VETERANS ADMINISTRATION
810 Vermont Avenue
Washington, D. C. 20420

SEP 17 1980

085

Dr. James L. Calver
State Geologist & Commissioner
Department of Conservation & Economic
Development
Natural Resources Building
P.O. Box 3667
Charlottesville, VA 22903

Dear Dr. Calver:

The Veterans Administration has undertaken an extensive program to evaluate the seismic resistance of its existing hospitals. A major emphasis is a realistic evaluation of the seismic risk at each site. The site evaluation studies were performed by leading consultants and reviewed by the Geological Survey.

Enclosed for your information is a copy of our new publication, "Earthquake Resistant Design Requirements for VA Hospital Facilities", and copies of the site evaluation studies for the VA Hospital, Salem, Virginia.

We hope this information will be useful in your work.

Sincerely,

V. P. MILLER
Assistant Administrator
for Construction

Enclosures

FINAL REPORT
SITE EVALUATION SURVEY
VETERANS ADMINISTRATION HOSPITAL
SALEM, VIRGINIA

VETERANS ADMINISTRATION
WASHINGTON, D.C.

PROJECT NO. 72-428-6

NOVEMBER 1974

E. D' Appolonia Consulting Engineers, Inc.

PITTSBURGH • CHESTERTON • WILMINGTON • DENVER • BRUSSEL

TABLE OF CONTENTS

	Page
LIST OF TABLES	i
LIST OF FIGURES	i
1.0 INTRODUCTION	1
2.0 SITE GEOLOGY	2
2.1 REGIONAL GEOLOGY AND TECTONICS	2
2.2 LOCAL GEOLOGY	6
3.0 SEISMICITY	8
3.1 LOCAL TECTONIC FEATURES	8
3.2 SEISMIC HISTORY OF THE SALEM AREA	9
3.3 MAXIMUM EXPECTED EARTHQUAKE INTENSITY	12
3.4 FREQUENCY OF OCCURRENCE ANALYSIS	14
3.5 MAXIMUM EXPECTED GROUND ACCELERATION	16
4.0 GENERAL SITE CONDITIONS	17
4.1 DESCRIPTION OF SITE	17
4.2 SITE HAZARDS	18
4.3 EXPECTED BEHAVIOR OF FOUNDATIONS	19
5.0 CONCLUSIONS AND RECOMMENDATIONS	20
LIST OF REFERENCES	
TABLES	
FIGURES	
APPENDIX A	

LIST OF TABLES

TABLE NO.	DESCRIPTION
I	List of Earthquakes with Epicenters Within 200 Miles of Site (Modified Mercalli ≥ IV)

LIST OF FIGURES

FIGURE NO.	DRAWING NO.	DESCRIPTION
1	72-428-6-B5	Regional Geologic Map
2	72-428-6-B6	Structural Geologic Map
3	72-428-6-B3	Geologic Structure Map
4	72-428-6-B1	Local Geologic Map
5	72-428-6-B2	Geologic Sections, A-A and B-B
6	72-428-6-A1	General Geologic Cross-Section Across Roanoke-Salem District
7	72-428-6-A3	Generalized Table of Geologic Formations for Roanoke-Salem District
8	72-428-6-B4	Location of Epicenters
9	72-428-6-A4	Seismic Probability Map of the United States
10	72-428-6-A5	Seismic Risk Map for the United States
11	72-428-6-A6	Isoseismal Map, Charleston Earthquake of August 31, 1886
12	72-428-6-A7	Isoseismal Map, Giles County, Virginia, Earthquake May 31, 1897
13	72-428-6-A8	Modified Mercalli Intensity Scale
14	72-428-6-A9	Attenuation Curves, Eastern United States
15	72-428-6-A10	Earthquake Intensity - Acceleration Relationship
16	72-428-6-B7	General Site Plan Showing Location of Photographs
17		Photographs
18		Photographs

FINAL REPORT
SITE EVALUATION SURVEY
VETERANS ADMINISTRATION HOSPITAL
SALEM, VIRGINIA

1.0 INTRODUCTION

In accordance with our proposal of May 13, 1972, and prior discussions with the Veterans Administration (VA), a site evaluation survey has been conducted for the Veterans Administration Hospital located on a 266-acre site overlooking the city of Salem, Virginia, approximately one mile west of the city of Roanoke, in the Roanoke Valley. Particular emphasis is placed on geological and seismological characteristics of the site with the main objective being an evaluation of the maximum earthquake which might reasonably be expected during the planned life of the facility and its frequency of occurrence. This earthquake is hereafter referred to as the "Maximum Expected Earthquake" or abbreviated as MEE.

The general procedures utilized in this evaluation survey are consistent with our proposal and generally follow Appendix A, 10 CFR Part 100 entitled, "Seismic and Geologic Siting Criteria for Nuclear Power Plants." Practically all of the data and information used in this report are based on prior reports by E. D'Appolonia Consulting Engineers, Inc. (EDCE) and others in the area, work of State and Federal geologic surveys and other documents in the literature.[1-10] No new borings, laboratory tests, or in situ velocity measurements have been conducted as these are not part of the scope of work requested by the Veterans Administration. The main exception to Appendix A, 10 CFR Part 100 is that the terms Operating Basis Earthquake (OBE) and Safe Shutdown Earthquake (SSE) are not used or considered in this work as suggested by the definition of the Maximum Expected Earthquake. If one wished to compare

earthquakes predicted for the design of a nuclear power plant with that postulated herein, it is expected that the MEE would have a peak ground acceleration equal to or slightly less than an Operating Basis Earthquake (OBE) at the same site.

The following sections of this report describe the regional and local geology, the site seismicity, the general site conditions and the expected behavior of the foundations. Finally, conclusions and recommendations resulting from the survey are presented in the last section.

2.0 SITE GEOLOGY

2.1 Regional Geology and Tectonics

Salem is located in southwestern Virginia in the Roanoke Valley, one of several northeast-trending valleys alternating with highlands in the Valley and Ridge Province of the Southern Appalachians. This topography has developed on Cambrian and Ordovician sedimentary rocks which were thrust faulted and folded in the late Paleozoic Allegheny orogeny. Relief of several hundred feet is common between ridge summits and valley bottoms in the area.

The region of interest includes parts of North Carolina, Virginia and West Virginia and can be conveniently divided geologically into the three zones listed below:

Coastal Plain

Crystalline-Metamorphic Zone

Overthrust Zone.

The two western zones, the Crystalline-Metamorphic Zone and the Overthrust Zone, are of primary importance to this investigation as shown

on Fig 1. In this area, the Crystalline-Metamorphic Zone can be divided into several belts based on the degree of metamorphism as follows:

a. The Eastern Slate Belt
b. The Carolina Slate Belt
c. The Charlotte Belt
d. Inner Piedmont Belt and Danville Basin (Triassic)
e. Brevard Belt
f. Blue Ridge Belt.

The rocks in these zones have been subjected to compression from the northwest-southeast direction, producing a series of thrust faults and folds whose axes are aligned parallel to one another in a northeast-southwest direction, i.e. normal to the direction of compression. Numerous thrust faults have been mapped in the Overthrust Zone as seen on Fig 2. These faults and most of the known faults in the Crystalline-Metamorphic Zone are associated with the formation of the Appalachian Mountains in Late Paleozoic time.

The exact age of the deformation is not definitely known, since the youngest Ordovician rocks in the area are affected. Elsewhere, the deformation affects Mississippian rocks suggesting a post-Mississippian age. Deformation occurred in episodes, probably all of which occurred during the Late Paleozoic Era, but may have occurred as late as Triassic time.

During the Triassic Period, non-marine sediments were deposited above the metamorphic rocks of the Crystalline-Metamorphic Zone in grabens such as the Danville Basin, approximately 55 miles southeast of the site. These Triassic basins may be the result of release of compressional forces which formed the Appalachians or tension associated with the opening of the Proto Atlantic Ocean. Later the Triassic deposits and the older underlying metamorphic rocks were intruded by a system of northwest-trending

diabase dikes and were cut by northwest-trending normal faults in late Triassic time. Some of the older faults within the Crystalline-Metamorphic Zone may have been reactivated at this time.

Since Cretaceous time, marine sediments of the Coastal Plain have been deposited over the Paleozoic metamorphic basement. These sediments thicken toward the southeast and effectively mask any ancient faults in the buried basement.

The names, distances and directions from the site and the probable age of the faults shown on Figs 2 and 3 are listed below:

Name	Distance-Direction From Site	Probable Age
Brevard Fault	30 Miles SE	Late Paleozoic
Max Meadows Fault	∿1 Mile N	Late Paleozoic
Salem Fault	∿2 Miles N	Late Paleozoic
Gold Hill Fault	95 Miles S	Late Paleozoic
Miller Fault	10 Miles NW	Late Paleozoic
Saltville Fault*	45 Miles W	Late Paleozoic
Hunter Valley Fault	150 Miles W	Late Paleozoic
Pine Mountain Fault	60 Miles W	Late Paleozoic
Holston Mountain Fault and Branches**	125 Miles SW	Late Paleozoic
Fries Fault**	2 Miles SW	Late Paleozoic
Blue Ridge Fault**	2 Miles SE	Late Paleozoic
Pulaski Fault* and Branches	9 Miles NW	Late Paleozoic

Name	Distance-Direction From Site	Probable Age
St. Clair Fault	30 Miles W	Late Paleozoic
Kentucky River Fault Zone	150 Miles W	Late Paleozoic
Rough Creek Fault Zone	230 Miles NW	Late Paleozoic
Richmond Basin	125 Miles E	Triassic
Triassic, Deep River Basin, N. C. and S. C.	110 Miles SE	Triassic
Triassic, Danville Basin, N. C.	50 Miles SE	Triassic
Unnamed Triassic Basins of Eastern Virginia	75 Miles E	Triassic
Culpepper Triassic Basins	135 Miles NE	Triassic

*Note: Several additional unnamed branches of these faults exist closer to the site.

**Note: The Holston Mountain Fault, Blue Ridge Fault and Fries Fault appear interrelated as suggested on Figs 2 and 3, but actually represent different thrust sheets.

The first 15 faults and their branches are associated with the formation of the Appalachian Mountains in Late Paleozoic time. The Blue Ridge and Fries Faults apparently form a fault complex with the Holston Mountain Fault and its branches to the south. In the immediate vicinity of the site, the thrust faults are closely spaced and may be linked by connecting faults such as the one between the Salem Fault and the Pulaski Fault. Continuity of horizons in the thick residual soils that blanket the region suggests that there has been no displacement along any of these faults during the Tertiary or Quaternary Periods.

All major faults of the region, such as the Blue Ridge Fault 2 miles southeast of the site, are considered inactive. Therefore, there is no indication of any structural hazard to foundations at the site from a displacement point of view.

2.2 Local Geology

The Salem VA Hospital is located in the Roanoke Valley in southwest Virginia, approximately one mile west of Roanoke between the Allegheny and the Blue Ridge Mountains. The underlying rocks in this area are the Cambrian Rome ("Watauga") and Elbrook Formations. The Rome Formation consists of shale with thin interbedded limestone and calcareous shale. The Elbrook Formation is composed of limestone and dolomite with interbedded calcareous shales as shown on Figs 5, 6 and 7. The Rome Formation, which underlies the site is believed to be at least 900 feet thick. The Elbrook Formation, which outcrops along the bank of the Roanoke River and underlies much of the low topography of the Roanoke Valley northeast of the site, weathers quickly and forms a thin red residual clay soil.

Subsurface soils information furnished by the VA to EDCE consists of boring logs and load test data which were used for the design of the building foundations. The original data secured in 1933 were used for Building Nos. 1, 2, 3, 4, 5, 6, 7, 13, 14, 15, 16, 44, 47, 50, 51, 52, 53, and 78. These borings were drilled 5 to 30 feet deep and indicate that the subsurface material is approximately one foot of topsoil

underlain by hard red and yellow clay with boulders and shale. Below El 1055 near Building No. 2, soft yellow and possibly moist clay was encountered but no water table was denoted in the logs. Test pits dug for Buildings Nos. 8, 9, 10, 11 and 12 during 1935, 1937 and 1939 indicate the subsurface materials in the area of the buildings are a clay loam topsoil underlain by hard red and yellow clay. The test pits were relatively shallow to 12 feet deep, with the deeper pits encountering gravel and/or rock. One auger boring for Building No. 12 encountered an anomalous 4-inch layer of soapstone. Again, no water table was denoted in the log.

Borings drilled in 1943 and 1944 in the vicinity of Buildings Nos. 74, 75, 76 and 77 indicate the subsoils consist of a thin layer of topsoil underlain by red and yellow clay which becomes harder with increasing depth and has traces of sandstone and shale. Apparently, water was not encountered in these 10- to 15-foot deep borings.

Borings drilled in 1957 for Building No. 97, which is located on an old floodplain of the Roanoke River, indicate the subsurface material to be alluvium. The 9-to 13-foot deep borings encountered "highly compacted yellow brown to reddish brown silty clay containing small amounts of coarse sand and pebbles." Twelve-foot deep test pits dug in 1956 for the water tank indicate approximately one foot of topsoil underlain by very hard red clay with sand and one-inch to three-foot diameter rocks. Borings drilled during 1957 in the area of the grandstand indicate soils similar to those described above, with groundwater encountered between El 1030 and El 1040.

3.0 SEISMICITY

3.1 Local Tectonic Features

As discussed in more detail above and as shown on Figs 3 and 4, a series of northeast-trending, long, linear thrust faults of considerable horizontal displacement exists in the Salem area and to the northwest. Locally the area can be divided into four blocks which are separated by the traces of three major thrust faults; the Blue Ridge, Max Meadows, and the Salem Faults. The Max Meadows Fault and the Salem Fault occur within a few miles of the site and are considered inactive. These faults are generally interpreted as low angle thrust faults; however, the Salem Fault has been interpreted as a high angle reverse fault.

In the general absence of subsurface information, interpretations of structure in the Valley and Ridge Province of the Appalachians differ. Rodgers[1] and Gwinn[2] support the hypothesis of "thin-skinned" tectonics; i.e., the cover of Paleozoic sedimentary rocks, the "thin skin" of the earth's crust, was deformed by Paleozoic compressional stress, but the underlying basement rocks were unaffected. Sparse well data from Pennsylvania support the hypothesis of bedding plane thrusts which break across bedding and extend upward toward the surface. Often, the leading edge of these thrust slices is folded. The major décollement is in the Lower Cambrian incompetent units just above basement, but bedding plane thrust faults are similarly located along incompetent units in the sequence of Paleozoic sedimentary rocks.

On the other hand, the presumed inability of the Paleozoic rocks to transmit forces sufficiently large to produce the large, observed

folds in the Valley and Ridge Province led Cooper[3] to hypothesize that deformation in the Paleozoic rocks is continuous with and a reflection of basement structures. Hubbert and Rubey[4] have shown that high pressure of interstitial fluids significantly reduces the magnitude of shear stress required to produce faulting. Thrusting and folding of Paleozoic rocks can occur under conditions of relatively low shear stress, especially where units of contrasting permeability are superposed. Thus, the mechanical objections to the "thin-skinned" hypothesis have been largely eliminated. Evidence can be cited in support of both hypotheses and it is probable that deformation of both types occurs in the Appalachians. Much more detailed subsurface information will be required before any clear answers to this problem can be found.

3.2 Seismic History of the Salem Area

The site lies in a region which is characterized by a moderate amount of earthquake activity and which can be divided into the several zones described previously; namely, the Coastal Plain, the Crystalline-Metamorphic Zone and the Overthrust Zone. The site is located in the Overthrust Zone just west of the Blue Ridge Belt. The Cincinnati Arch which lies west of the Overthrust Zone is relatively free of faults and epicenters, whereas the Overthrust Zone consists of a complex system of numerous thrust faults and includes many epicenters. As seen on Fig 8, the seismic activity of the Overthrust and Crystalline-Metamorphic Zones can be characterized by several seemingly distinct earthquake clusters--a western Virginia-West Virginia cluster, a cluster near Asheville and the

Brevard Fault, the Triassic Basin cluster 75 miles east of the site and the Richmond Triassic Basin cluster. No surficial displacements have been noted along any of these faults. With the exception of a few scattered earthquakes in the Carolinas and Georgia, the Coastal Plain has experienced only a few earthquakes outside the Charleston area.

According to Figs 9 and 10, the United States Coast and Geodetic Survey placed the site in a Zone 1 (minor damage) area and the Environmental Science Services Administration (ESSA) places the site in a Zone 2 (moderate damage) area. The nearest Zone 3 (major damage) area is near Charleston, South Carolina, which is located 320 miles from the site. It is noted that the USC&GS map was originally prepared in 1948, revised in 1949 and was made part of the 1952 edition of the Uniform Building Code. In that same year, it was withdrawn by the USC&GS as "subject to misinterpretation and too general to satisfy the requirements of many users." Therefore, it is presented here for information only and should not be accepted as an independant source of reliable data in a way comparable to that which the ESSA map might be treated. Figure 11, which is an isoseismal map of the famous August 31, 1886, Charleston, South Carolina, earthquake (Intensity MM IX-X), suggests that the Intensity of the Charleston earthquake was reduced to about V at the site. Figure 12 is an isoseismal map of the Giles County, Virginia, earthquake (Intensity MM VII) of May 31, 1897; the highest intensity earthquake to occur in Virginia. The isoseismal map indicates the Intensity at the site was MM VII. For reference purposes, the Modified Mercalli Scale is presented on Fig 13.

Table I lists the earthquakes having a Modified Mercalli (MM) Intensity IV or greater which have occurred within about 200 miles of the site. The epicenters of earthquakes for this area are located on Fig 8 along with the faults shown on Fig 2. Detailed descriptions of earthquakes with epicenters close to the site are given in Appendix A.

The worst earthquakes which have affected the site including the New Madrid and Charleston events have been considered. The estimated site Intensity has been determined using the attenuation curves provided on Fig 14 and isoseismal maps where available. The results are summarized in the following table.

Date	Epicentral Location	Epicentral Intensity	Distance From Site (Miles)	Estimated Site Intensity
1811-1812	3 earthquakes New Madrid, Mo. N36.6 W89.5	XII	550	VI
31 Aug 1886	Charleston, South Carolina N32.8 W79.8	IX-X	321	V
31 May 1897	Giles County, Virginia N37.3 W80.7	VII*	37	VII
22 Dec 1875	Arvonia, Virginia N37.6 W78.5	VII	83	V
23 Apr 1959	Virginia-West Virginia Border N37.5 W80.5	VI	33	V
25 Dec 1924	Roanoke, Virginia N37.3 W79.9	V	Close to Site	V

* See Reference 28.

Based on these considerations and the above tabulations, it is apparent that the worst Intensity felt at the site is Modified Mercalli VII, which is associated with the 1897 Giles County, Virginia, earthquake.

3.3 Maximum Expected Earthquake Intensity

As seen on Fig 8, many of the earthquakes occurring in the Overthrust Zone may possibly be associated with faults. Therefore, considering the location and extent of the faults and the proximity of the western Virginia-West Virginia cluster to the site, it is reasonable to expect an Intensity VII event might occur anywhere along the Saltville Fault or an Intensity VII event might occur along the other major faults in the area, such as the Pulaski or the Blue Ridge Faults. On the basis of this postulation, the maximum expected site Intensity is VII as caused by a VII on a nearby fault or directly at the site.

The relationship of seismicity to tectonics is poorly understood in eastern North America. Sbar and Sykes[5] cite evidence to show that the greatest principal stress in eastern North America is a nearly-horizontal compressive stress which is directed from the east-northeast. The orientation of most mapped faults in the northeast is incompatible with this stress system, suggesting that mapped faults are inactive and relate to an earlier stress system. However, in the Appalachians, no simple model can be fitted to the existing stress distribution. Uplift, remnant stresses and effects of sinking of oceanic crust on the continental margins are suspected of interacting with the extant stress system to produce the observed seismicity in the Appalachian region. Fox[6] noted that

seismicity in the Southern Appalachians correlates with areas where faults and intrusive rocks are present. Oliver and Isacks[7], and Sbar and Sykes[5] suspect that seismicity in eastern North America may be localized along unhealed fault zones. Woollard[8] could not ascertain any consistent relationship of seismicity and geologic or tectonic features, noting specifically that in the Appalachians the trend of seismicity is oblique rather than parallel to geologic strike. Sbar, et al,[9] from fault plane solutions of minor earthquakes in the southern Adirondack Mountains of New York, found that seismicity in that area was unrelated to any known geologic structures. Thus, in the absence of observable displacement, seismicity, though conceivably associated with mapped faults, cannot be definitely and unequivocably assigned to mapped faults in this area.

The cluster of epicenters near Asheville and along the Brevard Fault actually consists of an Intensity V event on February 10, 1874, and five aftershocks in the next two months, plus two Intensity VI events in 1926 and 1957 and an Intensity IV event in 1964. Even if one were to postulate an earthquake with Intensity VI-VII for this cluster, the site Intensity at Salem would be considerably less than the postulated event discussed above.

The events associated with the Virginia Triassic Basin have not exceeded Intensity VI and, therefore, site Intensity caused by future events in these Basins or the Richmond Basin further to the east are expected to be less than the site Intensity associated with the MEE postulated above. Similarly, future events at New Madrid or Charleston are expected to cause lower site Intensities than the postulated MEE site Intensity.

3.4 Frequency of Occurrence Analysis

In accordance with VA requests, the next step in the site evaluation is to assess the frequency of occurrence of the worst intensity felt at the site and the frequency of occurrence of the Maximum Expected Earthquake Intensity VII predicted above. It is generally believed by the profession that there is inadequate documented seismic history to predict frequency of occurrence or recurrence intervals, in the United States, as well as in other parts of the world where data exist for a longer period of time. Nevertheless, the Environmental Science Services Administration (ESSA) has provided some guidelines for these types of estimates in a publication by S. T. Algermissen,[10] which EDCE has adopted for this purpose. With some consideration given to focal depth, population and geographic location, Algermissen makes use of the common recurrence relationship of:

$$\text{Log } N = a + bI$$

where N is the number of earthquakes per year of Intensity I and "a" and "b" are statistically evaluated constants associated with each geographic area. Using the statistically evaluated constants and dividing by the planar area of each of the geographic areas, ESSA provides the following predictions which are compared with the actual occurrences within 200 miles of the site over a 197-year period, as listed in Table I. Also, shown in the last column are estimates of the same figures if only the last 71 years of data are considered.

NUMBER OF EARTHQUAKES OF GIVEN INTENSITY
PER 100 YEARS PER 100,000 KM^2

Intensity	ESSA Prediction	Actual (197 Years of Data)	Actual (Last 71 Years of Data)
V-VI or VI	3.39	3.50	6.60
VI-VII or VII	0.88	0.48	0.44
VII-VIII or VIII	0.23	0.16	0.16
VIII-IX or IX	0.062	0.098†	0.098†
IX-X or X	0.016	0.059*	0.059*
X-XI or XI	0.004	0.047†	0.047†
XI-XII or XII	0.001	0.038**	0.038**

*Derived from Charleston, South Carolina, Earthquake of 1886
†Interpolated from actual data
**Derived from New Madrid Earthquakes of 1811-1812

These data suggest that the ESSA predictions are in general agreement with the actual recurrence intervals, the actual data being more conservative than the ESSA predictions for the earthquakes of higher intensity.

Using the actual data listed above and considering the earthquakes which probably caused an Intensity VII at the site, EDCE estimates that the frequency of occurrence of such an event is once every 69 years, if 197 years of data are used, and once every 69 years if the last 71 years of data are used.

With respect to the frequency of occurrence for the Maximum Expected Earthquake (MEE) of Intensity VII, the results are identical to those above and indicate the MEE of Intensity VII should occur once in 69 years if either 197 years of data or the last 71 years of data are used.

It should be emphasized that our figures are based on interpolated values from actual data and that the periods of recurrence are highly sensitive to the earthquakes of high intensity. This illustrates the difficulties that can be encountered with an actual data frequency-of-occurrence analysis.

3.5 Maximum Expected Ground Acceleration

Given the postulated site Intensity VII, it remains to predict the level of ground acceleration associated with the MEE. There are numerous correlations relating intensity to peak horizontal ground acceleration, but that adopted by EDCE for the Salem area is shown on Fig 15. From this figure, it is seen that a site Intensity VII would normally have a peak horizontal ground acceleration of 0.10 g. In our opinion, due to the proximity of the site to reported epicenters, the possible errors in locations of epicenters and the possible inaccuracy in historical felt reports, we recommend adopting a peak horizontal ground acceleration of 0.12 g.

The peak vertical acceleration is usually taken as 1/2 to 2/3 of the peak horizontal value. EDCE recommends that 0.08 g be used as the peak vertical acceleration. These levels are considered applicable

to facilities founded on rock or in shallow soil deposits, but not for those founded in fill or alluvial soils. It is also noted that a response spectra for the site should consider high frequency wave content due to the proximity of possible epicenters.

4.0 GENERAL SITE CONDITIONS

4.1 Description of Site

The hospital complex consists of two quadrangles of buildings separated by the administrative facilities and the dining facility as shown on Fig 16. Buildings Nos. 1 through 16 and 120 were constructed in 1932 and include the west quadrangle and the administrative buildings. Buildings Nos. 74 through 77 and 80 were constructed in 1944 and include the east quadrangle. With the exception of Building No. 2, which has four stories, most of the quadrangle buildings as shown in Figs 17 and 18 are "H" shaped, of masonry construction and founded on spread footings.

Based on information gathered at the site from VA officials, on June 17, 1972, we understand that very few maintenance problems related to the foundations and structures have been encountered. This was partially confirmed by inspection of crawl spaces beneath several of the buildings. Wall plaster was cracked and one-fourth inch cracks were observed around windows in Building No. 42. The cracking has been associated with deformation of a structural beam, which has evidently been overloaded and subjected to equipment vibrations.

The hospital is located on a terrace approximately 100 feet above the Roanoke River. As discussed above, a subsurface investigation conducted by others indicates that the subsoils are predominantly compact, red clay with shale and sandstone fragments. Thin, patchy alluvial deposits of hard red silty clay and gravel appear on portions of the site and were probably deposited at the time the Roanoke River flowed at higher elevations. Stability under static conditions does not appear to be a problem with the slopes on the south and the east.

According to hospital personnel, 80,000 gallons of water are pumped once a week from the swimming pool to a large 40-foot depression in the northeast corner of the site. The water immediately disappears into the substrata, suggesting cavernous conditions. Considering the nature of the Rome and Elbrook Formations, this is a distinct possibility which should be considered in future construction at the hospital. The Roanoke River being 100 feet below the site elevation suggests that the caverns might be at the river elevation or lower, but this would require test borings for confirmation.

Two water towers, one of 600,000-gallon capacity and one of 100,000-gallon capacity are located on the site as shown on Fig 18-C We understand that the 150-foot chimney shown on Fig 18-D is to be demolished in the near future.

4.2 Site Hazards

As noted in an earlier section, the site is located near mapped faults; however, these are not considered to constitute a serious site

hazard as they are considered to be dormant and not expected to cause surficial displacement of appreciable magnitude. The swimming pool water disposal area indicates the possibility of underground caverns or solution channels; however, the existence and extent of these are not known. Under static conditions, the stability of the hillside south and east of the site does not appear to have been a problem in the past as there are no signs of sliding or sloughing.

4.3 Expected Behavior of Foundations

Test boring data furnished by the VA for this site indicates the subsoils to be predominantly compact, red clay with shale and sandstone fragments with areas of thin and patchy alluvial deposits of hard red silty clay and gravel. This material is not likely to lose strength under dynamic loads, and therefore loss of bearing capacity or liquefaction is not expected. According to drawings available to us, the majority of the structures are three-story brick buildings founded on reinforced concrete spread footings. It is doubtful that seismic loads have been considered in this foundation design, but our judgement and experience suggest that their behavior should not present a problem. On the other hand, the behavior of the masonry structures under the MEE is highly questionable and should be investigated further. Along this line, it is noted that practically all of the existing structures have experienced a site intensity of VI, or a peak horizontal ground acceleration on the order of 0.05 g, in 1957. This is less than one half of the MEE, but nevertheless, no damage reports were available.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The results of the seismic evaluation survey indicate that the worst earthquake experienced at the VA Hospital site in Salem in recorded history is equal to an MM Intensity VII. It is noted, however, that the present hospital structures have experienced only intensity VI, which yields a peak horizontal ground acceleration less than half that of the Maximum Expected Earthquake. The Maximum Expected Earthquake at the site during a reasonable life span will have an MM Intensity VII. On this basis we recommend a peak horizontal ground acceleration of 0.12g.

Recognizing the level and acceleration expected at the site and the type of structures involved, the following recommendations are provided:

1. Since the peak horizontal acceleration of 0.12g is less than the zonal acceleration of 0.16g normally considered for Zone 2 sites, it would appear that the VA should carefully check the design against the latest Local and Uniform Building Code Requirements for Zone 2 sites. Since the buildings were designed and constructed between 25 and 40 years ago, it is unlikely that the buildings will conform to this code. Furthermore, since the buildings are mostly three story masonry structures, it would not be unreasonable to expect parapets to fail or to have partial failure or even collapse of portions of some buildings. This undesirable behavior would certainly be related to the unknown quality of materials and construction techniques utilized during construction. We, therefore, recommend that the dynamic behavior of the masonry construction be investigated.

2. Due to the proximity of tectonic features and epicenters to the area, response spectra for the site should give consideration to high frequency wave content.

3. The method of disposal of the swimming pool water, as mentioned in the site description, indicates the possible presence of caverns or solution channels. If a high rise structure is anticipated for the site, this possible condition should be investigated. Furthermore, an extensive area of caverns or solution channels could certainly affect the stability of the hillside to the south and east when subjected to the expected earthquake loading. Therefore, it is recommended that the long term consequences of the effect of disposing of the water in this manner be investigated and that the stability of the hillside under earthquake loading be analyzed.

4. It is recommended that the two water towers be analyzed with respect to seismic behavior or that the consequences of an abrupt failure be considered. Special consideration should be given to possible amplifying effects that might be associated with the soil upon which the towers are founded.

Very truly yours,

E. D'APPOLONIA CONSULTING ENGINEERS, INC.

Paul C. Rizzo

72-428-6

November, 1974

LIST OF REFERENCES

LIST OF REFERENCES

1. Rodgers, J., "Mechanics of Appalachian Forland Folding in Pennsylvania and West Virginia," Bulletin of American Association of Petroleum Geologists, Volume 47, pp. 1527-1536, 1964.

2. Gwinn, V. E., "Kinematic Patterns and Estimates of Lateral Shortening, Valley and Ridge and Great Valley Provinces, Central Appalachians, South-Central Pennsylvania," in: Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr. and Weaver, K. N., Studies of Appalachian Geology: Central and Southern: New York, Interscience, pp. 127-146, 1970.

3. Cooper, B. N., "Grand Appalachian Excursion," Virginia Polytechnic Institute, Engineering Experimental Station Extension Services, Geological Guide Guidebook 1, 1961.

4. Hubbert, M. K., and Rubey, W. W., "Role of Fluid Pressure in Mechanics of Overthrust Faulting," Bulletin of Geological Society of America, Volume 70, pp. 115-166, 1959.

5. Sbar, M. L., and Sykes, L. R., "Contemporary Compressive Stress and Seismicity in Eastern North America: An Example of Intra-Plate Tectonics," Bulletin of Geological Society of America, Volume 84, pp. 1861-82, 1973.

6. Fox, F. L., "Seismic Geology of the Eastern United States," Bulletin of Association of Engineering Geologists, Volume 7, pp. 21-43, 1970.

7. Oliver, J., and Isacks, B., "Seismicity and Tectonics of the Eastern United States," abs. , Earthquake Notes, Volume 43, p. 30, 1972.

8. Woolard, G. P., "Tectonic Activity in North America," In the Earth's Upper Crust and Mantle, American Geophysical Union Monograph 13, pp. 125-133, 1969.

9. Sbar, M. L., Armbruster, J., and Aggarwal, Y. P., "The Adirondack, New York, Earthquake Swarm of 1971 and Tectonic Implications," Bulletin of Seismological Society of America, Volume 62, pp. 1303-1318, 1972.

10. Algermissen, S. T., "Seismic Risk Studies in the United States," Proceedings of the Fourth World Conference on Earthquake Engineering, Volume 1, Santiago de Chile, 1969.

Additional References*

11. Rodgers, J., The Tectonics of the Appalachians, Wiley, Interscience, New York, 271 p., 1970.

---

*These additional references, while not cited in the text, were used as sources of data and for the general interpretation of site conditions.

LIST OF REFERENCES
(Continued)

12. Woodward, H. P., "Geology and Mineral Resources of the Roanoke Area. Virginia," Virginia Geological Survey, 1932.

13. Latta, Bruce F., "Public and Industrial Groundwater Supplies of the Roanoke-Salem District, Virginia," Department of Conservation and Development, Virginia Division of Geology, 1956.

14. Amato, R. V., "Structural Geology of the Salem Area, Roanoke County, Virginia," Virginia Polytechnic Institute, 1968.

15. Butts, Charles, "Geology of the Appalachian Valley in Virginia," Virginia Geological Survey, Bulletin 52, 1941.

16. Fenneman, N. M., Physiography of Eastern United States, McGraw-Hill Book Company, 1938.

17. Bollinger, G. A., "Historical and Recent Seismic Activity in South Carolina," Bulletin of the Seismological Society of America, Vol. 62, No. 3, pp. 581-864, June 1972.

18 Bollinger, G. A., "Seismicity of the Central Appalachian States of Virginia, West Virginia and Maryland - 1758 through 1968," Bulletin of the Seismological Society of America, Vol. 59, No. 5, October 1969.

19. Bollinger, G. A. and Hopper, M. G., "Virginia's Two Largest Earthquakes - December 22, 1875 and May 31, 1897," Bulletin of the Seismological Society of America, Vol. 61, No. 4, pp. 1033 to 1039, August 1971.

20. Fox, F. L., "Seismic Geology of the Eastern United States," Bulletin of the Association of Eng. Geol., Vol. VII, Nos. 1 and 2, Fall 1970.

21. Gordon, C. H., "Earthquakes in the Eastern Tennessee," Bulletin of the Seismological Society of America, Vol. 3, No. 4 pp. 191 to 194, December 1913.

22. Hansen, R. J., Seismic Design for Nuclear Power Plants, The M.I.T. Press, 1970.

23. McClain, N. C., Seismic History of Seismicity of the Southeastern Region of the United States, Oak Ridge National Laboratory, ORNL-4582, June 1970.

24. Hopper, Margaret G. and Bollinger, G. A., "The Earthquake History of Virginia, 1774-1900," Department of Geological Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virgina, 1971.

LIST OF REFERENCES
(Continued)

25. Hopper, Margaret G. and Bollinger, G. A., "The Earthquake History of Virginia, 1900-1970," Department of Geological Sciences, Virgina Polytechnic Institute and State University, Blacksburg, Virginia, 1972.

26. Richter, Charles, Elementary Seismology, San Francisco, W. H. Freeman Company, 1958.

27. Eppley, R. A., "Earthquake History of the United States," Part I, U. S. Department of Commerce, Environmental Sciences Services Administration, No. 41-1, Revised Edition (through 1963).

28. Coffman, J. L. and von Hake, C. A., "Earthquake History of the United States," Publication 41-1, U. S. Department of Commerce, 1973.

29. Brunswick PSAR, Docket Nos. 50-324, 50-325.

30. Oconee PSAR, Docket Nos. 50-269, 50-270.

31. Robinson PSAR, Docket No. 50-261.

32. Zimmer PSAR, Docket No. 50-358.

33. McGuire PSAR, Docket No. 50-369.

34. Hatch PSAR, Docket No. 50-366.

35. Summer PSAR, Docket No. 50-395.

36. Sequoyah PSAR, Docket No. 50-327.

37 Barnwell PSAR, Docket No. 50-332.

38. Watts PSAR, Docket No. 50-390.

39. North Anna PSAR, Docket Nos. 50-338, 50-404.

40. Surry PSAR, Docket Nos. 50-280, 50-281.

41. United States Earthquakes, U. S. Department of Commerce, 1964.

42. United States Earthquakes, U. S. Department of Commerce, 1965.

43. United States Earthquakes, U. S. Department of Commerce, 1966.

LIST OF REFERENCES
(Continued)

44. United States Earthquakes, U. S. Department of Commerce, 1967.

45. United States Earthquakes, U. S. Department of Commerce, 1968.

46. United States Earthquakes, U. S. Department of Commerce, 1969.

47. Bulletin of the Seismological Society of America, Vol. 59, No. 4, August 1969.

48. Bulletin of the Seismological Society of America, Vol. 59. No. 5. Oct. 1969.

49. Bulletin of the Seismological Society of America, Vol. 60, No. 1, Feb. 1970.

50. Bulletin of the Seismological Society of America, Vol. 60, No. 2, April 1970.

51. Bulletin of the Seismological Society of America, Vol. 60, No. 3, June 1970.

52. Bulletin of the Seismological Society of America, Vol. 60, No. 4, Aug. 1970.

53. Bulletin of the Seismological Society of America, Vol. 60, No. 5, Oct. 1970.

54. Bulletin of the Seismological Society of America, Vol. 60, No. 6, Dec. 1970.

55. Bulletin of the Seismological Society of America, Vol. 61, No. 1, Feb. 1971.

56. Bulletin of the Seismological Society of America, Vol. 61, No. 2, April 1971.

57. Bulletin of the Seismological Society of America, Vol. 61, No. 3, June 1971.

58. Bulletin of the Seismological Society of America, Vol. 61, No. 4, Aug. 1971.

59. Bulletin of the Seismological Society of America, Vol. 61, No. 5, Oct. 1971.

60. Bulletin of the Seismological Society of America, Vol. 61, No. 6, Dec. 1971.

61. Bulletin of the Seismological Society of America, Vol. 62, No. 1, Feb. 1972.

62. Bulletin of the Seismological Society of America, Vol. 62, No. 2, April 1972.

TABLES

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

Year	Date	Locality	North Latitude	West Longitude	Area	Intensity
1758	Apr 24	Annapolis, Maryland	38.9	76.5		
1774	Feb 21	Eastern Virginia	37.5	77.5	58,000	VI-VII
1774	Feb 22	Eastern Virginia	37.5	77.5		V-VI
1776	Summer	Southeast Ohio				V
1776	Nov 6	Jackson County, West North Carolina	35.0	83.0		IV-V
1779		Kentucky				
1791-2	Apr-May	Kentucky				
1807	Apr 30 or May 1	Lynchburg - Richmond, Virginia area				V
1811	Jan 13	Louisville and Augusta, Ga.	33.2	82.2		V
1817	Jan 8	Virginia, N. Carolina, S. Carolina, Maryland area	37.0	81.0		
1828	Mar 9	Probably Virginia			218,000	V
1833	Aug 27	Central Virginia			52,000	V
1834	Nov 20	Northern Kentucky				V
1843	Feb 16	Kentucky				V
1852	Apr 29	Virginia, N. Carolina, Tennessee region	36.6	81.6	162,000	VI
1852	Nov 2	Central Virginia	37.8	78.5	32,000	V-VI
1853	May 2	Virginia, West Virginia region			72,000	V
1854	Nov 22	Tazewell City, Virginia	37.1	81.5		
1855	Feb 2	Charlotte Court House, Virginia	37.0	78.6	9,000	V
1859	Mar 22	Tazewell City, Virginia	37.2	81.5		
1861	Aug 31	Virginia	36.6	78.5	300,000	VI

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

Year	Date	Locality	North Latitude	West Longitude	Area	Intensity
1874	Feb 10	McDowell County, N.C.	35.7	82.1	Local	V
1874	Feb 22	McDowell County, N.C.	35.7	82.1	Local	V
1874	Mar 17	McDowell County, N.C.	35.7	82.1	Local	V
1874	Mar 26	McDowell County, N.C.	35.7	82.1	Local	V
1874	Apr 14	McDowell County, N.C.	35.7	82.1	Local	V
1874	Apr 17	McDowell County, N.C.	35.7	82.1	Local	V
1875	Dec 22	Arvonia, Virginia	37.6	78.5	50,000	VII
1876	Dec 21	Wytheville, Virginia	36.9	81.1		
1877	Apr 26	Franklin, North Carolina	35.2	83.4		III-IV
1879	Oct 26	Winnsboro, South Carolina	34.5	81.1		
1879	Dec 12	Charlotte, N. Carolina	35.2	80.8		V-VI
1879	Dec 13	Charlotte, N. Carolina	35.2	80.8		V
1880	Jan 28	Bald Mountain, N.C.	36.0	82.7		
1883	Mar 11	Harford County, Maryland	39.5	76.4	Local	IV-V
1884	Jan 18	Wilmington, N. Carolina	34.3	78.0		V
1885	Jan 2	Maryland and Virginia	39.2	77.5	3,500	V
1885	Feb 2	Wytheville, Virginia	36.9	81.1		IV
1885	Aug 6	Watauga County, Western North Carolina	36.2	81.6	Local	IV-V
1885	Aug 13	Watauga County, Western North Carolina	36.2	81.6		IV
1885	Oct 9	Virginia	37.7	78.8	20,000	VI

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

Year	Date	Locality	North Latitude	West Longitude	Area	Intensity
1886	Sept 3	Wytheville, Virginia	36.9	81.1		
1886	Sept 25	Wytheville, Virginia	36.9	81.1		
1888	Mar 17	Jonesboro, Tennessee	36.4	82.5		
1889	Mar 8	Pennsylvania	40.0	76.0	4,000	V
1889	Sept 28	Parksville, Polk County, Tennessee				III-IV
1897	Apr 30	Tennessee and Illinois				V
1897	May 3	Near Roanoke, Virginia	37.1	80.7	29,000	VI
1897	May 31	Giles County, Virginia	37.3	80.7	280,000	VII
1897	Sept 4	Wytheville, Virginia	36.9	81.1		
1897	Oct 21	Wytheville, Virginia	36.9	81.1	20,000	V
1897	Dec 18	Ashland, Virginia	37.7	77.5	7,500	V
1898	Feb 5	Pulaski-Wytheville, Va.	37.0	80.7	34,000	VI
1898	Nov 25	Pulaski-Wytheville, Va.	37.0	81.0	65,000	V
1899	Feb 13	Western Virginia	37.0	81.0	30,000	V
1901	May 17	Ohio	39.3	82.5	7,000	V
1902	May 17	Pearisburg, Virginia	37.3	80.7		
1904	Mar 4	Maryville, Tennessee	35.7	83.5	5,000	V
1907	Feb 11	Arvonia, Virginia	37.7	78.4	5,600	VI
1908	Aug 23	Powhatan, Virginia	37.5	77.9	1,500	V
1909	Apr 2	Virginia, West Virginia, Maryland and Pennsylvania	39.4	78.0	2,500	V-VI

E. D'Appolonia Consulting Engineers, Inc.

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

Year	Date	Locality	~~North~~ Latitude	~~West~~ Longitude	Area	Intensity
1910	Apr 23	New Jersey Coast			2,000	III-IV
1910	May 8	Arvonia, Virginia	37.7	78.4	4,000	V
1911	Apr 20	Caesar's Head, S.C.	35.2	82.7	600	V
1912	Dec 7	Union County, S.C.	34.7	81.7		III-IV
1913	Jan 1	Union County, S.C.	34.7	81.7	43,000	VI-VII
1915	Jan 14	Bristol, Tennessee	36.6	82.1		III-IV
1915	Oct 29	Near Marshall, N.C.	35.8	82.7	1,200	V
1916	Feb 21	Near Waynesville, N.C.	35.5	82.5	200,000	VI
1916	Mar 2	Anderson, S.C.	34.5	82.7		IV-V
1916	Aug 26	Statesville and Taylorsville, North Carolina	36.0	81.0	3,800	V
1917	Mar 25	Jefferson City and Talbott, Tennessee	36.1	83.5		III-IV
1917	Mar 27	Jefferson City, Tennessee	36.1	83.5		III-IV
1918	Apr 9	Virginia	38.7	78.4	60,000	VI
1919	Sept 5	Virginia	38.8	78.2		VI
1921	July 15	Mendota, Virginia	36.6	82.3	Local	VI
1921	Aug 7	Virginia	37.8	78.4	2,800	V
1922	Mar 30	Arcadia, Sullivan County, Tennessee	36.5	82.2		IV
1923	Oct 18	Hendersonville and Saluda, N. Carolina	35.3	82.5		
1924	Oct 20	Pickens County, S.C.	35.0	82.6	56,000	V

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

Year	Date	Locality	~~North~~ Latitude	~~West~~ Longitude	Area	Intensity
1924	Nov 13	Bristol, Tennessee	36.6	82.1		IV-V
1925	Mar 26	Southwestern Ohio				V
1925	May 15	Swift Creek, Virginia	37.0	81.0		
1926	July 8	South Mitchell County, North Carolina	35.9	82.1	Local	VI
1926	July 18	Tennessee-North Carolina border				VI
1926	Nov 5	Southeastern Ohio	39.1	82.1	350	VI-VII
1927	June 10	Virginia	38.0	79.0	2,500	V
1927	July 20	Knoxville, Tennessee	35.9	83.9		
1927	Oct 8	Chattanooga, Tennessee	35.0	85.3		V
1927	Nov 22	Southport, N. Carolina				IV
1928	Nov 2	Northeast Tennessee-West N.C. border region	36.0	82.6	40,000	VI
1928	Nov 20	West N.C. - East Tenn. border area	35.9	82.8	10,000	IV
1929	Dec 26	Central Virginia	38.1	78.5		VI
1937	Feb 2	Central Virginia				IV
1940	Mar 25	Near Woodstock, Virginia	38.9	78.6	Local	IV-V
1940	Dec 25	N. Carolina-Tennessee	35.9	82.9	7,000	V

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

Year	Date	Locality	North Latitude	West Longitude	Area	Intensity
1942	Nov 1	Winnsboro, S. Carolina	34.5	81.1		
1945	July 26	Murray Lake, S. Carolina	34.3	81.4	25,000	IV-V
1948	Jan 4	Buckingham County, Va.	37.5	78.5	2,000	V
1949	May 8	Powhatan, Virginia	37.5	78.0	500	
1949	Sept 17	Lee County, Virginia	36.7	83.0		IV-V
1950	June 19	Alcoa, Tennessee	35.7	84.0		IV
1952	June 11	Johnson City, Tennessee	36.6	82.4		
1952	June 20	Southeastern Ohio	39.7	82.2	10,000	VI
1953	Dec 31	Woodland Park, Kentucky	37.0	83.0		IV
1955	Jan 6	Bristol, Tennessee	36.6	82.2		IV
1955	Sept 28	North Carolina-Virginia border area	36.6	81.4	1,700	V
1956	Jan 5	Due West, S. Carolina	34.3	82.4		IV
1956	May 19	Due West, S. Carolina	34.3	82.4		IV
1956	May 27	Due West, S. Carolina	34.3	82.4		IV
1957	May 13	Western N. Carolina	35.7	82.0	8,100	VI
1957	July 2	Western N. Carolina	35.5	82.5		VI
1957	Nov 24	N. Carolina-Tennessee border	35.0	83.5	4,100	VI
1958	Mar 5	Wilmington, N. Carolina	34.3	77.7		V
1958	May 16	Asheville, N. Carolina	35.6	82.6		IV
1958	Oct 20	Anderson, S. Carolina	34.3	82.7		V

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

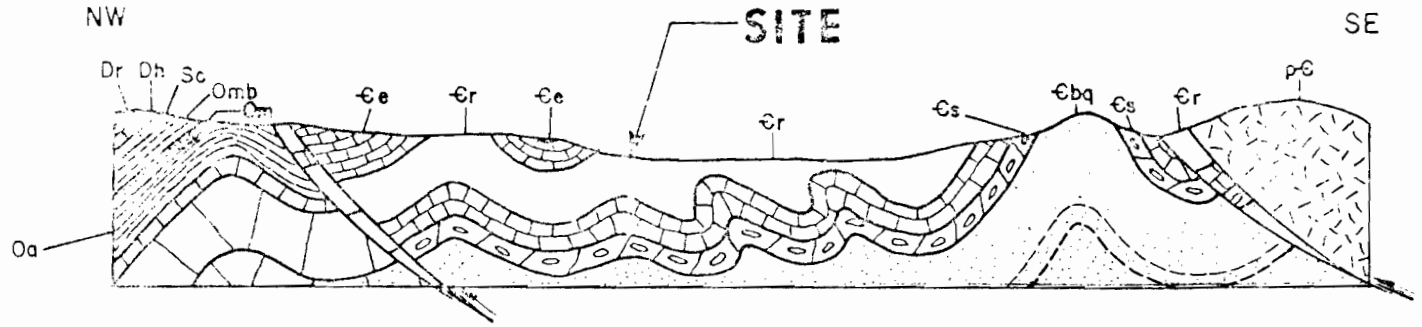
Year	Date	Locality	North Latitude	West Longitude	Area	Intensity
1959	Apr 23	Virginia-West Virginia border	37.5	80.5	3,000	VI
1959	Oct 26	Northeast S. Carolina	34.5	80.3	4,800	VI
1960	Feb 9	Henderson County, North Carolina				
1960	Apr 15	Near Knoxville, Tenn.	35.8	84.0	1,300	V
1963	Apr 11	Greenville, S. Carolina	34.8	82.4		IV
1963	Oct 28	Galax, Virginia	36.7	81.0	1,300	V
1964	Jan 20	Cane River, N. Carolina area	35.9	82.2		IV
1964	Apr 20	Near Columbia, S. C.	34.0	81.0		V
1965	Sept 9	Chester, S.C.	34.7	81.2		
1965	Sept 12	Chester, S. Carolina	34.7	81.2		
1966	May 31	Eastern Virginia	37.6	78.0	28,000	V
1967	Apr 8	Sugar Grove, Ohio	39.6	82.5	4,000	V
1968	Mar 8	Near Narrows, Virginia	37.3	80.8	3,200	V
1968	Sept 22	Central S. Carolina	34.0	81.5	400	V
1968	Nov 25	Southwest N. Carolina				IV
1969	Nov 19	West Virginia	37.4	81.0	100,000	VI
1969	Dec 11	Near Richmond, Virginia	37.8	77.4	6,500	V
1969	Dec 13	Western North Carolina	35.1	83.0	3,500	V
1970	July 30	West Virginia	37.0	82.2		V

TABLE I

LIST OF EARTHQUAKES WITH EPICENTERS WITHIN 200 MILES OF SITE
(MODIFIED MERCALLI INTENSITY ≥ IV)

Year	Date	Locality	North Latitude	West Longitude	Area	Intensity
1970	Aug 11	West Virginia	38.4	82.3		
1970	Sept 10	Northwest N. Carolina	36.1	81.4	2,000	V

FIGURES



DEVONIAN	Dr	ROMNEY SHALE
	Dh	HELDERBERG GROUP
SILURIAN	Sc	CLINTON FORMATION AND CLINCH SANDSTONE
ORDOVICIAN	Omb	MARTINSBURG SHALE
	Om	MOCCASIN FORMATION
	Oa	ATHENS SHALE
CAMBRIAN	€e	ELBROOK FORMATION
	€r	ROME FORMATION
	€s	SHADY DOLOMITE
	€bq	BASAL QUARTZITES
PRE-CAMBRIAN	p€	PRECAMBRIAN CRYSTALLINE ROCKS

REFERENCE
VIRGINIA DIVISION OF GEOLOGY
BULLETIN 69 DATED 1956.

"DO NOT SCALE THIS DRAWING"

FIGURE 6

D'APPOLONIA CONSULTING ENGINEERS, INC.
10 DUFF ROAD
PITTSBURGH, PA. 15235
AR 5229
CHESTERTON, IND. 46304

SALEM, VIRGINIA
GENERAL GEOLOGIC CROSS-SECTION ACROSS
ROANOKE-SALEM DISTRICT

VETERANS ADMINISTRATION
WASHINGTON, D.C.

DRAWN BY	PJF	7-6-72	DRAWING NO.
CHECKED BY	BOSACK	9-18-72	72-428-6-A1

19 1153 HERCULENE A.W. & B.S. KEYS CO., PGH., PA.

PR 1123-771

AGE	FORMATION	THICKNESS (FEET)	LITHOLOGY
QUATERNARY		0-50	UNCONSOLIDATED GRAVEL, SAND, SILT AND CLAY DERIVED BY WEATHERING AND EROSION OF OLDER ROCKS. OCCUR ALONG STREAMS AND IN TERRACE REMNANTS ALONG THE LARGER VALLEYS
DEVONIAN	ROMNEY SHALE	600	DARK GRAY TO BLACK, FISSILE CARBONACEOUS SHALE.
	HELDERBERG GROUP	25	GRAY-BROWN FRIABLE SANDSTONE.
SILURIAN	CLINTON FORMATION AND CLINCH SANDSTONE	400	RED AND WHITE FRIABLE SANDSTONE, COARSE CROSS-BEDDED GRAY SANDSTONE, AND BUFF AND RED SHALE
ORDOVICIAN	MARTINSBURG SHALE	900 - 1,100	GRAY-BROWN CALCAREOUS SHALE, THIN FLAGGY SANDSTONE, AND THINLY BEDDED CRYSTALLINE LIMESTONE
	MOCCASIN FORMATION	150 - 300	REDDISH SANDSTONE AND SHALE
	ATHENS SHALE	950	BLACK HACKLY SHALE CONTAINING THIN BEDS OF BLACK LIMESTONE IN LOWER PART
	STONES RIVER GROUP	325±	CRYSTALLINE LIMESTONE AT TOP AND BEDS OF DARK KNOTTY AND PURE LIMESTONE BELOW. NOT EXPOSED IN ROANOKE-SALEM DISTRICT, BUT OCCURS BENEATH ATHENS SHALE IN NORTHWESTERN PART OF THE DISTRICT.
	NITTANY DOLOMITE	800±	LIGHT-GRAY TO BLUE CHERTY DOLOMITE. NOT EXPOSED IN THIS DISTRICT, BUT OCCURS BENEATH YOUNGER STRATA IN THE NORTHWESTERN PART OF THE DISTRICT
CAMBRIAN	CONOCOCHEAGUE LIMESTONE	1,200 - 1,600	CHERTY MAGNESIAN LIMESTONE AND DOLOMITE. NOT EXPOSED IN THIS DISTRICT, BUT OCCURS BENEATH YOUNGER STRATA IN NORTHWESTERN PART
	ELBROOK FORMATION	1,000 - 1,600	BLUE AND BLUISH-GRAY, GENERALLY THINLY BEDDED, LIMESTONE ALTERNATING WITH BUFF AND GRAY CALCAREOUS SHALE. MIDDLE AND UPPER PARTS ARE THICKER BEDDED AND CONTAIN THIN BEDS OF DOLOMITE. UNDERLIES MOST OF NORTHERN THIRD OF THE DISTRICT
	ROME FORMATION	500±	CONSISTS LARGELY OF RED, RUSTY-BROWN, AND PURPLE SERICITIC SHALE THAT WEATHERS YELLOWISH-GRAY, BUT CONTAINS BEDS OF BLUISH-GRAY TO DARK-BLUE LIMESTONE AND DOLOMITE THAT ARE FROM A FEW FEET TO 100 OR MORE FEET THICK. UNDERLIES MOST OF CENTRAL PART OF THE DISTRICT.
	SHADY DOLOMITE	1,000 - 1,500	MASSIVE, COARSE-GRAINED, BLUE TO DARK-GRAY IMPURE DOLOMITE CONTAINING INTERBEDDED LAMINATED SHALE AND CLAY. LOWER PART IS GENERALLY SOFT AND CONSISTS OF FINELY LAMINATED CLAY AND OCHER. BASE OF THE FORMATION IS GENERALLY ARKOSIC. UNDERLIES THE DISTRICT SOUTH OF ROANOKE
	BASAL QUARTZITES	2,500 - 3,000	SANDSTONE, QUARTZITE, COARSE AND FINE CONGLOMERATE, GRAY SHALE, AND SOME SLATE. BASAL BEDS ARE ARKOSIC AND CONTAIN PEBBLES OF THE UNDERLYING ROCKS LOCALLY METAMORPHOSED
PRECAMBRIAN			MASSIVE IGNEOUS AND SCHISTOSE METAMORPHIC ROCKS

REFERENCE VIRGINIA DIVISION OF GEOLOGY, BULLETIN 69, TABLE 1, DATED: 1956, BY: B.F. LATTA.

"DO NOT SCALE THIS DRAWING"

FIGURE 7

E. D'APPOLONIA CONSULTING ENGINEERS, INC.

10 DUFF ROAD
PITTSBURGH, PA. 15235

MR 5225
CHESTERTON, IND. 46304

SALEM, VIRGINIA
GENERALIZED TABLE OF GEOLOGIC FORMATIONS
FOR ROANOKE-SALEM DISTRICT

VETERANS ADMINISTRATION
WASHINGTON, D.C.

DRAWN BY	PJF	8-24-72	DRAWING NO.
CHECKED BY	BOSACK	9-18-72	72-428-E-A3

A.B.A. SMITH CO. PGH., PA.

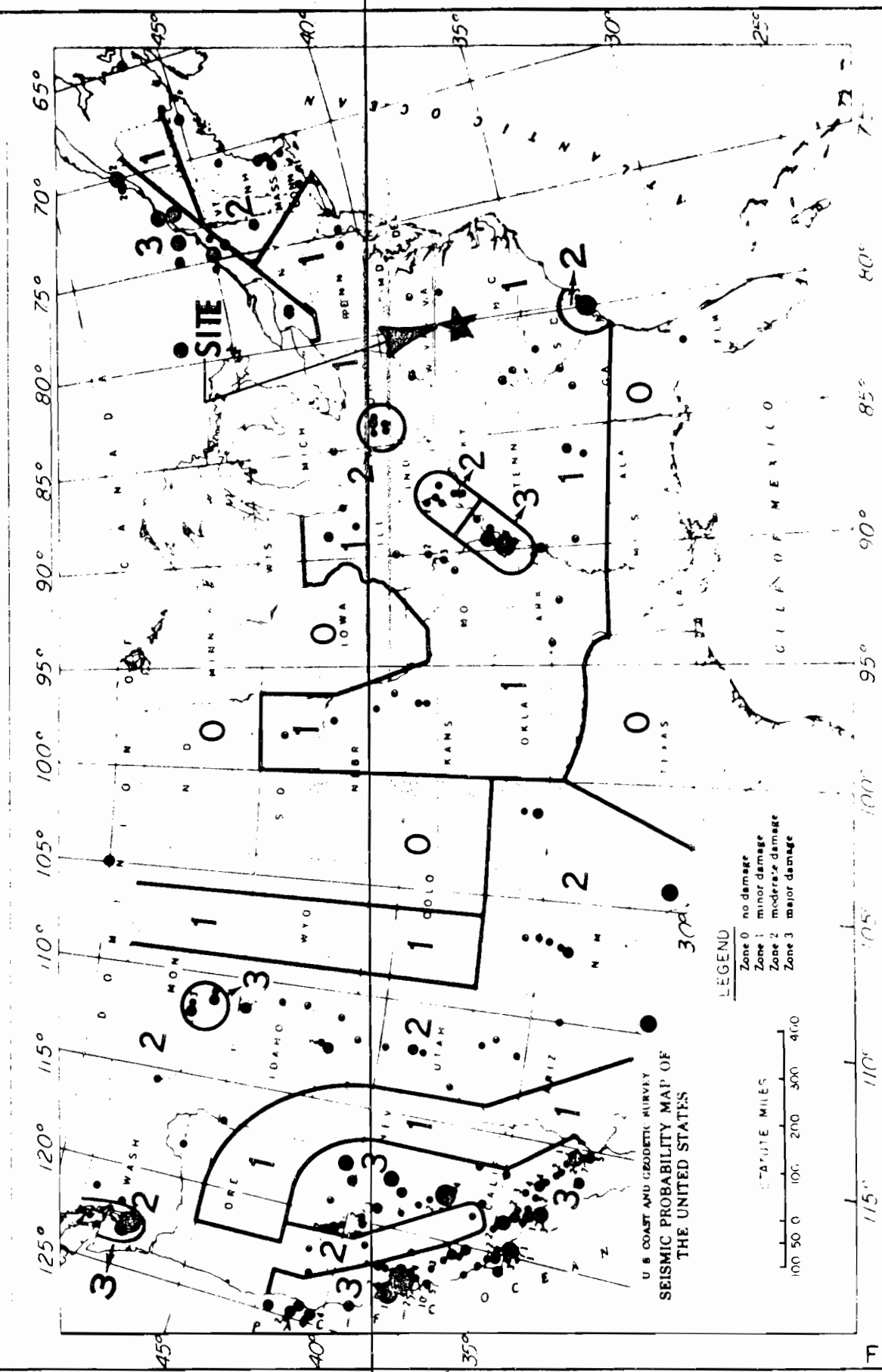
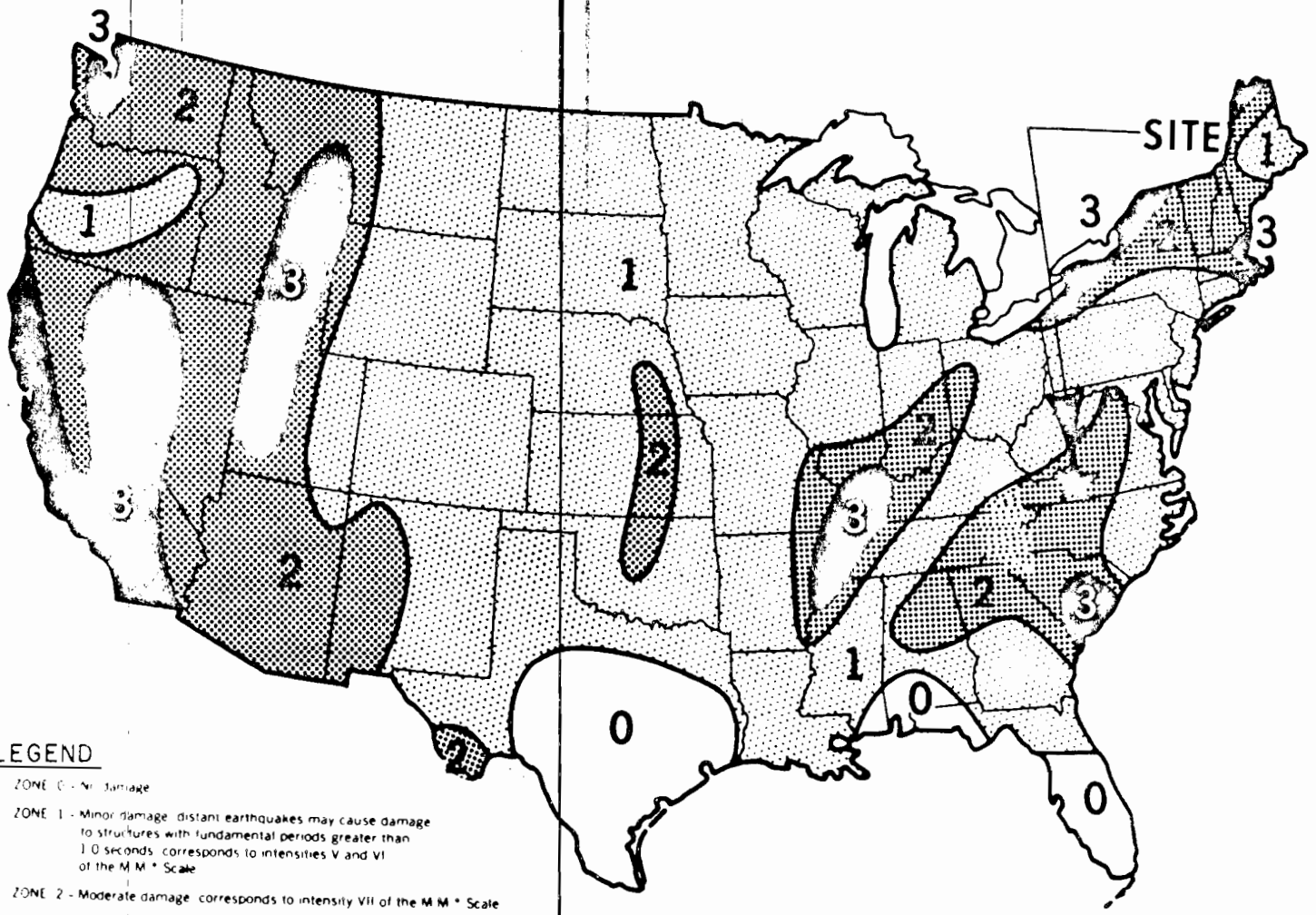


FIGURE 9

E. D'APPOLONIA CONSULTING ENGINEERS INC 15 DUFF ROAD PITTSBURGH PENNA 15235	MR 5225 CHESTERTON, IND 46304	SEISMIC PROBABILITY MAP OF THE UNITED STATES
VETERANS ADMINISTATION WASHINGTON, D C.	DWN BY NCF 10 21 68 CKD BY APPR D BY	DRAWING NO 72-428-6-A4

WILKINSBURG BLUEPRINT



LEGEND

ZONE 0 - No damage

ZONE 1 - Minor damage distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 seconds corresponds to intensities V and VI of the M.M.* Scale

ZONE 2 - Moderate damage corresponds to intensity VII of the M.M.* Scale

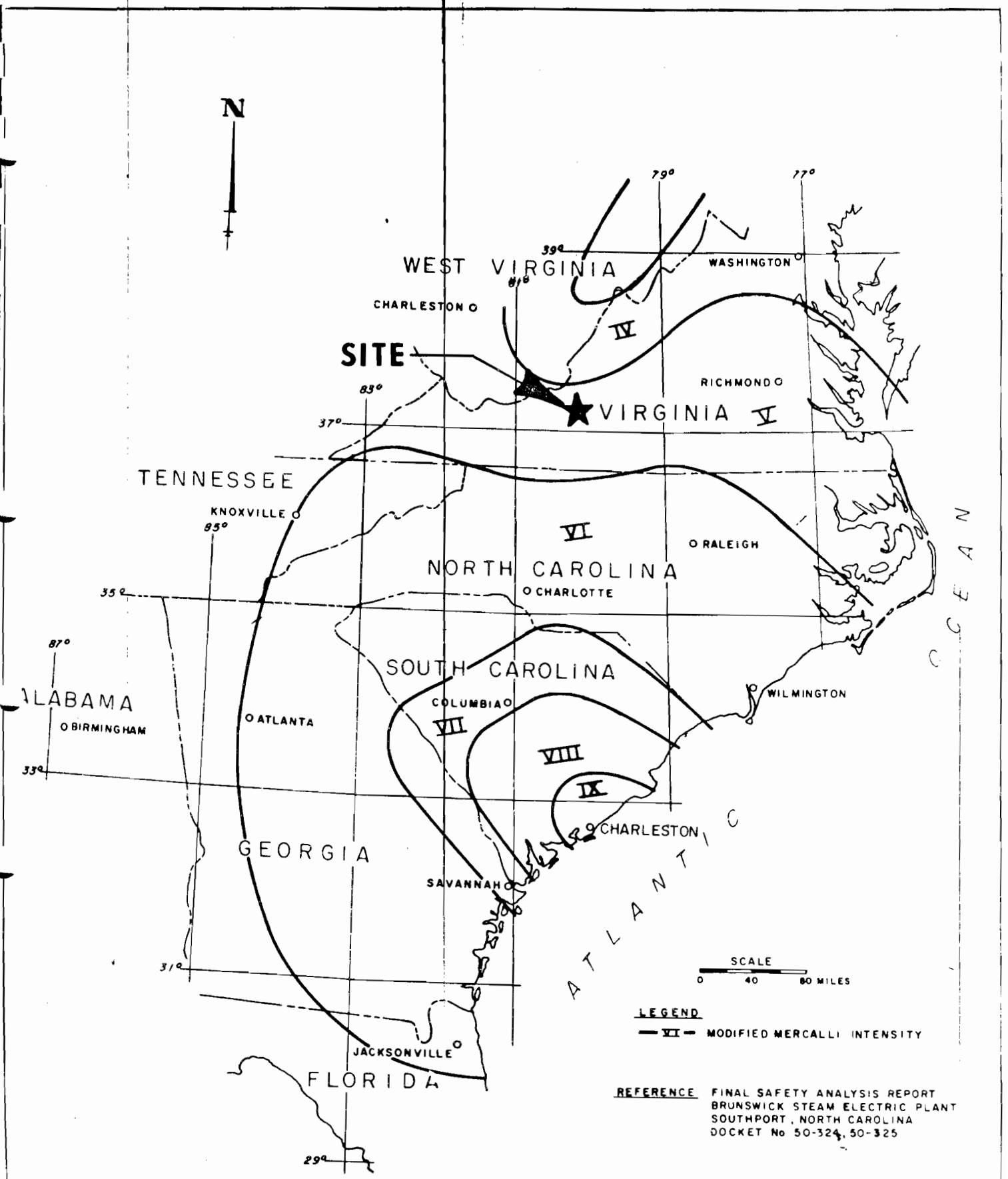
ZONE 3 - Major damage corresponds to intensity VIII and higher of the M.M.* Scale

* REFERS TO THE MODIFIED MERCALLI INTENSITY SCALE

"DO NOT SCALE THIS DRAWING"

FIGURE 10

E. D'APPOLONIA CONSULTING ENGINEERS, INC.	10 DUFF ROAD PITTSBURGH, PA. 15235 / NR 5228 CHESTERTON, IND. 46304	SEISMIC RISK MAP FOR THE UNITED STATES			
VETERANS ADMINISTRATION WASHINGTON, D.C.		DRAWN BY	PJF	7-12-72	DRAWING NO. 72-428-6-A5
		CHECKED BY			

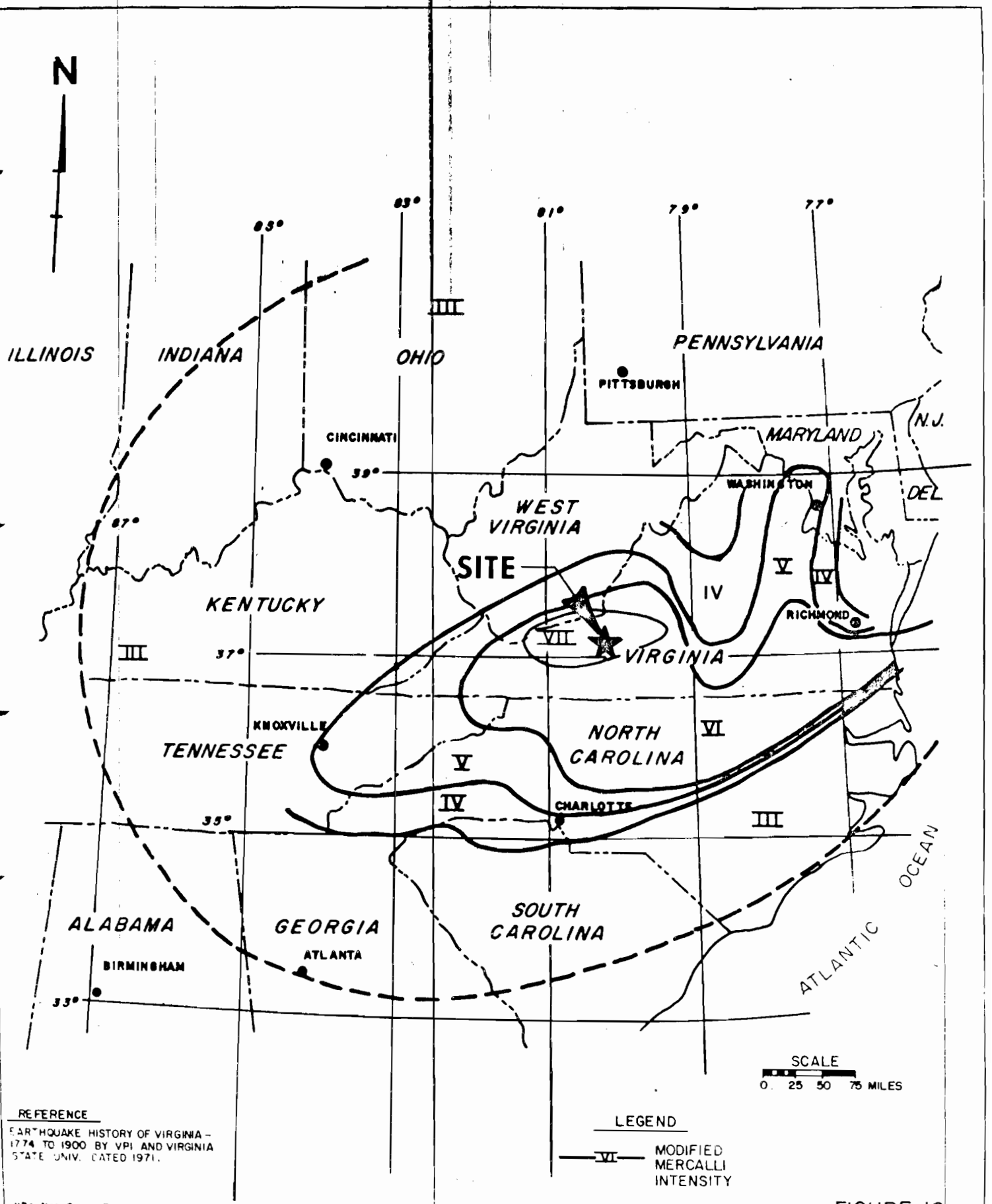


"DO NOT SCALE THIS DRAWING"

FIGURE 11

E. D'APPOLONIA CONSULTING ENGINEERS, INC.	NO DUFF ROAD PITTSBURGH, PA. 15235 / MR 522B CHESTERTON, IND. 46304	ISOSEISMAL MAP CHARLESTON EARTHQUAKE OF AUGUST 31, 1886
VETERANS ADMINISTRATION WASHINGTON, D.C.	DRAWN BY DAG 8-4-72 / CHECKED BY AJE WHB 8 12 72	DRAWING NO. 72-428-6-A6

® 1193 HERCULENE A. & B. SMITH CO., PGH., PA.



REFERENCE

EARTHQUAKE HISTORY OF VIRGINIA – 1774 TO 1900 BY VPI AND VIRGINIA STATE UNIV. DATED 1971.

"DO NOT SCALE THIS DRAWING"

FIGURE 12

E. D'APPOLONIA CONSULTING ENGINEERS, INC.	10 DUFF ROAD PITTSBURGH, PA. 15235 / MR 522B CHESTERTON, IND. 46304	ISOSEISMAL MAP GILES COUNTY, VIRGINIA EARTHQUAKE MAY 31, 1897
VETERANS ADMINISTRATION WASHINGTON, D.C.	DRAWN BY JJL 8-16-72 / CHECKED BY BOSACK 8-21-72	DRAWING NO. 72-428-6-A7

18 1193 HERCULENE A. & B. SMITH CO. PGH., PA.

MODIFIED MERCALLI INTENSITY SCALE

ABRIDGED MODIFIED MERCALLI INTENSITY SCALE

I	Not felt except by a very few under especially favourable circumstances.	
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.	
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars	may rock slightly. Vibration like passing of truck. Duration estimated.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sen-	sation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned.	Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.	
VII	Everybody runs outdoors. Damage **negligible** in buildings of good design and construction; **slight** to moderate in well-built ordinary structures;	**considerable** in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII	Damage **slight** in specially designed structures; **considerable** in ordinary substantial buildings with partial collapse; **great** in poorly built structures. Panel walls thrown out of frame structures.	Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed
IX	Damage **considerable** in specially designed structures; well designed frame structures thrown out of plumb; **great** in substantial buildings, with	partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations, ground badly cracked. Rails	bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

"DO NOT SCALE THIS DRAWING"

FIGURE 13

E. D'APPOLONIA CONSULTING ENGINEERS, INC.
10 DUFF ROAD
PITTSBURGH, PA. 15235
MR 522B
CHESTERTON, IND. 46304

MODIFIED MERCALLI INTENSITY SCALE

VETERANS ADMINISTRATION
WASHINGTON, D.C.

DRAWN BY	R.J.C. n.f.	7-22-72	DRAWING NO. 72-428-6-A8
CHECKED BY	BOSACK	8:2:72	

10 1193 HERCULENE A. & B. SMITH CO., PGH., PA.

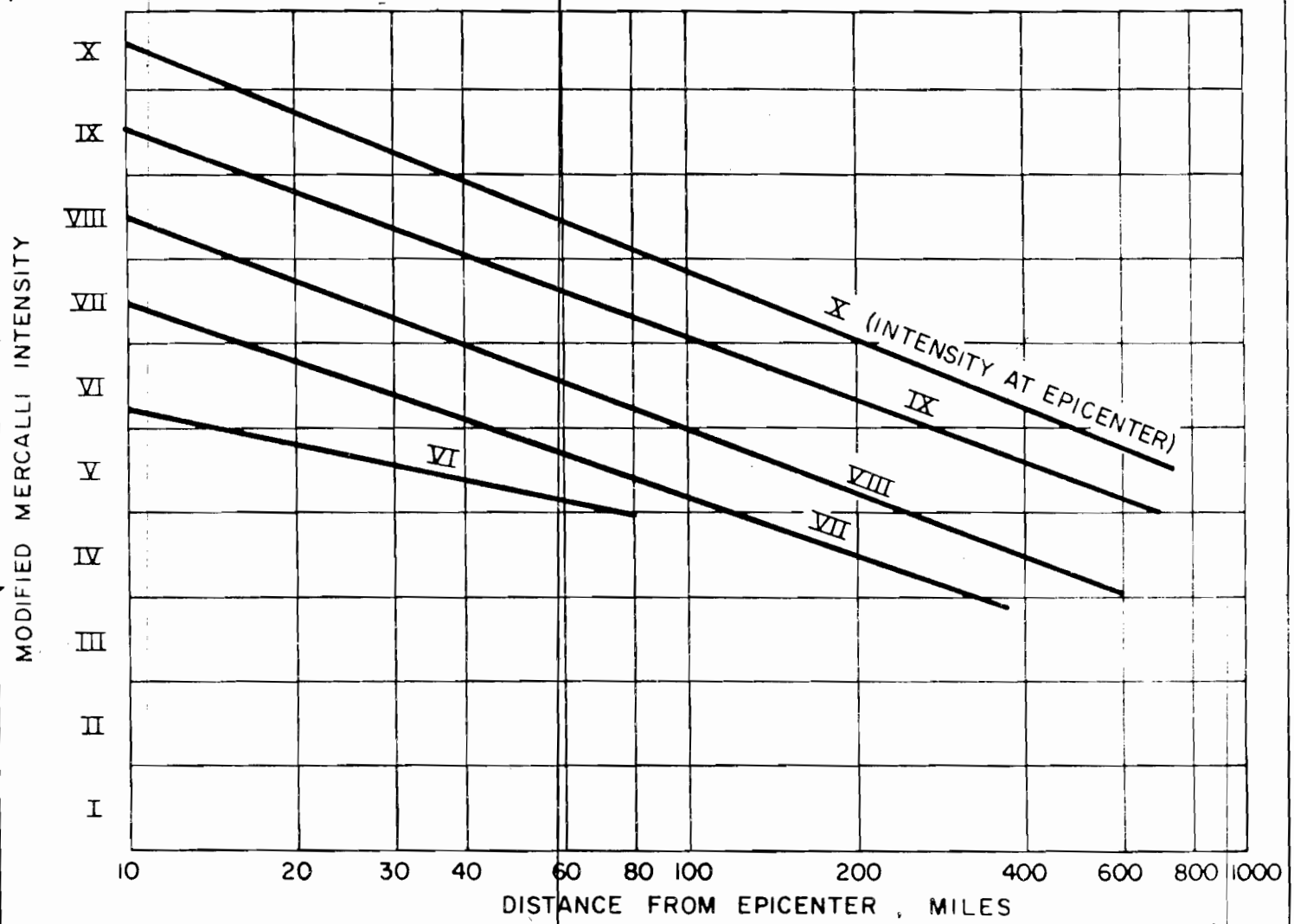


FIGURE 14

E. D'APPOLONIA
CONSULTING ENGINEERS INC
15 DUFF ROAD
PITTSBURGH PENNA 15235
MR 5228
CHESTERTON IND 46304

VETERANS ADMINISTRATION
WASHINGTON, D.C.

ATTENUATION CURVES
EASTERN UNITED STATES

DWN BY JJL 7-12-72
CKD BY
APPR'D BY

DRAWING NO
72-428-6-A9

WILKINSBURG BLUEPRINT

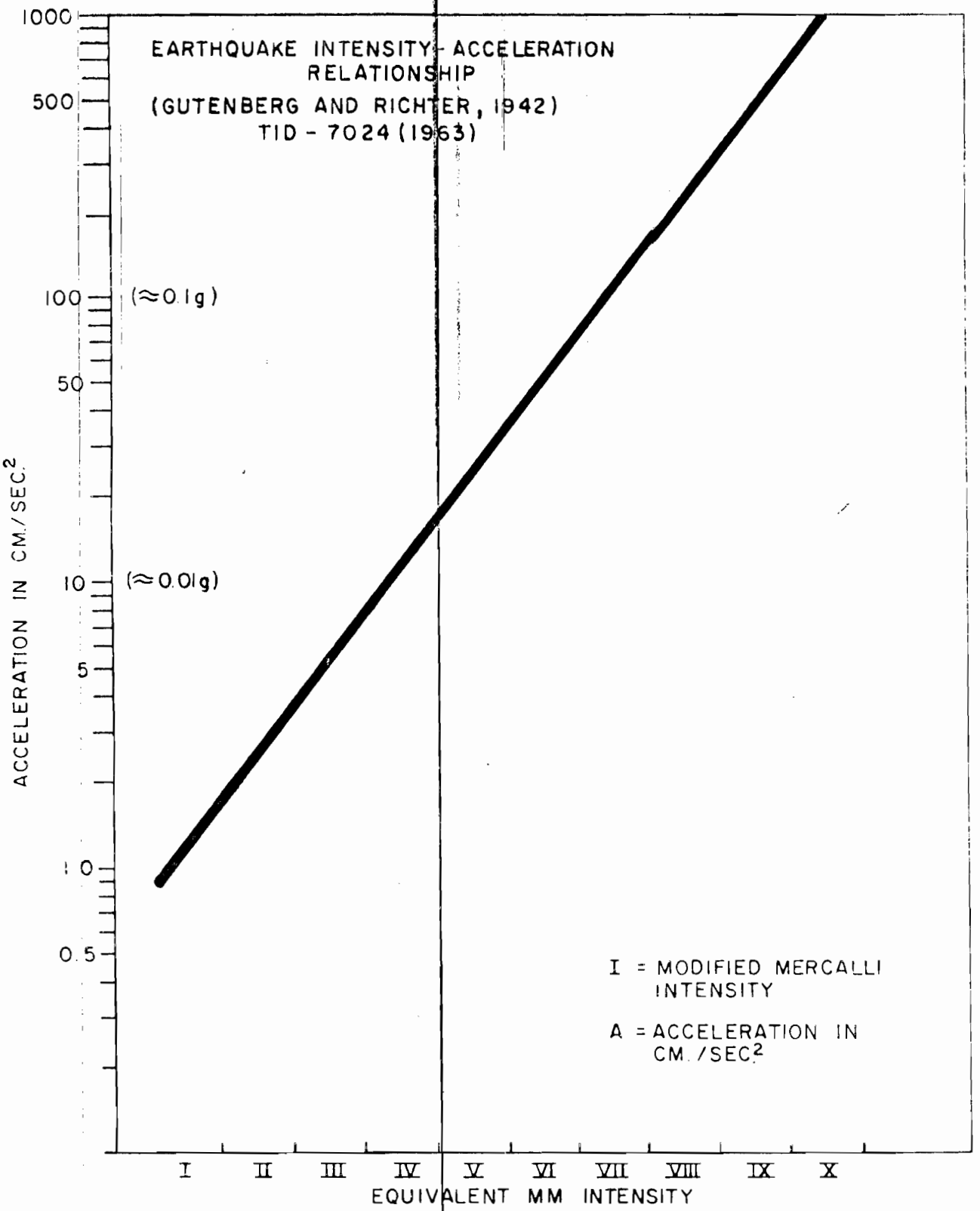
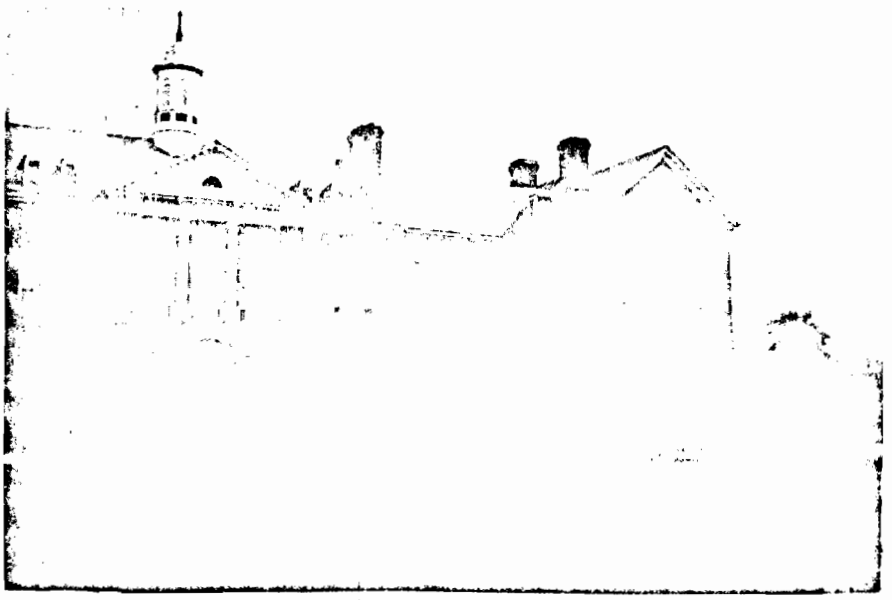


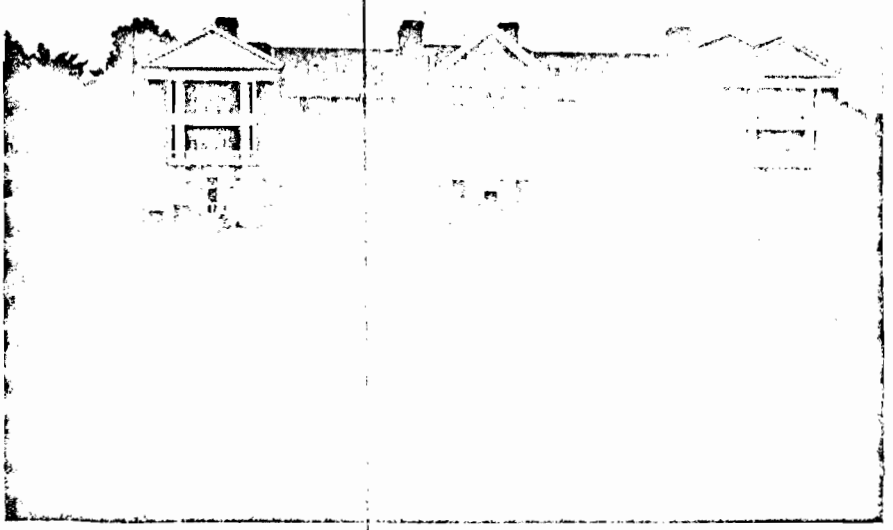
FIGURE 15

E. D'APPOLONIA CONSULTING ENGINEERS, INC. 15 DUFF ROAD PITTSBURGH, PENNA. 15235 / MR 4228 CHESTERTON, IND. 46304	EARTHQUAKE INTENSITY — ACCELERATION RELATIONSHIP	
VETERANS ADMINISTRATION WASHINGTON, D.C.	DWN BY NCF 8-2-72 / CKD BY BOSACK 8 7 72 / APPR'D BY	DRAWING NO. 72-428-6-A10

WILKINSBURG BLUEPRINT

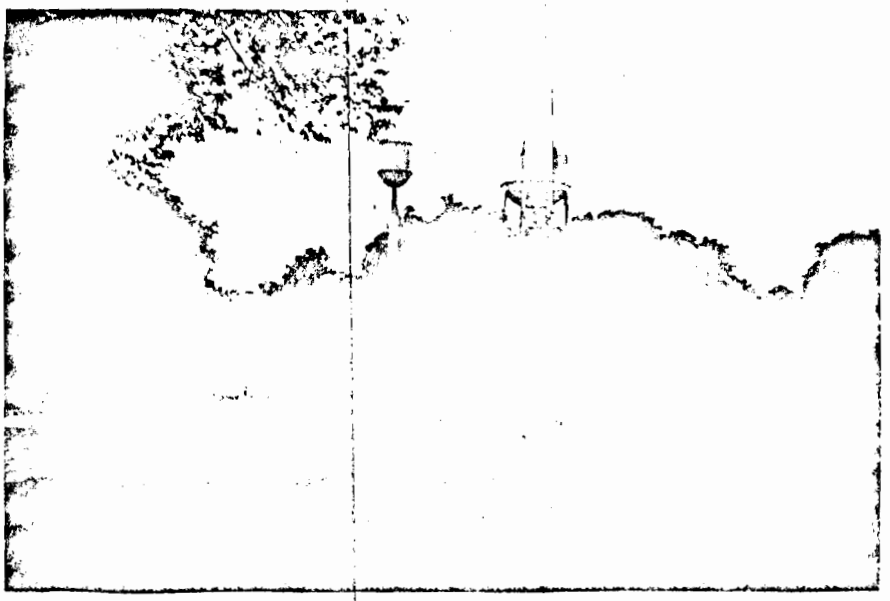


A. VIEW LOOKING SOUTH OF MAIN BUILDING.

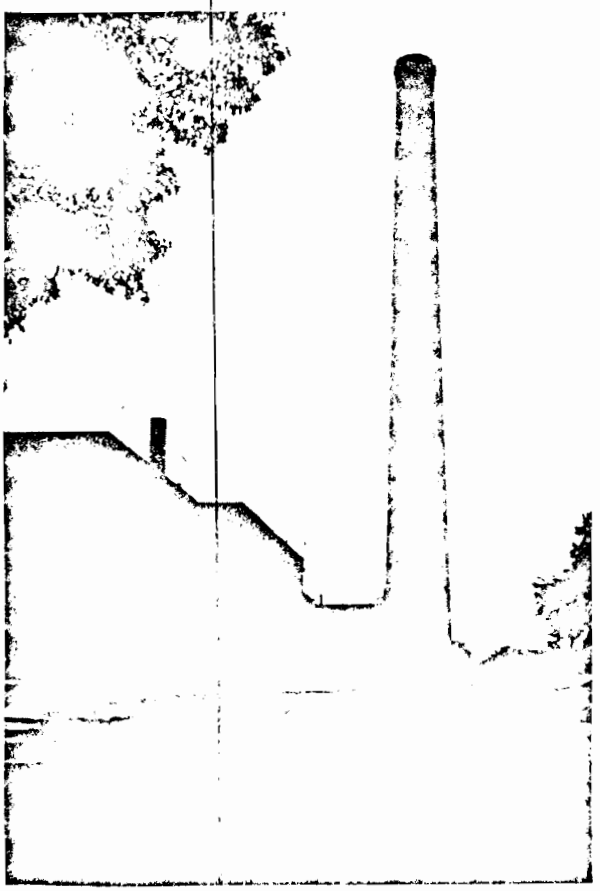


B. VIEW OF TYPICAL HOSPITAL STRUCTURE.

FIGURE 17



C. VIEW OF WATER TOWERS LOOKING WEST FROM POND.



D. VIEW OF BOILER PLANT AND CHIMNEY LOOKING WEST.

FIGURE 18

APPENDIX A

AVAILABLE DESCRIPTION OF 24 SELECTED EARTHQUAKES WHICH HAVE AFFECTED THE SALEM AREA

APPENDIX A

AVAILABLE DESCRIPTION OF 24 SELECTED EARTHQUAKES WHICH HAVE AFFECTED THE SALEM AREA

YEAR	DATE	DESCRIPTION
1807	May 1	Lynchburg, Virginia. On the morning of the first instance, a severe shock of an earthquake, was experienced at this place. The tremulous motion of the earth was such as to agitate the houses in such a manner, that the noise made by the furniture, windows, and doors, awoke the most of those who slept.
1861	August 31	Two shocks at Washington, D. C. at 5-second intervals. Felt along Atlantic coast from Washington, D. C. southward to Charleston, S. C. and westward to Cincinnati, Ohio; Louisville, Ky.; Gallatin, Tenn.; and Columbus, Ga. Bricks were shaken from Chimneys at Wilkesboro, N. C. Also reported felt at Charlotte, Raleigh, and Wilmington, N. C.
1875	December 22	Arvonia, Virginia. This earthquake was preceded by a minor shock on March 10. The December shock was of intensity VII or more. This was felt in Baltimore, Md. and Greensboro, N. C., 100 and 150 miles away, respectively and from the coast westward to Greenbrier and White Sulphur Springs, W. Va. Near the center there were five shocks in quick succession. Brick was thrown from chimneys in Goochland and Powhatan counties. Shingles were shaken from roof at Manakin and a chimney was thrown down at Wilmington, N. C. At Richmond, Va., the shock lasted 20 to 30 seconds with a deep rumbling. Plaster fell.
1885	October 9	Felt strongly at Variety Mills, Nelson County, Va.; also at Staunton and Lexington, where windows and furniture were shaken and people rushed out of buildings, and where a second shock occurred an hour later. The shock was felt in Rockingham County to the northwest and Petersburg to the east. It was claimed to be felt by one person in Washington, D.C.
1897	May 3	This shock was felt most strongly at Pulaski City, Va. Chimneys were damaged at Roanoke. Bricks fell from chimneys and plaster fell at Radford, Va. The shock was felt at Lynchburg and also at Winston-Salem, N. C. There was a rumbling like thunder in the central region. Two shocks felt at Lenoir, N. C.

APPENDIX A
(continued)

AVAILABLE DESCRIPTION OF 24 SELECTED EARTHQUAKES
WHICH HAVE AFFECTED THE SALEM AREA

YEAR	DATE	DESCRIPTION
1897	May 3	Salem, Va. "Plainly perceptible . . . . Made many houses rock, frightening the timid and causing many others wonder and astonishment." Only shock felt here since the Charleston earthquake of 1886. "Rattling the glassware on the cupboards." Only the initial shock was noticed. Most strongly felt at Pulaski, Va. Intensity about VII. Felt in most of southwest Virginia and adjacent areas. Not felt at Harrisonburg, Rocky Mountain, Lexington and Woodstock, Va.
1897	May 31	Rumbling was heard at various times between May 3 and 31, and on the latter date there was a strong shock felt from Georgia to Pennsylvania and from the Atlantic coast to Indiana and Kentucky. It was felt most strongly at Pearisburg, Giles County, Va., and is generally known as the Giles County earthquake. Old brick houses and chimneys were cracked and bricks were thrown from the chimney tops. There were fissures in the ground and small landslides in places where they were easy to start. At the Narrows it was claimed that a motion like the ground swell of the ocean was observed. Large rocks rolled down the mountains. There were loud sounds compared by veterans to that of siege guns. In Raleigh, N.C., two shocks were reported lasting 30 seconds, and chimneys were thrown down. These continued until June 6. The shock was felt at Spartanburg, S.C. and Cincinnati, Ohio. Salem, Va. Just before the shock, "a peculiar noise. . . resembling the reverberation of thunder" was heard. Bricks shaken from chimneys, goods thrown from shelves of stores, no damage. "People rushed pale and frightened from their houses." Houses "were trembling like autumn leaves in a stiff breeze."
1897	June 28	Pulaski, Va. An earthquake shock "distincty felt." Many people were awakened and frightened. No damage. (RD 6/30/97) Roanoke, Virginia. Another earthquake shock last night about 12 O'clock. Windows shaken and crockery rattled for a minute or more, but no serious damage. Salem, Virginia. "Nearly everyone who had not retired felt the earth vibrate, the vibration being accompanied by an ominous roaring." Third shock here in the last sixty days.

APPENDIX A
(continued)

AVAILABLE DESCRIPTION OF 24 SELECTED EARTHQUAKES
WHICH HAVE AFFECTED THE SALEM AREA

YEAR	DATE	DESCRIPTION
1897	September 3	Perisburg, Virginia. "An earthquake shock of decided uncomfortable proportions was experienced here last Friday morning, since which time several slighter shocks have been felt. Reports indicate that the disturbance was more severe in this immediate vicinity than elsewhere, although extending all over the county, and even throughout the adjoining territory. A slight shock was quite generally noticed between seven and eight on Wednesday, Sept 1, morning."
1897	October 21	Wytheville, Va. Felt in central and western North Carolina. Many were alarmed at Lynchburg, Va.
1899	February 13	Lynchburg, Va. Four shocks felt in western Virginia, eastern Tennessee, and western North Carolina. Almost all were awakened at Wytheville, Va.
1907	February 11	Intensity VI at Arvonia, Buckingham County, Va. Felt strongly from Powhatan to Albemarle County. Sound like thunder at Richmond. The shock lasted from 20 to 30 seconds with minor damage at a number of places.
1910	May 8	Arvonia, Va. Intensity V over an area 20 miles in diameter
1921	August 7	Intensity V in Buckingham County, Va. Strongest at New Canton. Many awakened. (Newspaper accounts stated that a meteor fell in this area on August 7.)
1924	December 25	Roanoke, Virginia. "Earth tremors that nearly shook people from their beds and that knocked pictures from the walls." Some recognized it as an earthquake. Began with a slight vibration and increased in intensity. Shook houses. Everyone awakened. Windows rattled as if shaken by a violent hurricane. A distinct rumble "heard by acute listeners." Floor of a brick building "trembled and the furniture bumped up and down on the floor with a jar" watchman at a mill thought a water tank had exploded. Severe earth tremors." About 11:30 p.m. Severe earth tremors. Pictures shaken from walls, vases crashed from tables, and buildings rocked. In one case, furniture is said to have "bumped up and down." Police and newspaper received hundreds of calls. Many thought their furnaces were exploding.

APPENDIX A
(continued)

AVAILABLE DESCRIPTION OF 24 SELECTED EARTHQUAKES
WHICH HAVE AFFECTED THE SALEM AREA

YEAR	DATE	DESCRIPTION
1927	June 10	Charlottesville and Richmond, Va. Houses rocked and people awakened. Rumbling noise.
1929	December 26	Moderate shock at Charlottesville, Va., shaking bricks from chimneys in a few cases. Felt in various parts of Albemarle County.
1955	September 28	Virginia-North Carolina border. Felt over approximately 1,700 square miles including most of Alleghany and northern Ashe counties in North Carolina, all of Grayson and parts of Smyth and Wythe counties in Virginia. Many were awakened and frightened Rumbling noise was reported.
1959	April 23	Virginia-West Virginia border. Felt over approximately 1,100 square miles of Virginia and West Virginia. Many alarmed at Eggleston and Pembroke. Chimneys damaged; wall plaster cracked. Articles fell from shelves; pictures knocked off walls. Also felt at Lindside, W. Va.
1959	July 7	Pearisburg, Va. Residents shaken by an earthquake--the third in three months. Windows and homes shook and cupboard dishes rattled. No damage. Golfers said "the earth shook under them."
		Windows rattled and dishes clattered. Brief. Caused no injuries or damage. Started at 6:20 p.m. and lasted no more than a second. Brought memories of April 23 shock.
1959	August 21	Pearisburg, Virginia. The fourth earth tremor in 4 months rocked Giles County but no injuries or damage. Shock occurred between 12:15 and 12:20 a.m. and was felt over the entire county. One resident thought one of his children had fallen out of bed.
		"A slight earth tremor" in the central Giles County area about midnight. Lasten only a few seconds. Centered near Pearisburg. Telephone switchboards flooded with calls requesting information on the tremor.
		Windows and loose objects rattled.

APPENDIX A
(continued)

AVAILABLE DESCRIPTION OF 24 SELECTED EARTHQUAKES
WHICH HAVE AFFECTED THE SALEM AREA

YEAR	DATE	DESCRIPTION
1963	January 17	Salem, Virginia. At Roanoke, Virginia, "Everything was shaking." "There was a deep rumbling noise. I didn't know what it was. It wasn't the sound of a jet breaking the sound barrier." It felt as if "several trucks were going by the house at the same time. But instead of just shaking the windows, they shook everything." The whole house quivered. I thought my furnace was going to blow up." The shocks "were scary." "The ground just started shaking. . . and the coal on top of the pile began rolling down the side." Salem, Va. "IV. Felt by several. Buildings creaked, loose objects and windows rattled. Abrupt onset; trembling motion."
1963	October 28	Near Galax, Virginia. Felt over an area of approximately 2,300 square miles of Virginia and North Carolina. Felt by all and frightened many at Galax and Oldtown. People fled from buildings at Sparta and Glade Valley, N. C. Rumbling earth noises were heard.
1968	March 8	Bluefield, Va. (Indoors, 1st floor, lying down, frame building. Felt by others, not respondent.) "Houses shook--windows rattled slightly." Damage: "Break in sewer line...Broke two places inside house and outside also." Narrows, Va. (Indoors, lying down, 2nd floor, old frame building. Felt by respondent, others.) Awakened "by either the noise or the motion. Heard only the noise of items in the house rattling. There appeared to be two distinct periods of movement." No damage. Pearisburg, Va. (Lying down, 1st floor, new frame building. Felt by respondent, others.) "A muffled explosion like sound followed by quakes." Damage: "None to our residence that I've found. I notice mortar had fallen from around a couple of beams in our church building." Pembroke, Va. (Indoors, lying down, 1st floor, brick building. Felt by respondent, others.) "Rumbling followed by explosive-type noise. Cracks in cement flower box attached to house."

APPENDIX A
(continued)

AVAILABLE DESCRIPTION OF 24 SELECTED EARTHQUAKES
WHICH HAVE AFFECTED THE SALEM AREA

YEAR	DATE	DESCRIPTION
1969	November 19	West Virginia. "Seismic waves generated by the November 19 earthquake in southern West Virginia were felt over an area of 125,000 sq. mi. in nine eastern states. Field reconnaissance of the epicentral region on November 20 and 21 revealed isolated cases of minor damage in Rich Creek, Va. (broken store window), Glen Lyn, Va. (cracked walls in a concrete block house), and Elgood, W. Va. (broken windows). Questionnaires were mailed to 500 localities. There were 421 responses which included 228 felt reports. Earthquake sounds were reported by almost all respondents who felt the shock. A maximum intensity of V was assigned to the epicentral area. "The tectonic setting of this shock is at the fault contact between the flat lying Mississippian sediments of the Allegheny highlands on the northwest and the strongly folded and thrust-faulted early Paleozoic rocks of the Valley and Ridge province on the southeast. The locale of the epicenter has a record of seismic activity including the historically significant intensity VIII Giles County, Va. earthquake of May 31, 1897, and, more recently the magnitude 4.1 Narrows, Va. shock of March 8, 1968."

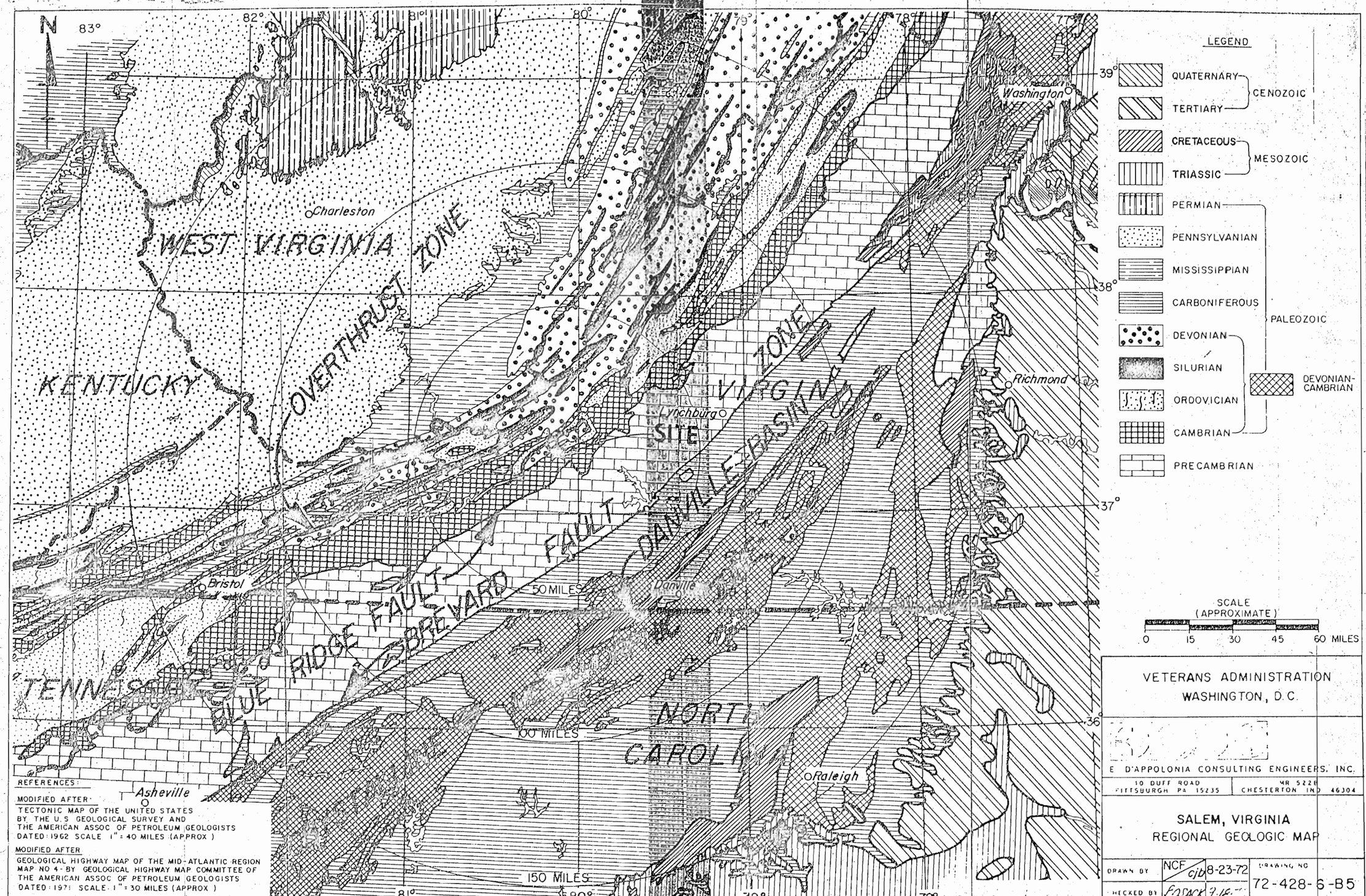
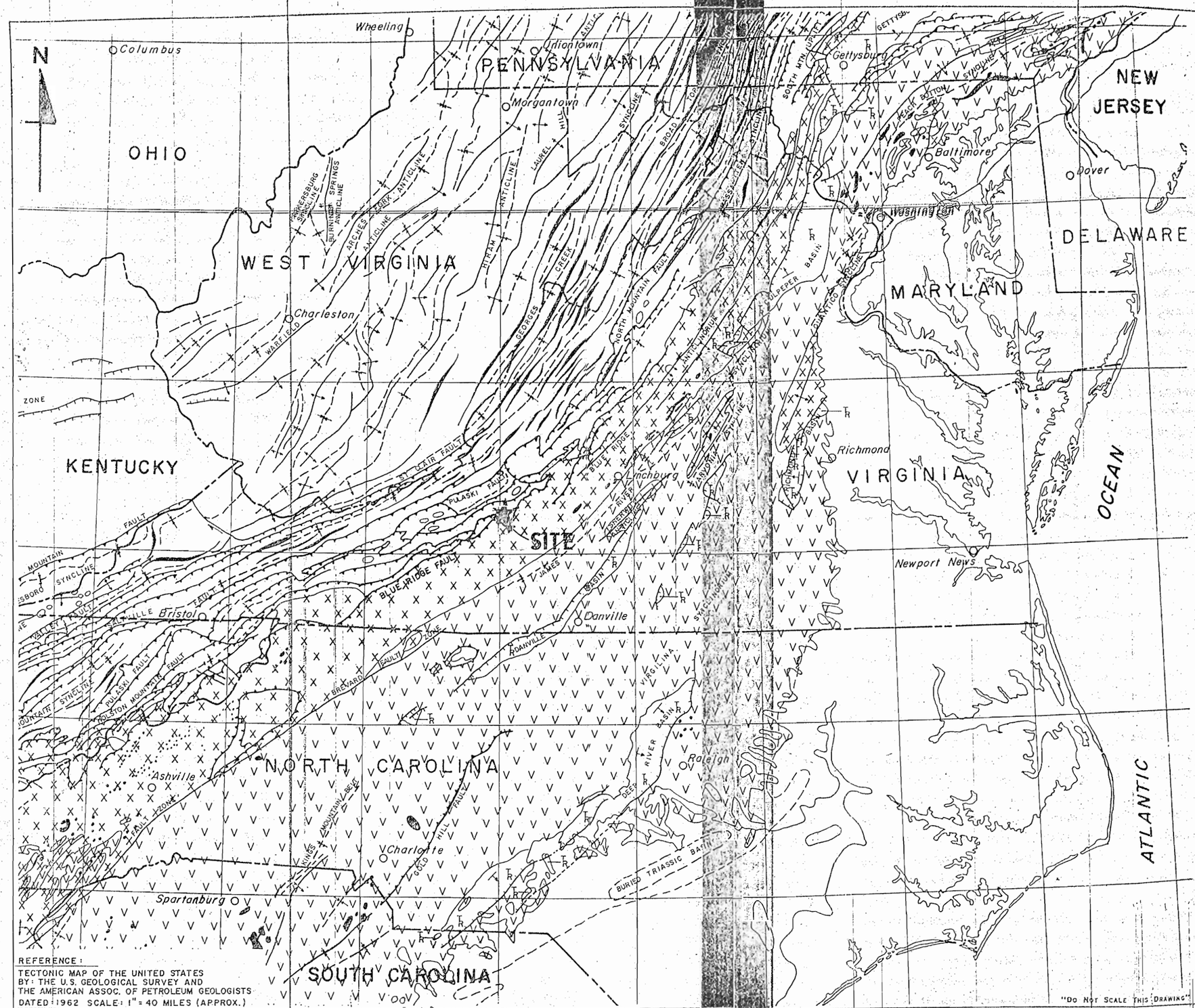

N
83°
82°
81°
80°
79°
78°
77°
39°
38°
37°
36°
Charleston
WEST VIRGINIA
KENTUCKY
OVERTHRUST ZONE
Washington
Richmond
Lynchburg
SITE
VIRGINIA
BASIN
DANVILLE
FAULT
Bristol
BREVARD
FAULT
50 MILES
Danville
BLUE RIDGE
TENNESSEE
100 MILES
NORTH
CAROLINA
Raleigh
Asheville
150 MILES
LEGEND
QUATERNARY
TERTIARY
CENOZOIC
CRETACEOUS
TRIASSIC
MESOZOIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PALEOZOIC
DEVONIAN-CAMBRIAN
PRECAMBRIAN
SCALE (APPROXIMATE)
0 15 30 45 60 MILES
REFERENCES:
MODIFIED AFTER:
TECTONIC MAP OF THE UNITED STATES BY THE U.S. GEOLOGICAL SURVEY AND THE AMERICAN ASSOC OF PETROLEUM GEOLOGISTS DATED: 1962 SCALE 1" = 40 MILES (APPROX.)
MODIFIED AFTER
GEOLOGICAL HIGHWAY MAP OF THE MID-ATLANTIC REGION MAP NO 4 - BY GEOLOGICAL HIGHWAY MAP COMMITTEE OF THE AMERICAN ASSOC OF PETROLEUM GEOLOGISTS DATED: 1971 SCALE: 1" = 30 MILES (APPROX.)
VETERANS ADMINISTRATION
WASHINGTON, D.C.
E. D'APPOLONIA CONSULTING ENGINEERS, INC.
10 DUFF ROAD
PITTSBURGH PA 15235
MR 522E
CHESTERTON IND 46304
SALEM, VIRGINIA
REGIONAL GEOLOGIC MAP
DRAWN BY NCF cjb 8-23-72
CHECKED BY E.D'SACK 7-18-
DRAWING NO
72-428-6-B5

FIGURE 1



REFERENCE:
TECTONIC MAP OF THE UNITED STATES
BY: THE U.S. GEOLOGICAL SURVEY AND
THE AMERICAN ASSOC. OF PETROLEUM GEOLOGISTS
DATED: 1962 SCALE: 1" = 40 MILES (APPROX.)

12 1/53 HERCULENE A. & B. SMITH CO., PGH., PA.

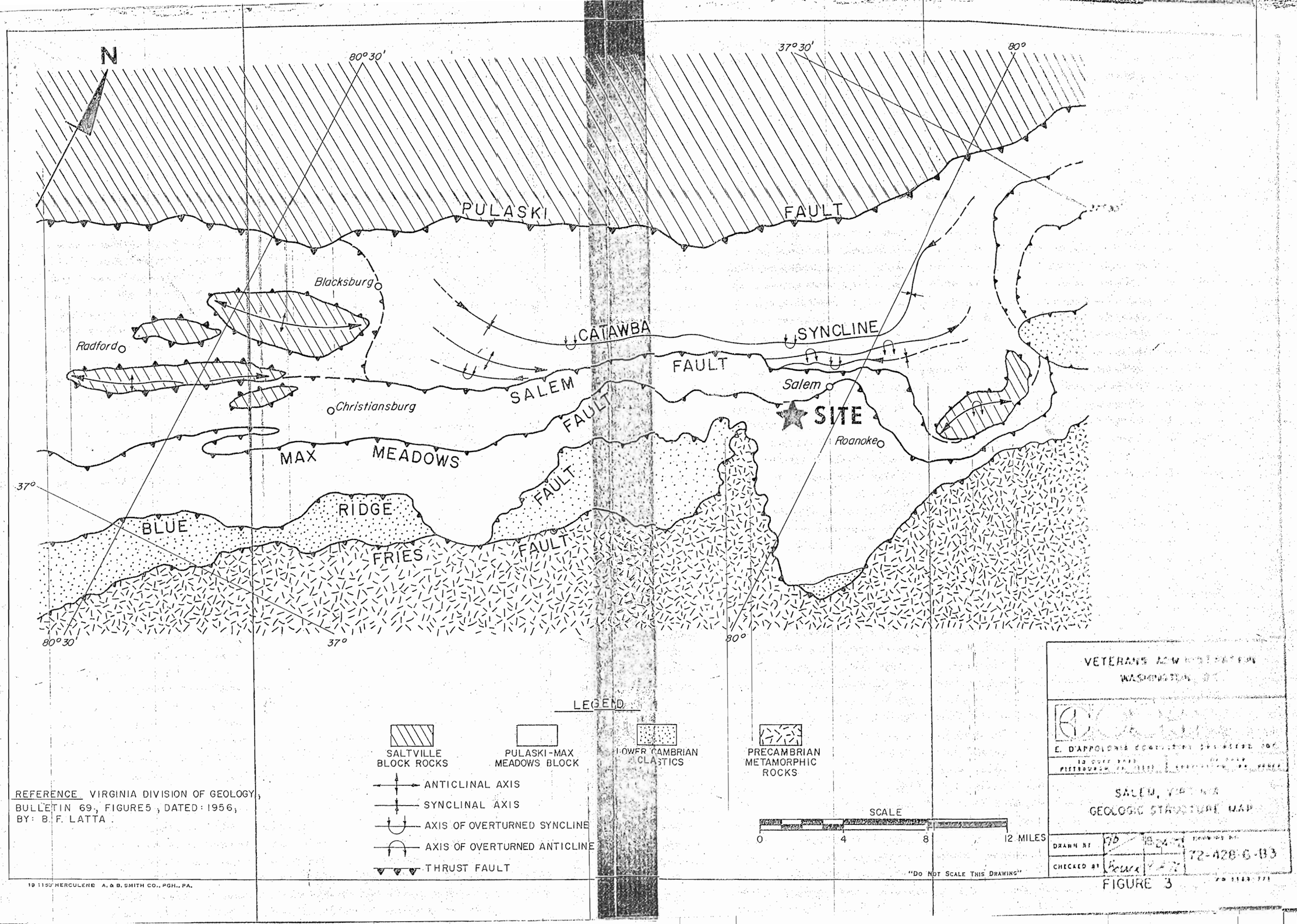
LEGEND

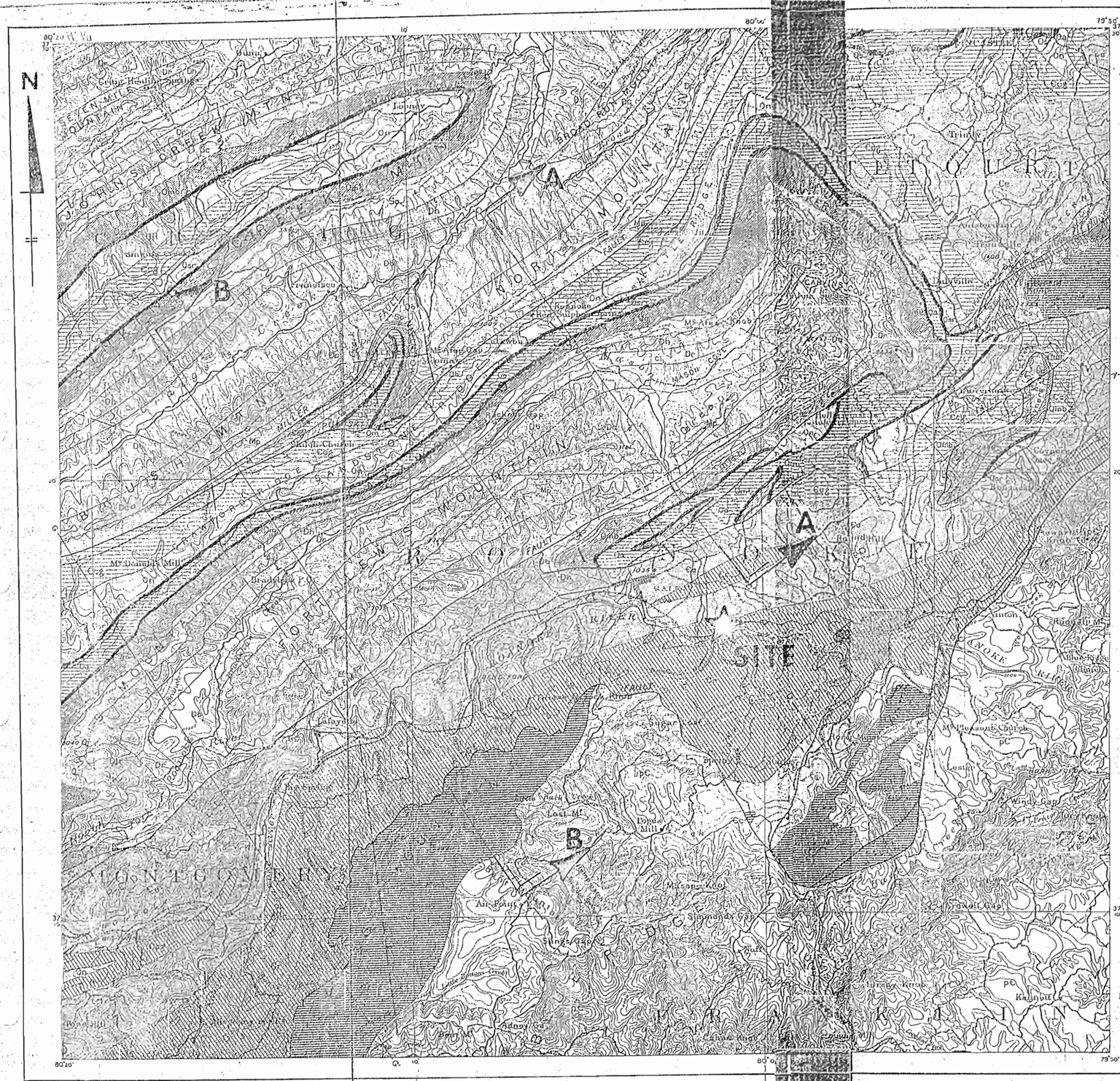
VETERANS ADMINISTRATION
WASHINGTON, D.C.

SALEM, VIRGINIA
STRUCTURAL GEOLOGY MAP

DRAWN BY
CHECKED BY

FIGURE 2


N
80° 30'
37° 30'
80°
PULASKI
FAULT
Blacksburg
Radford
CATAWBA
SYNCLINE
FAULT
SALEM
FAULT
Salem
SITE
Christiansburg
Roanoke
MAX
MEADOWS
FAULT
37°
RIDGE
BLUE
FRIES
FAULT
80° 30'
37°
80°
LEGEND
SALTVILLE BLOCK ROCKS
PULASKI-MAX MEADOWS BLOCK
LOWER CAMBRIAN CLASTICS
PRECAMBRIAN METAMORPHIC ROCKS
ANTICLINAL AXIS
SYNCLINAL AXIS
AXIS OF OVERTURNED SYNCLINE
AXIS OF OVERTURNED ANTICLINE
THRUST FAULT
SCALE
0
4
8
12 MILES
"DO NOT SCALE THIS DRAWING"
REFERENCE VIRGINIA DIVISION OF GEOLOGY, BULLETIN 69., FIGURE 5, DATED: 1956, BY: B. F. LATTA.
VETERANS ADMINISTRATION
WASHINGTON, D.C.
E. D'APPOLONIA CONSULTING ENGINEERS, INC.
SALEM, VIRGINIA
GEOLOGIC STRUCTURE MAP
DRAWN BY
CHECKED BY
72-428-6-113
FIGURE 3
19 1150 HERCULENE A. & B. SMITH CO., PGH., PA.



LEGEND :

MISS.

- **Mp** — PRICE FORMATION (SANDSTONE WITH SHALE IN UPPER PART AND THIN BEDS OF CONGLOMERATE. SOME BEDS OF COAL)

DEVONIAN

- **Dc** — CHEMUNG FORMATION (SHALE, SANDSTONE, AND THIN BEDS OF CONGLOMERATE)
- **Db** — BRALLIER SHALE (SHALE AND INTERBEDDED THIN SANDSTONE)
- **Dr** — ROMNEY SHALE (FISSILE SHALE)
- **Scd Dh** — HELDERBERG GROUP (SANDSTONE AND CHERTY LIMESTONE)

SILURIAN

- **Sc** — CLINCH AND CLINTON FORMATIONS (CLINCH FORMATION ABOVE IS SANDSTONE AND SHALE. CLINTON SANDSTONE BELOW IS QUARTZITIC SANDSTONE AND CONGLOMERATE WITH SOME THIN BEDS OF SHALE)

ORDOVICIAN

- **Omb** — MARTINSBURG SHALE (CALCAREOUS AND SANDY SHALE, THIN SANDSTONES, AND THIN BEDS OF IMPURE LIMESTONE)
- **Om** — MOCCASIN FORMATION (SANDSTONE AND SHALE)
- **Oa** — ATHENS SHALE (SHALE AND THIN BEDS OF LIMESTONE. INCLUDES CRYSTALLINE WHITESBURG LIMESTONE AT BASE)
- **Osr** — STONES RIVER GROUP (LENOIR LIMESTONE ABOVE AND MOSHEIM LIMESTONE BELOW. INCLUDES CRYSTAL--LINE HOLSTON LIMESTONE AT TOP.)
- **On** — NITTANY DOLOMITE (DOLOMITE HAVING ABUNDANCE OF CHERT ON OUTCROP.)

CAMBRIAN

- **Ꞓcg** — CONOCOCHEAGUE FORMATION (LIMESTONE, DOLOMITE, AND CALCAREOUS SHALE, WITH SOME BEDS OF CALCAREOUS SANDSTONE)
- **Ꞓe** — ELBROOK FORMATION (LIMESTONE AND DOLOMITE WITH INTERBEDDED CALCAREOUS SHALES)
- **Ꞓr** — ROME ("WATAUGA") FORMATION (SHALE WITH THIN INTERBEDDED LIMESTONES AND SOME CALCAREOUS SHALES)
- **Ꞓs** — SHADY DOLOMITE (DOLOMITE AND CALCAREOUS SHALE)
- **Ꞓc** — CHILHOWEE GROUP (QUARTZITE [ERWIN] ABOVE; SHALE CONGLOMERATE, QUARTZITE, ARKOSE, AND HEMATITE BEDS [HAMPTON AND UNICOI] BELOW)

UNCONFORMITY

PRE-CAMBRIAN

- **p€** — METAMORPHIC AND IGNEOUS ROCKS (UNDIFFENTIATED METAMORPHIC AND IGNEOUS ROCKS, INCLUDING SCHISTS, GNEISSES, GRANITES AND GABBROS)

REFERENCE: VIRGINIA GEOLOGICAL SURVEY - BULLETIN 34 DATED 1932.

NOTE

FOR SECTIONS A-A AND B-B SEE DWG. 72-428-6-B2.

SCALE

14,200 0 14,200 28,400 FT.

"DO NOT SCALE THIS DRAWING"

VETERANS ADMINISTRATION
WASHINGTON, D. C.

E. D'APPOLONIA CONSULTING ENGINEERS, INC.

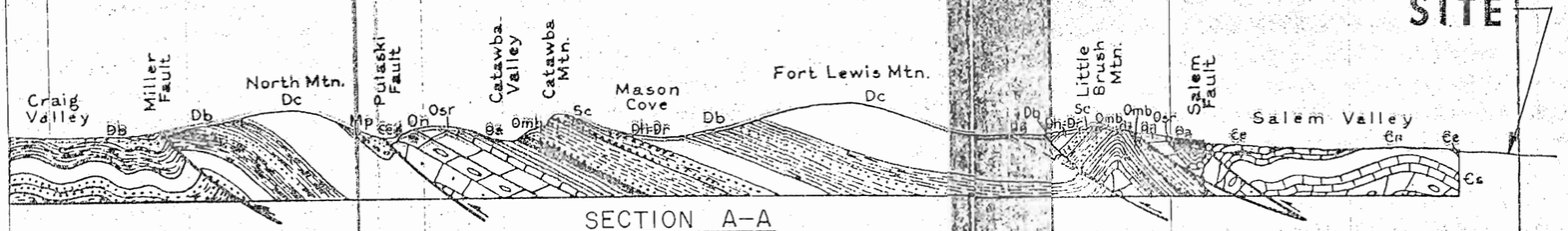
10 DUFF ROAD
PITTSBURGH, PA. 15235

MR 5228
CHESTERTON, IND. 46304

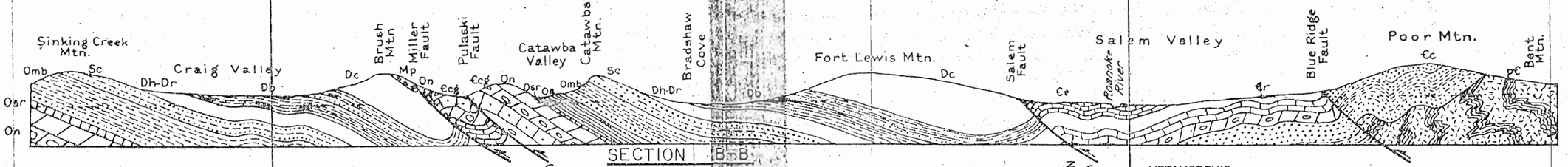
SALEM, VIRGINIA
LOCAL GEOLOGIC MAP

DRAWN BY	JJL	7-17-72	DRAWING NO. 72-428-6-B1
CHECKED BY			

FIGURE 4



SECTION A-A



SECTION B-B

LEGEND

MISS.

- **Mp** — PRICE FORMATION - SANDSTONE WITH SHALE IN UPPER PART AND THIN BEDS OF CONGLOMERATE, SOME BEDS OF COAL.

DEVONIAN

- **Dc** — CHEMUNG FORMATION - SHALE, SANDSTONE AND THIN BEDS OF CONGLOMERATE.
- **Db** — BRALLIER SHALE - SHALE AND INTERBEDDED THIN SANDSTONE.
- **Dr** — ROMNEY SHALE - FISSILE SHALE.
- **Dh** — HELDERBERG GROUP - SANDSTONE AND CHERTY LIMESTONE.

SILURIAN

- **Sc** — CLINCH AND CLINTON - CLINTON FORMATION ABOVE IS SANDSTONE AND SHALE. CLINCH SANDSTONE BELOW IS QUARTZITIC SANDSTONE AND CONGLOMERATE WITH SOME THIN BEDS OF SHALE.

ORDOVICIAN

- **Omb** — MARTINSBURG SHALE - CALCAREOUS AND SANDY SHALE, THIN SANDSTONES, AND THIN BEDS OF IMPURE LIMESTONE.
- **Om** — MOCCASIN FORMATION - SANDSTONE AND SHALE.
- **Oa** — ATHENS SHALE - SHALE AND THIN BEDS OF LIMESTONE. INCLUDES CRYSTALLINE WHITESBURG LIMESTONE AT BASE.
- **Osr** — STONES RIVER GROUP - LENOIR LIMESTONE ABOVE AND MOSHEIM LIMESTONE BELOW. INCLUDES CRYSTALLINE HOLSTON LIMESTONE AT TOP.
- **On** — NITTANY DOLOMITE - DOLOMITE HAVING ABUNDANTS OF CHERTS ON OUTCROP.

CAMBRIAN

- **Ꞓcg** — CONOCOCHEAGUE FORMATION - LIMESTONE, DOLOMITE AND CALCAREOUS SHALE, WITH SOME BEDS OF CALCAREOUS SANDSTONE.
- **Ꞓe** — ELBROOK FORMATION - LIMESTONE AND DOLOMITE WITH INTERBEDDED CALCAREOUS SHALES.
- **Ꞓr** — ROME ("WATAUGA") FORMATION - SHALE WITH THIN INTERBEDDED LIMESTONES AND SOME CALCAREOUS SANDSTONE.
- **Ꞓs** — SHADY DOLOMITE - DOLOMITE AND CALCAREOUS SHALE.
- **Ꞓc** — CHILHOWEE GROUP - QUARTZITE. SHALE CONGLOMERATE, QUARTZITE, ARKOSE AND HEMALITE BEDS BELOW.

PRE-CAMBRIAN

- **p Ꞓ** — METAMORPHIC AND IGNEOUS ROCKS - UNDIFFERENTIATED METAMORPHIC AND IGNEOUS ROCKS, INCLUDING SCHISTS, GNEISSES, GRANITES AND GABBROS.

FAULTS

NOTE: FOR PLAN AND LOCATION OF SECTIONS SEE DWG. 72-428-6-B1.

REFERENCE
VIRGINIA GEOLOGICAL SURVEY BULLETIN 34 DATED 1932.

SCALE
1 0 1 2 MILES

VETERANS ADMINISTRATION
WASHINGTON, D.C.

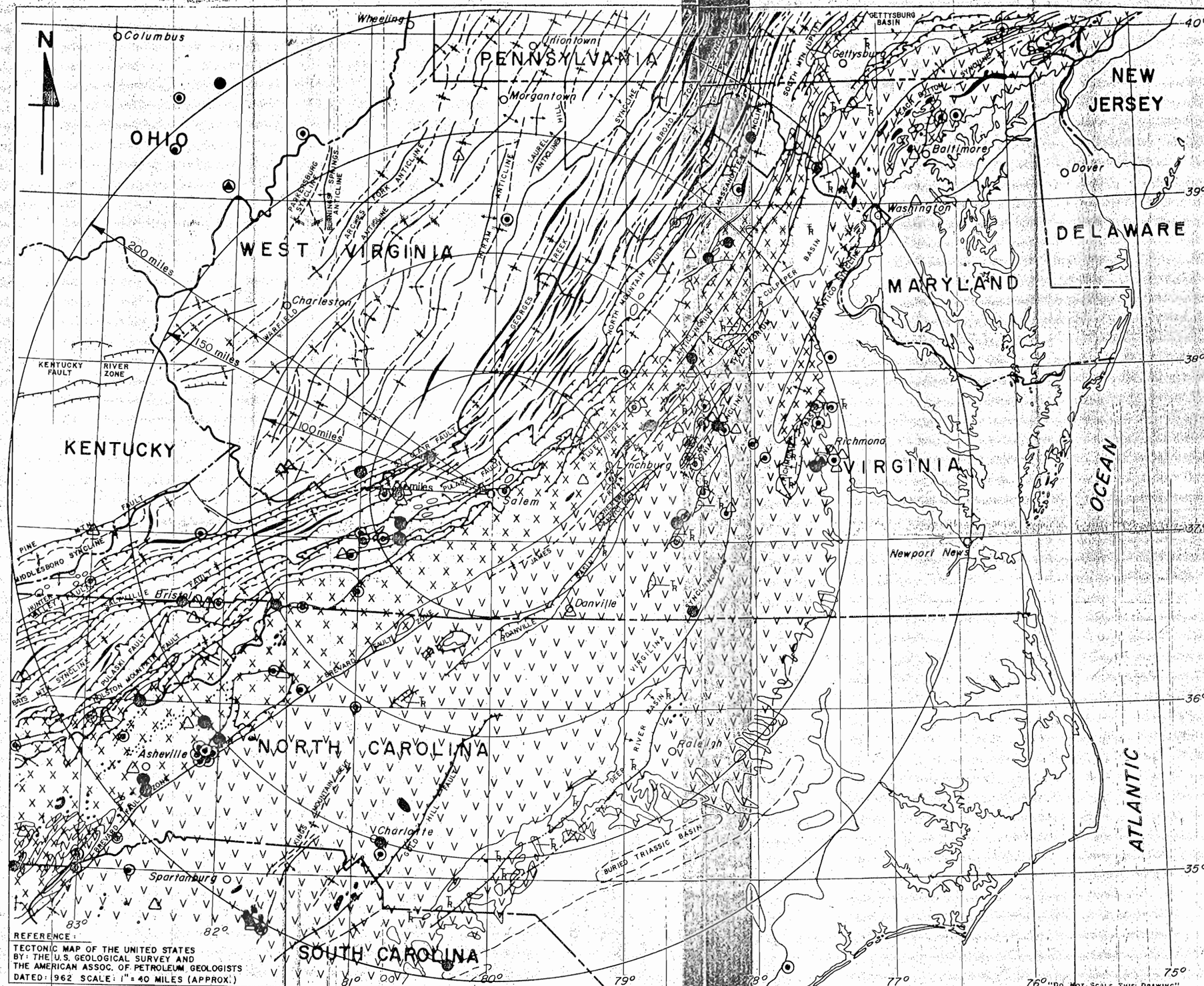
E. D'APPOLONIA
CONSULTING ENGINEERS, INC.

15 DUFF ROAD	MR 5228
PITTSBURGH PA. 15235	CHESTERTON, IND. 46304

SALEM, VIRGINIA
GEOLOGIC SECTIONS
A-A AND B-B

DRAWN BY	PJF	8-2472	DRAWING NO.
CHECKED BY			72-428-6-B2
APPROVED BY			

FIGURE 5



REFERENCE:
TECTONIC MAP OF THE UNITED STATES
BY: THE U.S. GEOLOGICAL SURVEY AND
THE AMERICAN ASSOC. OF PETROLEUM GEOLOGISTS
DATED: 1962 SCALE: 1" = 40 MILES (APPROX.)

LEGEND:

- PRECAMBRIAN ROCKS
- PALEOZOIC ROCKS
- TRIASSIC BASIN DEPOSITS
- THRUST FAULT
- NORMAL FAULT
- LATERAL FAULT
- UNCLASSIFIED FAULTS
- BURIED FAULTS
- EN ECHELON FAULT SYSTEM
- ELONGATE, CLOSELY COMPRESSED ANTICLINE
- ANTICLINAL AXIS
- AXIS OF OVERTURNED ANTICLINE
- MONOCLINAL FLEXURE
- DOME
- SYNCLINAL AXIS
- AXIS OF OVERTURNED SYNCLINE
- STRIKE AND DIP OF BEDS
- ULTRAMAFIC BODIES

- △ INTENSITY IV OR III - IV
- ⊙ INTENSITY V OR IV - V
- ● INTENSITY VI OR V - VI
- ◮ INTENSITY VII OR VI - VII
- ▲ INTENSITY VIII OR VII - VIII
- ◕ INTENSITY IX OR VIII - IX
- ⊕ INTENSITY X OR IX - X

NOTE:
EPICENTRAL LOCATIONS FOR EARTHQUAKES WITH MAXIMUM INTENSITIES OF IV OR GREATER (MODIFIED MERCALLI) ARE SHOWN.

SCALE
0 20 40 60 80 MILES

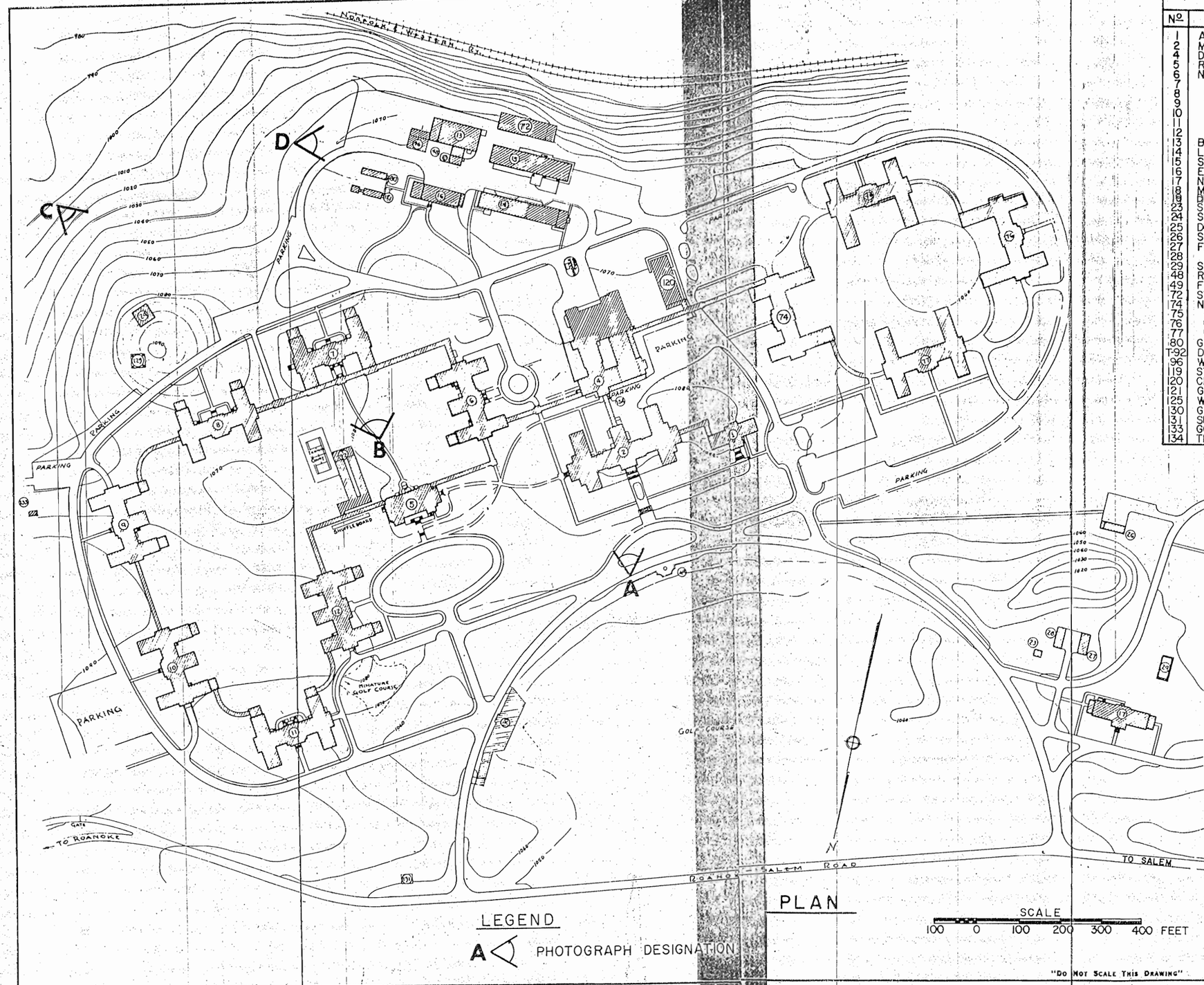
VETERANS ADMINISTRATION
WASHINGTON, D.C.

E. D'APPOLONIA CONSULTING ENGINEERS, INC.
10 DUFF ROAD
PITTSBURGH, PA. 15235
MR 5228
CHESTERTON, IND. 46304

SALEM, VIRGINIA
LOCATION OF EPICENTERS

DRAWN BY	CJB	7-12-72	DRAWING NO.
CHECKED BY			72-428-6-B4

FIGURE 8



BUILDING SCHEDULE	
Nº	BUILDING
1	ADMINISTRATION BUILDING
2	MAIN BUILDING
4	DINING HALL & ATTENDANTS QUATERS
5	RECREATION BUILDING
6	N. P. TREATMENT
7	" " (FEMALE)
8	" "
9	" "
10	" "
11	" "
12	" "
13	BOILER HOUSE, INCINERATOR AND COAL BUNK
14	LAUNDRY
15	SUPPLY OFFICES AND WAREHOUSE
16	EMERGENCY OFFICE, GARAGE AND FIRE STA.
17	NURSES QUARTERS
18	MANAGERS QUARTERS
19	DUPLEX QUARTERS
23	SEWAGE PUMP HOUSE
24	STEEL WATER TANK AND TOWER
25	DUPLEX QUARTERS
26	SIX CAR GARAGE
27	FIVE CAR GARAGE
28	" " "
29	SWIMMING POOL
48	RADIAL BRICK CHIMNEY
49	FLAG POLE
72	STORAGE AND EMERGENCY GENERATOR
74	N.P. TREATMENT
75	" "
76	" "
77	" "
80	GREENHOUSE
T-92	DOUBLE Q. HUT (BOWLING ALLEY)
96	WATER SOFTENING PLANT
119	STORAGE
120	CHAPEL
121	GREENHOUSE
125	WATER TANK
130	GRANDSTAND
131	SUBSTATION
133	GOLF CLUBHOUSE
134	TRANSFORMER PAD

LEGEND

A PHOTOGRAPH DESIGNATION

PLAN

SCALE
100 0 100 200 300 400 FEET

"DO NOT SCALE THIS DRAWING"

VETERANS ADMINISTRATION
WASHINGTON, D.C.

E. D'APPOLONIA CONSULTING ENGINEERS, INC.

10 DUFF ROAD
PITTSBURGH, PA. 15235

NR 5228
CHESTERTON, IND. 46304

SALEM, VIRGINIA
GENERAL SITE PLAN SHOWING
LOCATION OF PHOTOGRAPHS

DRAWN BY	D.J.D.	10-7-74	DRAWING NO. 72-428-6-B7
CHECKED BY	WHB	10-8-74	

PR 9268-074

FIGURE 16

19 1188 HERCULENE A. & B. SMITH CO., PGH., PA.