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REVIEW OF POTENTIAL HOST ROCKS FOR RADIOACTIVE WASTE DISPOSAL IN THE SOUTHERN PIEDMONT

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ABSTRACT

A federal geologic repository is being considered for the disposal of radioactive waste. The geological literature on the Southern Piedmont was studied to identify rock bodies worthy of field exploration for site selection. The study was geotechnical in nature and no consideration was given to socioeconomic factors. There were 13 geotechnical criteria applied in this study of the Southern Piedmont to arrive at a recommendation for further studies on 29 rock bodies.

In general, information from the literature included the geometry and depth of the rock body, the lithology and mineralogy of the body, mineral resources, and seismicity of the area. Some rock properties, such as physical, chemical, and thermal characteristics, can be inferred from the lithology and mineralogy of the rock. The subjects on which information from the literature was generally lacking were hydrology and in situ stress. This study was unable to infer the gross hydrologic characteristics from the abundant data in the literature on lithology and structure because few geologic studies report the hydrologic characteristics.

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INTRODUCTION

The major question that has delayed a demonstrated solution to the permanent disposal of high-level nuclear waste has not been one of technology to treat and handle the waste, but of where to dispose of the radioactive waste so that it will not constitute a public risk. A number of alternatives have been suggested and investigated in various degrees including:

- extraterrestrial disposal
- seabed disposal
- ice sheet disposal
- deep geologic disposal

The alternative that appears to be the the most promising is that of permanent disposal in the geologic environment; specifically, the placement of the waste in a mined cavity in the subsurface that would isolate it from the bioshpere for sufficient time to make the risk to man insignificant.

As part of the National Waste Terminal Storage Program of the U.S. Department of Energy (DOE), the Savannah River Laboratory conducted a series of literature studies related to the storage of radioactive waste in the geologic environment of the Southeast United States.

The study region for the purposes of this investigation consisted of the igneous and metamorphic rocks of the Piedmont Province, the sands and clays of the Coastal Plain, and the mudstones and shales of the Triassic basins from Maryland to Georgia. This paper will consider only the results of the Piedmont investigations.

OBJECTIVE

The immediate purpose of these studies was to designate areas that, from a geotechnical point of view, offer a potential for field exploration to investigate their characteristics and suitability for the disposal of solidified high-level radioactive waste. The work included a review of published and unpublished geologic reports and maps including academic and industrial studies. No field work was involved and no consideration was given to socioeconomic factors. State and federal geological surveys were consulted for their most recent work and discussions

were held with persons knowledgeable in the geology of the Piedmont. State Geologists of each state included in the study were kept informed as to the progress of the studies and all reports were sent to the State Geologist for their technical review prior to publication. Their detailed technical or editorial points were incorporated as necessary into the respective reports to which they applied.

The initial literature study by Acres American, Inc., of Buffalo N.Y. was completed in 1978. However, because of the geologic complexity of the Piedmont and its generally high potential for waste storage, this general study was complemented by more detailed studies of the literature and existing knowledge by recognized experts in the local geology.

Each state was reviewed on an individual basis, since most of the geologic literature, stratigraphic nomenclature, and maps are limited by state boundaries. Different philosophics have been used by the different states in their geologic mapping problems. Maryland, Virginia, and North Carolina, for the most part, classify rocks by their formation names, while South Carolina and Georgia's geologic maps are based on grouping of rocks by type.

The Piedmont of Virginia and Maryland was investigated by Dr. William Brown of the University of Kentucky (Figure 1); North Carolina by Dr. Robert Butler of the University of North Carolina; South Carolina by Dr. Donald Secor of the University of South Carolina; and Georgia by Dr. David Wenner and Kenneth Gillon of the University of Georgia. These reports were published in 1980 by SRL as DP's-1561-1564.

CRITERIA

The selection of an area that might contain a suitable site for radioactive waste repository requires the existence of a geologic formation possessing certain physical and chemical characteristics, hydrologic properties, and structural stability.

The following list (Figure 2) of geologic and hydrologic characteristics which are applicable to any region or rock type were developed and provided to the subcontractors to aid in the selection of candidate field-study areas after the information on potential host rocks in the Southeast were obtained. These criteria were used during the reviews of the Southeast Piedmont.

- The areal extend and thickness of the geologic formation should be sufficient to contain the necessary structures for a repository, and to ensure containment of the waste. Because this study did not focus on siting a repository but on locating

areas suitable for field study, the size of the designated areas were several times larger than required to contain a repository. As a rough guide, it was suggested that the recommended areas be larger than 100 square kilometers.

- The depth below ground surface should be sufficient to isolate the formation from any externally imposed environmental changes and deep enough to be in a region of extremely slow ground-water circulation. On the other hand, the depth should not be so great as to impose extremely large in situ rock stresses on the facility. As a rough guide, it was suggested that the host rock should be between 300 and 1500 m deep.

- The formation should be homogeneous. Homogeneity is desirable because it enhances the ability to extrapolate information obtained during the exploration phase. Zones of heterogeneity also tend to be avenues of ground-water migration.

- Bedding in sedimentary rocks should be relatively flat. Flat lying bedding indicates little structural deformation. Extrapolation of geologic and hydrologic characteristics is more difficult in structurally deformed areas.

- The area should be tectonically stable and be located in a zone of low seismicity, removed from active or capable faults. With the exception of the areas around Charleston, South Carolina, seismicity was not a major consideration in the southeastern United States.

- The formation should have properties that would ensure a stable excavation. In general, most metamorphic and igneous rocks in the Piedmont Province subregions fullfill this consideration.

- The geologic host formations should be of extremely low permeability and be surrounded by formations that permit no unacceptable leakage to the biosphere. These conditions should be simple and determinable. This information was generally not available for the depths of interest. Commonly, even indirect information from which a qualitative evaluation of the permeability could be made was not available. Even though these criteria are of great importance, they could not always be applied using information available from literature studies.

- The chemical exchange characteristics of the formation should favor containment. Ion exchange information was generally lacking on specific rocks, thus was not an influencing consideration in selecting study areas.

- The thermal conductivity of the rock should be high. In general, this information was not available in detail for specific host rocks and so was not an influencing consideration in selection of areas. The thermal conductivity of the crystalline rocks is generally high.

- The formation should be resistant to chemical or mechanical alterations. In general, the rocks studied do not show large differences in chemical resistance.

- The area should not possess high in situ stresses. Information on in-situ stresses is not generally available and will have to be determined during a subsequent phase of investigation.

- The area should not contain minerals or other resources of current or projected value. Information on current and estimated reserves of mineral resources is generally available and was used in evaluating the areas.

- The area should be removed from high exposure to current or projected activities of man. This subject was not addressed in this geotechnical study, except as it may relate to mineral resources. A subsequent socioeconomic study of the recommended areas should properly address this subject.

These criteria were expanded (where necessary) to apply to the individual characteristics of the subregions being investigated.

It should be realized that, in most cases, specific information could not be obtained from a literature review, and only with detailed field work can these considerations be properly addressed. However, it was necessary to establish these general guidelines for consideration in pursuing this investigation.

In surveying the literature, the most abundant and definitive information was available on the size, lithology, mineralogy, and resource potential of the rock bodies. Structural characteristics were also generally available in the literature. General characteristics of homogeneity were also available. In many instances, information was also available on the thickness, depth, and shape of the rock body. Commonly this information was interpreted from geophysical studies in the area. Certain general characteristics related to criteria could be inferred from the lithology and mineralogy; such as, stability of excavation, ion exchange characteristics, thermal conductivity, and resistance to chemical and mechanical alteration.

Information on seismicity was generally available, but was not thought to be very restrictive in selecting rock bodies in the Piedmont.

Thus the two criteria on which information is least likely to be found in the literature were hydrology and in-situ stress. This is probably also true in regions other than the Southern Piedmont. These two characteristics -- hydrology and in situ stress -- are among the more significant of the criteria and should be sought in early phases of field investigation.

Hydrologic data at depth in igneous and metamorphic rocks similar to those underlying the Piedmont Province are available from deep mines in the Lake Superior region. These data show that most mines are completely dry with no evidence of running, seeping, or moving water reported at depths exceeding 1000 m (3000 ft) (Yardley, 1975). At depths less than 1000 m (3000 ft), minor seepages occur, that increase with decreasing depth. These observations suggest that a repository in any type of igneous or metamorphic rock may be free from circulating groundwater if located at depths below 1000 m (3000 ft).

Unfortunately, knowledge concerning the hydrology of Piedmont rocks at depths below a few hundred feet is very sparse. It is known that groundwater flow in Piedmont rocks is generally restricted to interconnected joints, fractures, and shear zones. However, in general, groundwater movement decreases with increasing depth in all lithologic types. Rock units that consist of steeply dipping intermixed lithologies might be expected to provide preferred pathways for relatively deep subsurface water migration. Thus, areas of steeply dipping rocks should be avoided in selecting field-study areas.

Another factor to be considered in repository siting is the generally increasing competition for subsurface space. Although at present this does not seem to be restrictive in selection of areas for exploration in the Southern Piedmont, it may become a factor deserving greater consideration in the future. There is a trend for greater use of subsurface space for storage or protection.

Recent examples are the strategic petroleum reserves and subsurface command facilities. Many military activities utilize subsurface space. As civilization becomes more complex, utilization of the subsurface will increase. Storage of radiaoctive waste is but one of these uses.

The identification of potential study areas within the Piedmont Province has been directed chiefly toward igneous and metaigneous plutons, primarily because the pluton boundaries are

relatively easy to determine and because these plutons tend to be more homogeneous than other rock types. Plutonic igneous rocks tend to have high strength characteristics and are mineralogically stable under high temperaure and pressure. They are also generally resistant to chemical and mechanical alteration. Thermal conductivity is higher in most igneous rocks than in most sedimentary rocks with the exception of salt and quartzose sandstones.

Slates, schists, and phyllites of the Piedmont Province are generally not considered for candidate study areas because of undesirable structural characteristics that might cause difficulties in excavation and heterogenieties that would make exploration difficult.

A total of 29 areas are recommended for further consideration in the Piedmont Province: one area in Maryland, 8 areas in Virginia, 4 areas in North Caolina, 6 areas in South Carolina, and 10 areas in Georgia (Figure 3).

Most of these areas are granitic plutons with the exceptions of one gabbro and three gneisic areas.

FIGURE 1. Geotechnical Reviews of the Southern Piedmont

General - Acres American, Inc., Buffalo, N.Y.

Virginia and Maryland - Dr. William Brown, University of Kentucky

North Carolina - Dr. Robert Butler, University of North Carolina

South Carolina - Dr. Donald Secor, University of South Carolina

Georgia - Dr. David Wenner and Kenneth Gillon, University of Georgia

FIGURE 2. Criteria Used in Study

- Areal extent and thickness
- Depth below ground surface
- Homogeneity
- Structural simplicity
- Low seismicity
- Stability of excavation
- Low permeability
- Ion exchange characteristics
- Thermal conductivity
- Resistance to chemical or mechanical alteration
- Low in situ stress
- Low potential mineral or energy resource value

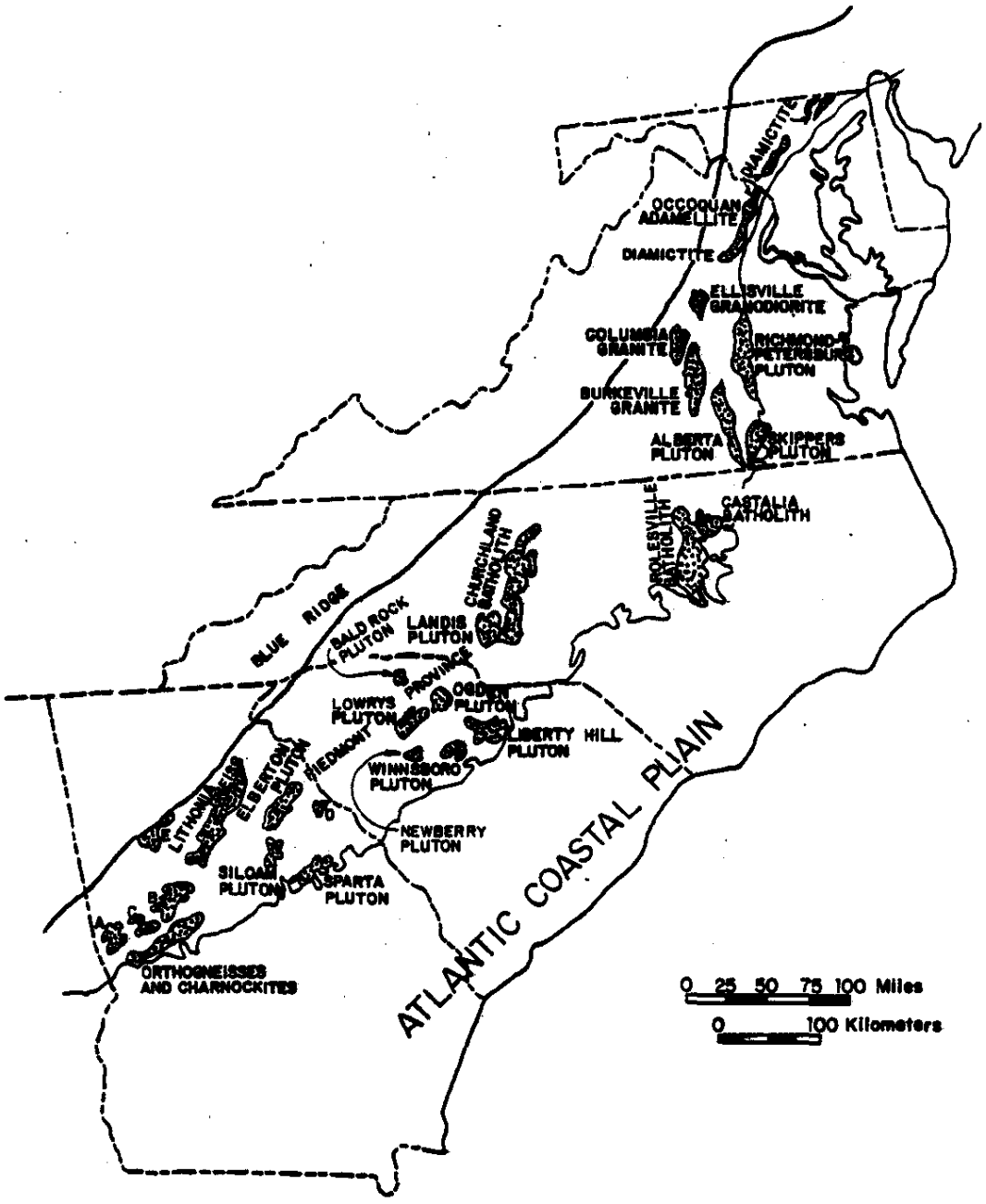

FIGURE 3. Potential Field-Study Areas within the Southeastern Piedmont Province