs on the surface of the limestone and in its residual clays as irregular nodules and porous replacements with a marked development in pockets. The barite is both dense and cavernous, and is greatly contaminated with limestone and clay. The ore was mined entirely from

shallow open cuts, which had been abandoned in 1926. It seems probable that the barium was derived from the containing Elbrook limestones and was concentrated at the surface as replacements and cavity fillings along zones of fracture. The transporting agent was probably shallow-circulating meteoric waters. Barite of both pure and impure quality has been also reported from North Mountain and from Mills Mountain. A general discussion of the deposits of barite in Virginia may be found in the Transactions of the American Institute of Mining Engineers for 1907, Vol. XXXVIII, pages 710 to 733.

Bentonite

The term bentonite is applied to certain clayey rocks which have been derived from the decomposition of volcanic ash. The material is sometimes used for refining petroleum oils and other fluids by filtration. It is a product of weathering, and differs from ordinary clay in that it contains much water and has low plasticity. Chemical analyses are of little aid in determining whether the material is of commercial value.

A thin seam of bentonite occurs in this area about 80 feet above the base of the Martinsburg shale. The bentonite is about two feet in thickness and has been observed at several places, especially along Catawba Mountain (see page). The writer does not consider this deposit to be of commercial value in consequence of the small amount of available material and its inaccessibility.

Construction Stone and Crushed Rock

Roanoke County contains an abundance of stone which may be used for construction work of all kinds, from rough street work to polished interior decoration.

The syenites and gneisses of the crystalline area are admirably suited for many uses, but have not been developed on any considerable scale. Either of these rocks may be used for road construction, ballast, retaining walls, foundations or work of similar nature. The rocks occur in such abundance in the area east of the Blue Ridge Fault that the selection of areas suitable for quarrying could be largely governed by accessibility. Some of the fresh syenites would take a good polish and could be used for interior work. Granites of good grade are exposed along the road ascending Bent Mountain from Poages Mill to Air Point, and could be used for masonry or heavy construction. A green serpentine rock has been quarried at the Roanoke-Rocky Mount road bridge over Back Creek about seven miles south of Roanoke. This quarry was opened up by Dr. R. B. Hudson, and the rock has been used in Roanoke for sills, steps, and curbs. It dresses easily and is soft when first extracted but becomes hard upon exposure and weathers well.

The mica schists of the crystalline belt are very abundant and are often suitable for street work. They are quarried for this purpose about forty miles south of Roanoke near Rocky Mount, and have been used in Roanoke. Slates of fair quality are quarried in Craig Valley from the Devonian black shales, and similar rock occurs in Masons Cove

and in Catawba Valley.

Abundant quarries have been opened up for crushed stone and for building material in the various limestones of the region. The limestones of the Shady, Watauga, and Elbrook formations have been more extensively used than any of the other limestones. The largest quarries of this kind are in the limestones of the Elbrook formation, and the Blue Ridge quarry near Blue Ridge Springs is the most extensive quarry in the area. Here the Elbrook formation is exposed by a great surface cut which extends for a quarter of a mile at right angles to the strike of the beds. The quarry is connected with the Norfolk and Western Railroad by a short narrow-gauge railway. The rock which is quarried is a blue or gray shaly limestone which is thin bedded and highly jointed. Several small thrust and normal faults may be seen along the quarry faces. The rock has been extracted largely by surface stripping, and has not been quarried to depths.

East of Roanoke along Tinker Creek near the old toll-gate is located the Mundy Brothers quarry which is also in the Elbrook limestone. The rock in this quarry is similar to that in the Blue Ridge quarry, but is less disturbed by folds and faults. (See Plate figure). The stone is carried to Roanoke in trucks. The city of Roanoke maintains a large quarry in the Elbrook limestone in the northwest section of town. The rock from this quarry is used for municipal work. Salem operates a city quarry in the Elbrook about one mile west of Salem near the Lake Spring. The Elbrook limestones have also been used by the Virginian Railroad and by the Norfolk and Western Railroad in the western part of the area. The rock has been extracted from cuts along the tracks and used for ballast and culverts. The Elbrook forma-

tion is extensively distributed throughout this area (see geologic map accompanying this report), and could be used for extraction of crushed rock and lime at any place along its belt of outcrop.

Some of the limestone members of the Watauga shale have proved very satisfactory for crushed stone. The most important of these members is one at or very near the top of the formation. This member is about 50 feet in thickness and is very persistent. The formation is exposed along the Roanoke-Lynchburg highway and strikes very nearly parallel to that highway from Bonsacks into the city of Roanoke. The member parallels Orange Avenue in the western part of Roanoke. At least ten small quarries have been opened along the strike of this limestone. Few of these are being worked at the present time, although the supply of stone has by no means been exhausted. The stone is of equal quality with that of the Elbrook, but does not occur in as great quantities. It is not recommended that large quarrying operations be undertaken in this limestone unless the nearness to the demand for the stone offsets the relatively small quantity of material available. Many other small quarries are in operation in other members of the Watauga shale, but in each case the supply of material is small compared with the reserves of the quarries in the Elbrook formation.

No extensive quarries have been opened in either of the Cambro-Ordovician limestones, and these rocks have not been used for crushed stone except along the railroads where large cuts have been necessary and the material is readily available. These rocks are inferior to the Elbrook limestones for crushed stone. It is possible, however, that some of the Cambro-Ordovician members could be found of a quality

suitable for building stone. The stone used in building the Second Presbyterian Church of Roanoke is local limestone quarried within Roanoke County from the Cambro-Ordovician formation.

The Erwin quartzite, the Clinch and Clinton sandstones, and the Price formation are all of good quality for rough construction work but have been little used. The Clinton sandstones of Catawba Mountain have been worked for glass sand, and the same rock has also been used for curbs, steps, and windowsills. The College Lutheran Church of Salem is constructed of this stone.

Glass Sand

For the manufacture of glass, a relatively pure quartz sand is used which may be derived from either quartzose sands, sandstones, or quartzites. This sand must be free from clay, iron, or any other impurity which will discolor or cloud the glass. Where the impurities are of mineral grains other than quartz they may be screened out, but where they occur within the quartz grains, the sand is unsuitable for glass manufacture. The grains should be uniform in size, and should range between 30 and 120 mesh when free or should be ground to this degree of fineness.

Near Roanoke there are several formations which are sufficiently sandy and siliceous to be considered as possible sources of glass sands. The Unicoi formation of Lower Cambrian age contains many siliceous members, but these are usually too impure to meet the rigid requirements of the glass industry. The Erwin quartzite is likewise very siliceous, and several of its members appear to have the proper purity to be used for this purpose. The outcrop of the formation, however, is very limited and it is doubtful if sufficient quantity of good sand could be obtained for economic use. The Clinch and Clinton sandstones when pure are admirably suited for the glass industry, and furnish deposits of good sand, either as fresh rock or as weathered accumulations. A Clinton sandstone was used for glass manufacture by the Salem Glass Company of Salem. The sandstones of the Price formation are sometimes of the desired quality, but in general are too clayey or carbonaceous for glass manufacture.

In the Catawba Valley about 9 miles northeast of Salem, there

are deposits of fine white sand which were utilized by the Salem Glass Company which was located at Salem. The sand was transported from Catawba to Salem by a short railroad which connects with the Norfolk and Western Railroad at Salem. The sand is derived from one of the purer members of the Clinton formation and was mined from the southern slopes of Catawba Mountain. Analyses of the sands are as follows:

	A.	B.
SiO_2	98.78%	96.99%
Al_2O_3	0.27	0.01
Fe_2O_3	0.41	0.02
MgO		0.07
CaO		0.80
Na_2O		1.40
K_2O		0.20
Water and organic material		0.31
	99.46%	99.80%

A. Sand from Catawba Mountain, 9 miles northeast of Salem. Courtesy of Salem Glass Company Inc., Salem, Virginia. (Watson 38, p. 801.)

B. Do., analyzed by Mr. H. H. Hill of V. P. I. (Watson 35, p. 393.)

The glass plant located at Salem was one of five plants in operation in Virginia in 1921, and was the only one located in the Appalachian Ridge Province. The plant was closed in 1922, and was not in operation in 1927.

Graphite and Talc

Mention should be made of the possible occurrence of graphite and talc in the rocks of Roanoke County. There is no likelihood of either of these two products being of commercial value in this area, but they may be included among the occurrences of economic minerals.

Both of these minerals are occasionally associated with the metamorphic schists of the crystalline area east of the Blue Ridge. Talc is an alteration product, derived from the metamorphism and alteration of highly magnesian rocks often sediments, and in Roanoke County it is an occasional constituent of the schists of the pre-Cambrian series. In this area the mineral occurs in varying quantities as alterations of pyroxenes, tremolite, and other magnesian minerals in micaceous and chloritic schists of various kinds. At no place are the rocks sufficiently talcose to warrant prospecting, nor is the talc sufficiently pure for commercial use. Talcose schists outcrop along the extreme southeastern border of the county, and may be observed in the road cuts along the Falling Creek road west of Stewartsville, and in the cliffs along Back Creek from the Rocky Mount Road bridge to the Roanoke River. They also occur in the extreme southwestern corner of the county along the Bent Mountain road about five miles southwest of Air Point. They have no economic value.

Graphite is sometimes present as finely disseminated grains and flakes in similar schists in the same metamorphic series. It likewise has no economic value in its occurrences in this area. Graphitic and talcose schists with graphitic flakes have been reported near Kings on the Mills land along the Bent Mountain road near Copper Hill in Floyd

County (Boyd 2, p. 261.) This occurrence was not verified by the writer, and no other occurrence was observed.

M a r l

Marl deposits do not occur in this area in quantity of commercial value. A small deposit of marl was formerly worked about one-half mile northwest of Daleville, and is at present owned by Messrs. Ikenberry and Thomas. The marl is about fifteen feet thick, and is irregularly deposited in the floor of an old lake whose area was less than an acre in extent. A small crusher was located here but has been idle since 1920. The marl was used for fertilizer. It contains great numbers of fossil leaves and shells of fresh-water animals. Another small occurrence of marl is found near the Lynchburg or Grubb iron mines near Blue Ridge Springs. Marl has also been found along Catawba Creek on the old McCormick farm about six miles southwest of Catawba Sanatorium.

Millstones or Buhrstones

The tough Ingles conglomerate at the base of the Price formation is occasionally of quality suitable for the manufacture of millstones and buhrstones, and has been quarried for this purpose along Brushy Mountain in Montgomery County. The demand for millstones has greatly

decreased with the advent of steel-roller mills, and this industry has largely been abandoned. Stone of suitable grade for this purpose, however, can be found on North and Brushy Mountains.

O c h e r

Commercial ocher is ordinarily hematite or limonite in pulverized or earthy form, more or less admixed with clayey or argillaceous material. Natural ochers are commonly red, brown or yellow, depending upon the chemical composition and amount of clay present. Ocher is found under widely varied conditions, and may result from several kinds of processes. The most common mode of occurrence is in irregular masses and lumps resulting from the decomposition and alteration of limonite or hematite. In the Roanoke area the ocherous clays are largely associated with the brown iron ores along the Blue Ridge. The main uses of ochers are in the manufacture of paints and pigments.

No deposits of ocher have been worked in the Roanoke area, but a cursory examination of ocherous material at several of the brown iron mines showed the presence of this substance in the region. Ocher was observed at the Lynchburg or Grubb iron mines, Rorer mine and Gale mine, and ocherous clays of fine tecture, brown color and good body were noticed about a mile and one-half south of Salem. Doctor W. S. Sayers of Roanoke showed the writer specimens of ocher from Pulaski, Montgomery and Roanoke Counties which were being tested for commercial use.

Sand and Gravel

Sand and gravel are in great demand in Roanoke for concrete. Sand is being extracted from the bed of Back Creek south of Buck Mountain. It is of good grade and is being dredged from the creek bottom with scoop-buckets. Large floodplain deposits of sand and gravel occur along the Roanoke River, and are being worked by two companies between Roanoke and Salem. The Roanoke Wash Sand Company is the largest operator, and its plant is located two miles east of Roanoke along the river. The sand is pumped from the river bottom through pipes, and loaded into cars on the Virginian Railroad. Another company nearby is chain-dredging the river and loading sand on boats from which the sand is distributed by trucks.

GENERAL SUMMARY OF THE MINERAL RESOURCES OF THE ROANOKE AREA

Under the descriptions of the various mineral products which are found within this area there have been given short statements of the present and future possibilities for commercial development. The following paragraphs contain suggestions as to general development of groups of these products, and a statement of the known mineral reserves of the area as a whole.

Over a score of natural economic products have been discovered in the rocks of this region. Some of these have been mined or prospected and thus proven of commercial value. Many of them, however, have failed to show ore either in sufficient quantity for profitable extraction or of a suitable grade for present use. The materials described fall into four classes, viz.:

Class A. Products of known economic value at the present time, and which are now being utilized

Class B. Products which are of economic value and can be worked under favorable conditions

Class C. Products which may be of economic value under future conditions

Class D. Products for whose economic value there is no known supporting geological data

Products of Class A.

The materials of this class are nelsonite, clays and shales, construction and crushed stone, and sand and gravel. Each of these products is being extracted from the rocks of the Roanoke area at the present time under conditions which presumably provide for a profitable re-

turn. The writer believes that larger operations will be similarly successful, provided that the supply of materials and the demand for them are maintained. It would appear that the resources of clay, nelsonite and crushed stone, sand and gravel are of sufficient size and quality to warrant further investigation. Haphazard development, however, should not be undertaken, and further operations should be attempted only with a thorough understanding of the geologic relations of the deposits and adequate knowledge of the limitations which may later be imposed by lack of demand, failure of supply, or exhausting of ore of good quality. The writer is prepared to recommend additional development of the deposits of clay for brick manufacture, and of the deposits of nelsonite for titanium and for phosphate. Demands for crushed stone, sand and gravel can easily be met by additional development of the abundant supply of these materials.

Products of Class B.

The materials of this class include lime and cement, glass sand, and ocher. None of these products are being mined at the present time, although they occur in deposits which are of undoubted economic value. It is the suggestion of the writer that commercial development of these deposits be undertaken, since the geologic conditions of their occurrence are such as to warrant an adequate supply of suitable materials. It is recommended that an attempt be made to develop the Mosheim limestone for cement purposes particularly in the vicinity of Catawba P. O., and possibly near Keslers Mill. These deposits lie near the Salem-Catawba Railroad, and the product could be easily distributed or brought to Roanoke. The deposit of glass sand on Catawba Mountain although

once worked still has abundant reserves of good sand. Many of the ocherous clays of the area are entirely suitable for the manufacture of paints or pgiments and should be developed. For the materials of Class B there are supporting geologic evidences of favorable conditions of occurrence.

Products of Class C.

The materials of this class include iron and manganese, coal, barite, marl, arsenic and millstones. None of these products is now being mined, nor is it probable that profitable mining could be undertaken at the present time in these deposits. The future probabilities of the iron and manganese reserves of this area depend entirely upon outside factors which have already been mentioned in the larger discussion of these deposits. There is a fair supply of ore of iron in the area, but of such grade that profitable extraction is impossible at the present time. It is not possible to predict far enough into the future to prophecy the ultimate value of these ores. They offer, however, the best possibilities for future mining operations in the area, and may be considered the most valuable mineral reserves of the region.

Coal, barite, marl and arsenic are present in the area, but in deposits of unknown amount. The chances are heavily against the future value of such deposits although small-scale operations may be practicable under exceptional conditions. The Price sandstone contains lenses entirely suitable for the manufacture of millstones if the demand for these becomes greater.

Products of Class D.

These products are not known to be of economic value, and group themselves into two minor divisions as follows:

a. Materials whose occurrence in deposits of economic value is highly improbable --

1. Oil
2. Gas
3. Silver
4. Gold

b. Materials whose occurrence in deposits of economic value is not expectable --

1. Copper
2. Lead and zinc
3. Nickel and cobalt
4. Graphite and talc
5. Asbestos
6. Bentonite

The writer is prepared to discourage any attempts toward the search for or the development of oil and gas, and gold and silver deposits in this area. The geologic conditions of the region are such as to preclude any accumulation of these materials in quantity deserving commercial attention.

The products listed in Division b of Class D are not known to occur in important quantities. It is impossible to predict that none of these materials will ever be of economic value in this area. It is, however, possible and necessary to emphasize that so far as is now known the geologic relations of the observed deposits are entirely against the chances of their commercial development. It may safely be asserted that prospecting for the above materials will meet with discouraging results. It might seem that the discussion of these substances should not have been included in a report on the mineral

resources of the area, since none of them shows promise of profitable development. The writer is under the impression that information of a negative nature is often as valuable as positive information, and that it is equally as important to discourage profitless work as to encourage profitable work.

It is a reasonable deduction that future mining operations in this area will be based largely upon the mineral resources which have been described in this chapter, although it is entirely possible that other resources will be found, or that new uses will create demands for materials which have little value at the present time. Indeed, it may be hoped that opportunity for new development will be provided by improvements in methods of mineral preparation, through extension of transportation facilities, and by the normal increase of market demands, so that additional deposits may be brought into the field of practical operation.

SELECTED REFERENCES ON THE MINERAL RESOURCES OF THE ROANOKE AREA.

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

2. Boyd, C.R., Resources of southwest Virginia, New York, 1881.

3. Campbell, J.L., Geology and mineral resources of the James River Valley, Virginia, U.S.A., New York, 1882.

4. Campbell, M.R. et al, The Valley coal fields of Virginia, Virginia Geol. Survey, Bull 25, 1925.

5. Catlett, Charles, Iron ores of the Potsdam formation in the Valley of Virginia, Am. Inst. Min. Eng., Trans., 29, 1900, page 308.

6. -------, -------, Cement resources of the Valley of Virginia, U.S. Geol. Survey Bull. 225, 1903, pp. 457-462.

7. Currey, R.O., The copper and iron regions of the Floyd Carroll Grayson Plateau of the Blue Ridge in Virginia, The Virginias, Vol. 1, 1880, pp. 62-4, 69-71, 74-77, 80-91.

8. Eckel, E.C., The Oriskany and Clinton iron ores of Virginia, U.S. Geol. Survey Bull. 285, 1906, p.183.

9. ---------, Portland cement materials and industry in the United Stated, U.S. Geol. Survey Bull. 522, 1913.

10. Fontaine, W.M., Notes on the geology and mineral resources of the Floyd , Virginia Plateau, The Virginias, Vol. IV, pp. 167, 178-80, 185-92.

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

12. ----------, Manganese deposits of the United States, U.S. Geol. Survey Bull. 380, 1909, pp. 255-81.

13. ----------, Manganese deposits of the United States, U.S. Geol. Survey Bull. 427, 1 910.

14. Hess, F.L., Nickel in 1915, Mineral Resources of the United States for 1915, part I, 1915, pp. 756-7.

15. Holden, R.J., The Iron ores of Virginia, Mineral Resources of Virginia (by T.L.Watson), Lynchburg Va., 1907, pp. 402-491.

16. Hotchkiss, Jed., Sundry articles, editorials, and other items, The Virginias, Vol I, 1880.

17. ----------, do., The Virginias, Vol II, 1881.

18. ----------, do., The Virginias, Vol III, 1882.

19. Hotchkiss, Jed., Sundry articles, editorials, and other items, The Virginias, Vol. IV, 1883.

20. ----------, do., The Virginias, Vol V, 1884.

21. ----------, do., The Virginias, Vol VI, 1885.

22. Kemp, J.F., The iron resources of the world, Internat. Geol. Cong. XI, Vol II, Stockholm, 1910, page 764.

23. Kinzer, C.W., A chemical interpretation of the limestones of the Roanoke and Catawba valleys, unpublished thesis, Roanoke College, Salem Virginia, 1924.

24. McCreath, A.S., The iron ores of the Valley of Virginia, The Virginias, Vol IV, 1883, pp. 94-6.

25. ----------, The mineral wealth of Virginia, Harrisburg 1883.

26. Pechin, E.C., The iron development and ore resources of Virginia, Am. Inst. Min. Eng. Trans., Vol 19, 1891, pp. 1016-1035.

27. Ries, Heinrich, Clays of the United States east of the Mississippi River, U.S. Geol. Survey Prof. Paper, 11, 1903.

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

29. Rogers, W.B., Geology of the Virginias, edited by Jed Hotchkiss New York 1884, 1840-42.

30. Stose, G.W. et al, Manganese deposits of the west foot of the Blue Ridge, Virginia, Virginia Geol. Survey, Bull. 17, 1919.

31. --------, and Miser H.D., Manganese deposits of western Virginia, Virginia Geol. Survey Bull. 23, 1922.

32. --------, and Schrader, F.C., Manganese deposits of east Tennessee, U.S. Geol. Survey Bull 737, 1923.

33. Topham, A.J., The natural economic resources of Roanoke County, Virginia, unpublished thesis, Roanoke College, Salem, Virginia, 1923.

34. Watson, T.L., Lead and zinc deposits of Virginia, Virginia Geological Survey, Boll. I, 1905.

35. ----------, Mineral resources of Virginia, Lynchburg Virginia, 1907.

36. ----------, The occurrence of nickel in Virginia, Am. Inst. Min. Eng. Trans., 38, 1908, pp. 683-697.

37. ----------, Geology of the Virginia barite deposits, Am. Inst. Min. Eng. Trans., Vol 38, 1908, pp. 710-83.

38. Watson, T.L., Glass-sand resources of Virginia, Am. Ceramic Soc. Jour., Vol 2, No. 10, 1919, pp. 794-803.

39. ----------, and Taber, S., Geology of the titanium and apatite deposits of Virginia, Virginia Geol. Survey Bull. 3R, 1913, pp. 235-247.

40. Weeks, J.D., Mineral resources of the United States, 1885, pp. 303-356.

41. Weld, C.M., The Oriskany iron ores of Virginia, Econ. Geol., Vol. X, 1915, pp. 399-422.

42. Anonymous, Mining notes, Eng. and Min. Journ, Vol. XLI, 1886.

43. -------, do., Eng. and Min. Journ, Vol.XLII, 1886, pp.156

44. -------, do., Eng. and Min. Journ, Vol.XLVI, 1888, p. 159.

45. -------, do., Eng. and Min. Journ, Vol.LII, 1891, p. 463.