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GEOTHERMAL ENERGY FOR THE EASTERN UNITED STATES [1]

Geothermal energy is commonly associated with regions of recent volcanic activity and earthquake activity such as those that exist in the western part of the United States. In comparison, the relative stability of the eastern United States with respect to earthquakes and volcanic activity does not immediately suggest that a vast reserve of low-to-moderate temperature (40°C-100°C) geothermal energy may exist there. The resource would consist primarily of liquid-dominated, low-temperature systems. In order to supply housing and industrial complexes with economical heat, the resource in the East must be both large and favorably located with respect to potential utilization. This resource should be identified and developed because approximately 40 percent of our energy consumption currently is devoted to space heating. Use of geothermal energy in the East probably will be oriented first toward non-electric power applications using relatively low-temperature fluids as a source of energy for space heating and industrial processes.

Geothermal energy in the Earth's crust is stored predominantly in rock, and only subordinately in water, steam, or other fluids that fill pore space or fractures within rock. A typical rock contains approximately five times as much heat as an equal volume of water at the same temperature. Heat energy must be collected from large volumes of rock and transported to a discharge point before it can be utilized. It is the water contained in rocks and sediments of the upper part of the earth's crust that provides the transfer mechanism by which this collection and transportation can be accomplished.

Systematic efforts to estimate the geothermal resources of the entire United States have been made by the U.S. Geological Survey (White and Williams, 1975; Muffler, 1979; Sammel, 1979; Muffler and Cataldi, 1979). Attention is being directed toward the importance of potential geothermal energy in the eastern United States (Sammel, 1979). Much exploration remains to be done before the extent of the geothermal resource in the East can be adequately defined.

HEAT FLOW AND THE GEOTHERMAL GRADIENT

It is well known that temperature (T) in the earth increases with depth (z). Reliable determinations of geothermal gradients, however, usually can be obtained only from depths greater than 30 to 50 m (100 to 160 ft.) because of movement of near-surface groundwater and other disturbances. This increase with

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depth is defined as the geothermal gradient (change in temperature with change in depth, or $\Delta T/\Delta z$). In the eastern United States, measured geothermal gradients are in the range of 10 to 50°C/km (0.6 to 2.7°F/100 ft.). Of primary interest at present are locations where gradients exceed 30°C/km. Gradients higher than this arbitrary value are considered positive geothermal anomalies. Geothermal exploration is the search for such anomalies, i.e., locations where relatively high temperatures will be encountered at relatively shallow depths. Accordingly, it is important to understand the major factors that cause geothermal anomalies in the eastern United States.

The flow of heat leaving the earth by conduction is described by the equation:

$$q = k\,(\Delta T/\Delta z)$$

where q is the heat flow leaving the earth, k is the thermal conductivity of rocks, and $(\Delta T/\Delta z)$ is the geothermal gradient. In response to the geothermal gradient, thermal energy continually moves toward the earth's surface by conduction of heat through solid rock as described by the above equation.

The geothermal gradient depends on both heat flow and thermal conductivity because:

$$\Delta T/\Delta z = q/k$$

It is clear that high conduction gradients will be found where the local heat flow has a high value, and where the local thermal conductivity of rocks is low.

Because of the low thermal conductivity of rocks, heat transfer by conduction only is inadequate to develop a geothermal resource, even in the western parts of the United States where molten rock occurs near the surface of the earth. The efficient transfer and use of geothermal energy always requires convective transport of thermal energy by fluids. In any geothermal system, the most desirable locations are those in which the warmest fluids can be extracted from the shallowest depths. These locations are usually, but not always, coincident with regions where the conductive heat flow is highest.

HEAT FROM RADIOACTIVITY

Birch and others (1968), Lachenbruch (1968), and Roy and others (1968) showed that the local heat flow in the eastern United States has a well-defined relationship to the concentration of uranium and thorium in fresh, unweathered samples of crystalline rock (mostly granite) collected from the surface of the earth. The generation of heat by the radioactive decay of naturally occurring isotopes is a process that converts mass to energy according to Einstein's equation $E = mc^2$. Isotopes of only three elements occur in sufficient abundance and have half-lives sufficiently long relative to the age of the earth to be important for heat generation from radioactivity in rocks (Birch, 1954). These are isotopes of uranium (U), thorium (Th), and potassium (K). Radioactive isotopes of these elements have half-lives of the order of 1 billion years or more. The heat contribution, H, in calories per gram of rock per year is given by the equation:

$$H = 0.72\,U + 0.20\,Th + 0.27\,K$$

where U is uranium content of rock in parts per million, Th is thorium content of rock in parts per million, and K is potassium content of rock in weight percent. From the above equation, it is apparent that decay of a uranium atom produces about four times as much heat as the decay of thorium atom. However, thorium/uranium ratios in many granitic rocks are about equal to four so that thorium is usually as important as uranium for heat generation. The heat generated from uranium and thorium in typical granites is about 85-90 percent of the total; heat from potassium decay is considerably less important, about 10-15 percent. The immediate implication of this is that the distribution of uranium and thorium in the upper 10 to 15km (33,000 to 50,000 ft.) of the earth's crust is primarily responsible for the observed lateral variations in surface heat flow over the eastern United States.

Granite plutons and batholiths relatively enriched in uranium and thorium are exposed in the Piedmont province (Figure 1). The basement rocks exposed in the Piedmont are concealed to the southeast by a seaward-thickening wedge of sediments beneath the Atlantic Coastal Plain. To date, no basement material has been recovered from beneath the Atlantic Coastal Plain with a heat generation capacity as high as some plutons of the Piedmont, but such rocks undoubtedly exist because heat flow as determined in Coastal Plain sediments is high, about 80 milliwatts per square meter (mW/m^2) in parts of Maryland, Virginia, and North Carolina.

TYPES OF GEOTHERMAL RESOURCES IN THE EASTERN UNITED STATES

Geothermal resources in the Appalachian Mountain System and the Atlantic Coastal Plain may be grouped into four types:

I. Water-saturated sediments of low thermal conductivity overlying radioactive heat-producing granites

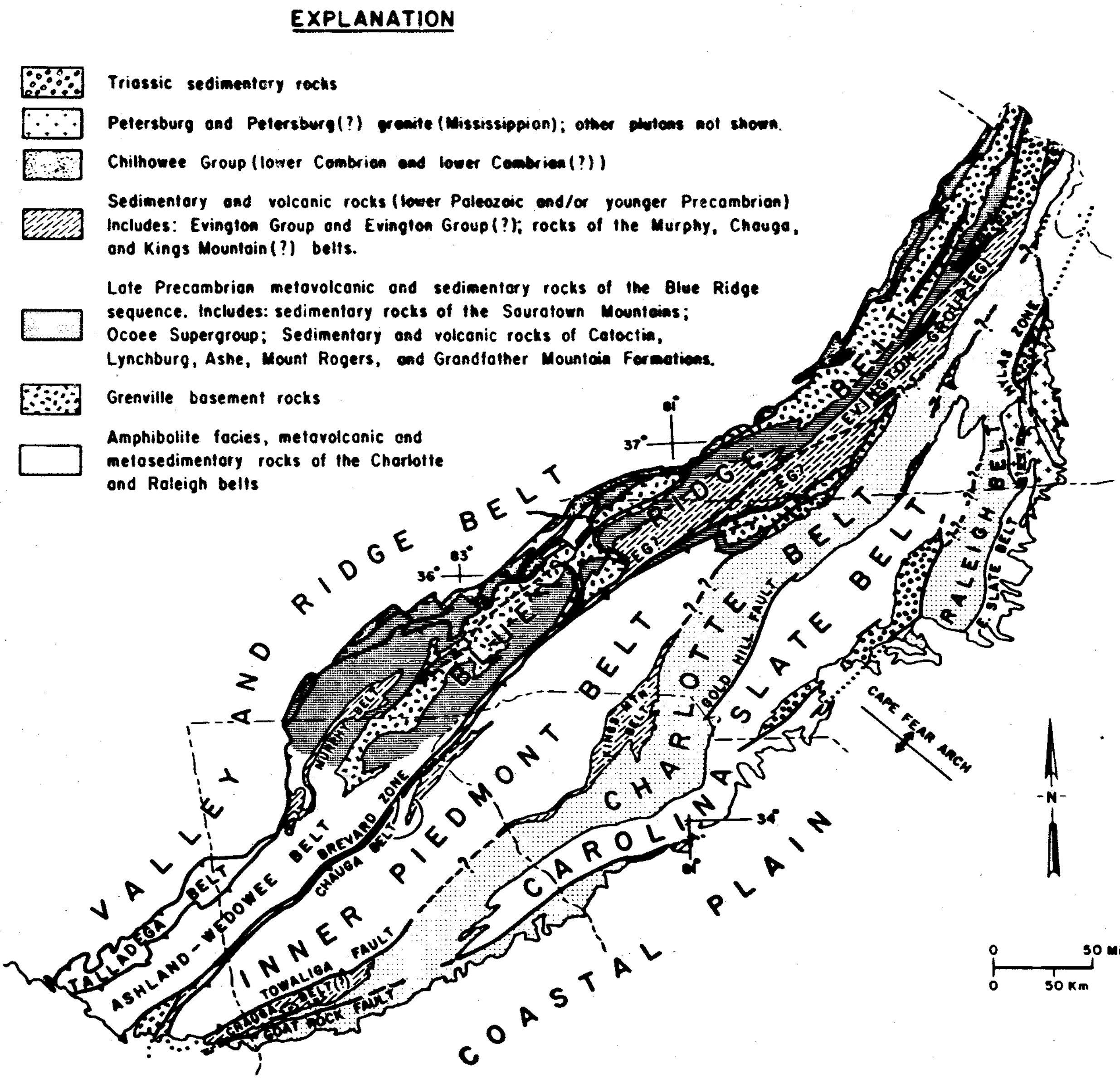

Figure 1. Geologic map of central and southern crystalline Appalachians. Modified 1977 by L. Glover, III, and A. Bobyarchick, primarily from: Fisher and others (1970), Rankin (1975), and Pichering (1976).

II. Areas of normal geothermal gradient
III. Hot and warm springs emanating from fault-fracture zones as a result of leakage from greater depths
IV. Hot dry rock, especially radioactive granites beneath sediments of low thermal conductivity

The resources are listed in the order in which they are most likely to be exploited in the East on a large scale.

The Radiogenic Model

Resource Type I is referred to as the "radiogenic model" (Costain, Glover, and Sinha, 1980) and is shown in Figure 2. Temperature gradients are steep in areas where the resource exists because basement rocks are covered with a thick sequence of sediments of relatively low thermal conductivity (Figure 3). The concentrations of uranium and thorium in granites are low, a few parts per million, but these concentrations

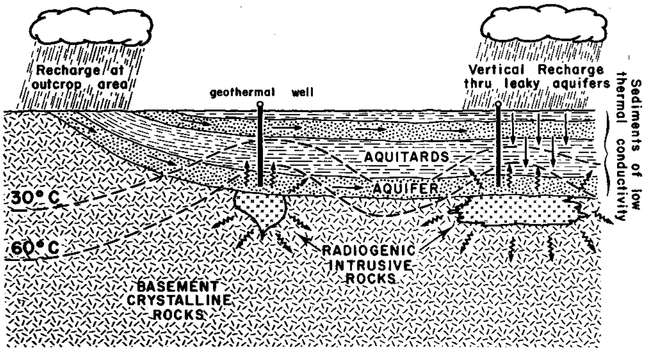

Figure 2. Radiogenic model showing concealed granite intrusions in basement rocks beneath insulating sediments of the Atlantic Coastal Plain.

are higher than those in basement rocks into which th granite is intruded (country rocks). In spite of thes low concentrations, large volumes of granite with uranium and thorium will increase the subsurface temperature substantially, and relatively higher temperatures will be found at shallow depths within sediments that overlie such bodies, as indicated in Figure 3. Heat flow from the decay of locally concentrated radioactive elements can be more than a factor of 2 greater than the earth's normal heat flow. In some parts of New England, for example, radiogenic heat from granite consititutes two-thirds of the total heat flow leaving the earth (Birch and others, 1968). An understanding of the distribution of granites and of uranium and thorium in the basement rock is therefore important in order to define locations where the highest temperatures occur at the shallowest depths.

Optimim sites for the development of geothermal energy in the eastern United States probably will be associated with the flat-lying, relatively unconsolidated sediments that underlie the Atlantic Coastal Plain. These sediments have a relatively low thermal conductivity, and there are many potential aquifers within the sandy, deeper parts of the sedimentary section that probably contain large quantities of hot water.

Normal Geothermal Gradient Resources

This resource is widely available throughout much of the United States (Sammel, 1979). The entire Atlantic Coastal Plain would fall into this resource category. Another area with moderate resource potential lies west of the Blue Ridge where thick sequences of Paleozoic sediments blanket crystalline basement rocks of

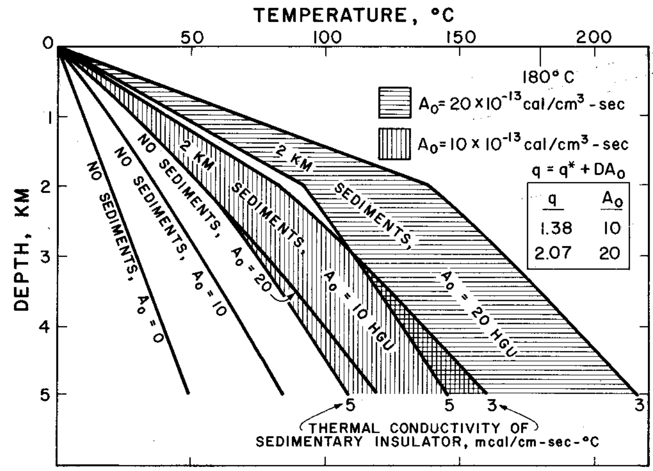

Figure 3. Theoretical curves showing effect of a) heat generation in basement rocks and b) insulating sediments, of low thermal conductivity. Curve labeled "no sediments, A_o=10" effect of addition of heat-producing elements such that heat production is 10^{-12} cal/cm^2-sec. Patterned regions show temperatures at depth in sediments and granite for thermal conductivity of sediments ranging between 3-5 TCU for heat production in basement granites of 10 HGU (vertical lines) and 20 HGU (horizontal lines) (1 TCU = 1 thermal conductivity unit=10^{-3} cal/cm- °C ; 1 HGU=1 heat generation unit=10^{-13}cal/cm^3-sec; q=het flow; A= rate of heat generated per volume of rock. D=depth in cm (1km=10^5 cm), mcal=millicalories).

unknown heat generation. In such areas, thick shales will have a higher thermal gradient within them than would carbonate rocks or sandstones, even where the heat flow is normal.

As noted by Sammel (1979), the low-temperature geothermal waters of the central and eastern United States are known or inferred to be areally extensive. Their utlization is dependent on identification of locations where conditions are economically favorable for recovery.

Warm Springs in the Eastern United States

In the northwestern part of Virginia and adjacent parts of West Virginia, there are approximately 100 springs that have temperatures ranging from slightly above the mean annual air temperature (9-12°C) to approximately 41°C. In Virginia, nearly all of the warm springs appear to issue from limestone formations of Middle Ordovician age where these formations are brought to the surface by anticlinal folding. The geographic distribution of the springs has been described by Reeves (1932) and summarized by Sammel (1979). The hydrology and geochemistry of the springs have been studied by Hobba and others (1977;1979).

The hottest springs are located in the Warm Springs anticline in Bath and Alleghany counties in Virginia where four groups of springs known as the Warm Springs, Hot Springs, Healing Springs, and Falling Springs occur. Each group of springs consists of at least three separate springs in close proximity. All of the warm springs in the valley are grouped near topographic gaps apparently associated with vertical transverse fracture zones (linears) that cut across adjacent folds to the east and west (Geiser, 1976). Faults and/or joints play an important role in the location of the warm springs, because warm springs are always near gaps. The gaps probably have developed along zones of increased fracture or joint density. At one location, the Warm Springs anticline, there is evidence of offset along a fault. The anticline has a near-vertical to overturned western limb, where there are several prominent topographic gaps. Resistant Silurian quartzites are responsible for the high topographic relief in the area. There are no data to support suggestions that the source of heat for the springs is a still-cooling pluton at depth. In fact, the heat flow in the area is normal (Perry and others, 1979).

The origin of the warm springs in northwestern Virginia as proposed by Perry and others (1979) is as follows. Meteoric water enters the steeply-dipping Silurian quartzites on the northwest limb and permeates to depths sufficient to heat the water in the presence of the normal geothermal gradient (about 10°C/km near Hot Springs, Virginia). Groundwater flowlines near the surface and halfway between the topographic gaps are essentially vertical within the quartzites because of the boundary condition imposed by the topographic relief between the gaps. At depth, the water moves horizontally and intersects east-west trending, vertical, transverse fracture zones. The temperature of the water issuing from springs located along the transverse fracture zones depends on the depth reached by the water, and on the degree of its mixing with cooler, shallower water. Mixing takes place as the meteoric water rises to the surface along the relatively permeable fracture zone. In support of this model, there appears to be a correlation between the presence of water gaps, the occurrence of warm springs, and the occurrence of nearby, steeply dipping quartzites in areas other than at Hot Springs, for example at Bolar, Virginia. Implicit in the model is the requirement that the aquifer have an uninterrupted vertical relief large enough to allow the water to reach depths sufficient to heat it.

A similar situation may exist where the New River crosses the Narrows fault zone near Pearisburg, Virginia. An abnormally high heat flow value of 123 mW/m^2 was observed in a hole drilled by VPI & SU on the hanging wall of the Narrows fault. Water from great depth may be rising along the Narrows fault or along a transverse fracture zone beneath the hole and exiting in the river bottom (the topographic low).

Large quantities of heat can be obtained from a warm spring resource. The water flow from the warmest spring (Boiler Spring; 40°C) at Hot Springs, Virginia, is 86,220 gallons/day (Hobba and others, 1979). The flow at Bolar Spring (22°C), about 20 km (12 miles) northeast of Hot Springs, is about 3,000,000 gallons/day. Because the total amount of heat released at the larger but cooler springs is much greater than that released at the smaller but warmer springs (Hobba and others, 1979, Table 3), the geothermal potential of the larger, cooler springs is much higher.

Hot Dry Rock in the Eastern United States

Rocks hot enough to be a potentially useful energy source exist everywhere, but it must be possible to reach the depths of these rocks economically. Hot dry rock is rock of extremely low permeability. The resource is utilized by fracturing the rock, injecting water into the fracture system, and then extracting the heated water. Regional heat flow data indicate that almost 250,000 km^2 in the western U.S. is underlain by hot dry rock at temperatures above 290°C at a depth of 5 km (Pettit, 1979).

Los Alamos Scientific Laboratory, a leader in the development of hot-dry-rock resources, predicts that there are large such resources in the East, and that the most likely heat source is radioactive granite (Pettit, 1979). At any given depth, temperatures in hot dry rock in the East will be lower than those in the West because of the high level of tectonic activity and vulcanism in the West. The range of temperatures to be expected in the East can be estimated from Figure 3. A recent report (Schubert and Johnson, 1980) evaluates the hot-dry-rock potential near Wallops Island, Virginia.

EXPLORATION FOR GEOTHERMAL RESOURCES IN THE EASTERN UNITED STATES

Regional Geology

Uranium and thorium concentrations can be correlated with rock type, and magma source with regard to its chemistry, state of differentiation, age, geographic locality, grade of metamorphism, and hydrothermal alteration. Locations of areas of high heat flow can be inferred from the regional and geologic framework (1979). This is particularly important for the Atlantic Coastal Plain where regional geology of the basement beneath the sediments cannot be studied directly and the distribution of rock types must be interpreted from available drill core, gravity, magnetic, and seismic data.

The increased concentrations of uranium, thorium, and potassium in granitic rocks are the primary cause of elevated heat flow in the eastern U.S. Not all granites are similarly enriched, and characterization of the granites is necessary to identify those with the highest potential. Plutons of Paleozoic age in the Blue Ridge and Piedmont generally fall into three age groups: 650-520 m.y., 450-385 m.y., and 330-264 m.y. (Wright and others, 1975: Fullagar and Butler, 1979; unpublished data at VPI & SU). Plutons of the two earlier groups, which have been metamorphosed, have low heat generation values and therefore low heat flows. Regional metamorphism and deformation play a key role in the evolution and location of radioactive heat sources. Uranium and thorium in particular are mobilized in fluids and granitic melts that evolve during regional metamorphism. Under the influence of gravity, chemical gradients, thermal gradients, and deformation, much of the uranium and thorium may be permanently lost from or homogenized in a metamorphic terrain. Thus, in general, the younger synmetamorphic and postmetamorphic granites are of greater interest than older granites as potential radiogenic heat sources (Speer and others, 1979).

In addition to age, variation in heat generation and heat flow can be correlated with mineralogy and chemistry of the Piedmont granites, features which reflect the source of the magma and the physical conditions during and subsequent to crystallization. Higher heat generation and heat flow values occur in more evolved granites, those with increased fluid contents and where there has been significant contributions of material from the crust.

Heat Flow Data

The most important geophysical data for the exploration of geothermal resources are heat flow measurements (Costain, 1979). A hole drilled to a depth of 300 m (1000 ft.) usually will pass through several rock types, each with a different thermal conductivity. Because heat flow is the same at any depth in the hole, decreases in thermal conductivity must be matched by increases in the geothermal gradient. This means that for any given heat flow, the highest geothermal gradients occur in rocks with the lowest thermal conductivities. Thus, higher temperatures will be reached at shallower depths if holes are drilled into thick sequences of shale instead of dolomite or sandstone, because shale is a poorer heat conductor (better insulator) than dolomite or sandstone. The unconsolidated clays of the Atlantic Coastal Plain have lower average thermal conductivity than shales and are excellent insulators.

It is apparent that the coincidence of high heat flow and low thermal conductivity will result in the highest subsurface temperatures at the shallowest depths. Both of these characteristics are found in the radiogenic model for the Atlantic Coastal Plain because it is associated with (1) high heat flow from radioactive decay, and (2) low thermal conductivity of overlying, relatively unconsolidated sediments which insulate the source of heat.

The development of a resource will depend on the porosity and permeability of the sediments and the availability of a user.

Seismic Data

Standard techniques of reflection seismology are essential to define the subsurface geometry of potential geothermal resources in the eastern United States. In general, reflection seismology offers the highest resolution of any geophysical method used to investigate subsurface geology. In particular, reflection seismology is appropriate to:

(1) determine depth to crystalline basement,
(2) define faults in the basement and/or overlying sediments, and
(3) Examine lateral and vertical changes in velocity in th sedimentary section which can be correlated with lateral changes in thermal conductivity or changes in thickness of potential deep aquifers.

Gravity Data

The magnitude of the gravitational field at any location on the surface of the earth depends locally on the depth and densities of the rock types. Because granite usually is less dense than the country rocks into which it has been emplaced, granite occurrences commonly can be located by negative Bouguer gravity anomalies.

Magnetic Data

The normal magnetic dipole field of the earth is distorted by the presence of magnetic minerals (mainly magnetite) in rocks. Granite plutons usually contain a small percentage of magnetite, and magnetic minerals can be formed in a contact aureole in rocks into which the pluton is intruded (Speer, 1979). Thus, positive magnetic anomalies may be associated with granites. Granite bodies concealed beneath the sediments of the Atlantic Coastal Plain might be detected by their magnetic signatures if the depth of burial is not too great and if metamorphism has not destroyed the magnetic properties of the mineral assemblages. Examination of existing magnetic data obtained over the Coastal Plain suggests that a number of undiscovered granitic plutons may occur in the basement.

ATLANTIC COASTAL PLAIN

The Atlantic Coastal Plain is underlain by a wedge-shaped body of chiefly unconsolidated sediments that thickens from west to east. There are structural features superimposed on the wedge that influence the thickness of the sedimentary section; thickness can reach 3 km. One of the principal objectives of the geothermal program at Virginia Polytechnic Institute and State University is to locate uranium-bearing and thorium-bearing heat-producing granites in the basement rocks beneath potential aquifers within the Atlantic Coastal Plain sediments.

Results of Geothermal Exploration on the Atlantic Coastal Plain

During 1978-79, 49 holes were drilled to a depth of approximately 300 m (1000 ft.) on the Atlantic Coastal Plain from New Jersey to North Carolina. Test holes were drilled to determine the geothermal gradient and thermal conductivity, i.e., the heat flow, within the sediments of the Atlantic Coastal Plain. The geographic distribution of the holes and the results of the drilling program in the Piedmont and on the Atlantic Coastal Plain are given in a series of reports to the Department of Energy (Costain, Glover, and Sinha; 1979); these are available from the National Technical Information Service, Springfield, Virginia 22151. Results from the Coastal Plain have been summarized by Lambiase and others (1980). The locations of the drill sites were chosen on the basis of:

(1) gravity data,
(2) magnetic data,
(3) known thickness of Coastal Plain sediments,
(4) apparent thermal anomalies based on geothermal gradients determined in existing holes,
(5) available basement core data,
(6) suitable sites for the evaluation of the radiogenic pluton model, and
(7) proximity to energy markets.

Because differing concentrations of uranium and thorium in basement rocks affect the geothermal gradient in the overlying sediments, it was important to locate several holes both on and off potential field anomalies. The Portsmouth, Virginia, gravity anomaly (Figure 4) is an excellent example of a negative gravity anomaly over a confirmed concealed heat-

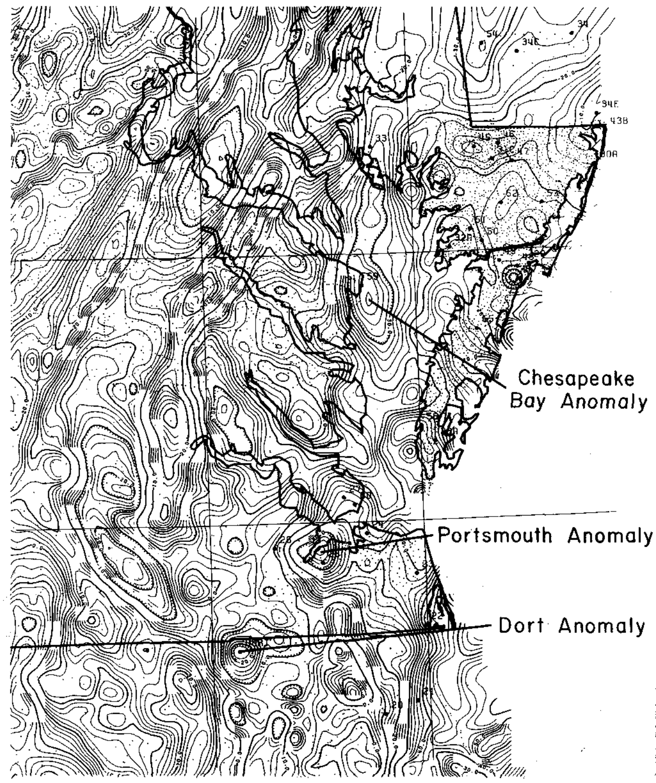

Figure 4. Gravity map of parts of Delaware, Maryland, Virginia and North Carolina. Contour interval is 2 milligals.

producing granite. A magnetic anomaly is also present. The overlying sediments are about 600 m (1900 ft.) thick. A test hole was drilled into granite to a depth of about 600 m, and 90 m (300 ft.) of continuous granite core were recovered. The geothermal gradient in the hole over the gravity anomaly is about 42°C/km; the gradient is 27°C/km in a hole drilled nearby (12 km) but off the anomaly in the same lithologic sequence of sediments. The heat flow over the granite is about 79 mW/m^2; off the anomaly at Isle of Wight the heat flow is only 49 mW/m^2. This is excellent confirmation of the radiogenic pluton model. Another gravity anomaly at Dort, North Carolina is associated with a post-metamorphic granite with high heat flow beneath Coastal Plain sediments.

Results of First Deep Geothermal Test on the Atlantic Coastal Plain

One promising area for geothermal development discovered to date in the northern Atlantic Coastal Plain is on the Eastern Shore in the area between Crisfield in southern Maryland and Oak Hall in northern Virginia. A test site was located at Crisfield, Maryland because of the known high geothermal gradients there and the moderate depth to basement.

Upon completion of the Crisfield well, it was discovered that the "basement" seismic reflector marked the top of a poorly known 75-m-thick, (locally) indurated, high-velocity section of Coastal Plain sediments, and that true crystalline basement was at the base of this indurated sequence at a depth of 1.36 km (Gleason, 1979). Temperature at the top of crystalline basement was found to be approximately 58°C.

The temperature predicted at the base of the Coastal Plain sediments at Crisfield was about 16 percent less than the actual temperature; the difference was entirely due to the uncertainty in estimating the thermal conductivity of Coastal Plain sediments in the lower 78 percent of the sedimentary sequence.

The Crisfield hole was not intended to be completed as a production well; however, limited pump tests were made to estimate potential fluid production by perforating the casing. Three zones in the Coastal Plain sediments were perforated. The depth intervals were selected from geophysical logs (Lambiase and others, 1980). Results of temperature logging and aquifer testing are from Dashevsky and McClung (1979).

Zone No. 1 was perforated between 1262 m and 1285 m (4142 ft. — 4217 ft.). A down-hole pump set at 180 m (600 ft.) lowered the head from near ground surface to a depth of 180 m below the ground surface in 8 minutes at a rate of 150 gpm (gallons/minute). The temperature of the water flowing from the perforated zone was 57.2°C at the level of perforation.

Zone No. 2 was perforated from 1187 m to 1227 m (3895 ft. - 4026 ft.) and a pump was set at a depth of 210 m (700 ft.). Water pumped from this zone for 48 hours at an average rate of 119 gpm produced a head drawdown of 84 m (275 ft.). The temperature of water at the level of perforation was 56°C and at the surface the discharge temperature was 51°C. Under high production for an extended period of time, it is expected that the temperature difference between the well head and aquifer would be less.

Zone No. 3. was perforated between 1155 m and 1170 m (3792 ft. - 3840 ft.). A low-volume pump was set at a depth of 125 m (410 ft.) and produced an averaged discharge of 32 gpm for 36 hours, resulting in a static drawdown of 30 m (98 ft.). Down-hole water temperature was 54°C and surface discharge temperature reached 35°C.

Basement rocks at Crisfield were hydraulically fractured by a team from Los Alamos Scientific Laboratory in order to evaluate the potential of the area as a hot dry rock resource. This evaluation is still in progress.

Thermal Lifetime of a Hydrothermal Resource in Sediments of the Atlantic Coastal Plain

Limited hydrologic and heat flow data now available make it possible to estimate the thermal lifetime of a geothermal resource within the sediments beneath the Atlantic Coastal Plain. Laczniak (1980) modeled the response of a leaky aquifer system to a single dipole (pumping plus injection well). The model was run for a simulated period of 15 years or until steady-state thermal and fluid flow was reached. A doublet system (dipole) with direct injection back into the reservoir was shown to be a feasible method of extracting heat in the low-temperature, liquid-dominated geothermal systems of the Atlantic Coastal Plain.

Important conclusions of Laczniak's study were:

a) direct injection back into the reservoir may be necessary to maintain sufficient fluid pressure at the production well for systems with a low permeability,

b) temperature distribution within the system is only slightly affected by changes in permeability in the range 10-100 md (millidarcies),

c) resting the system for periods of 6 months does not result in a significant recovery of heat at the production well,

d) a doublet system with thermal and hydrologic conditions similar to those encountered at Chrisfield, Maryland, a well spacing of 1000 m, a permeability of 100 md, and a pumping-injection stress of 500 gpm (injection temperature 44°C) could produce 5.5 million Btu's per hour over a period greater than 15 years.

Assuming a value of 70,000 Btu's per hour for energy expenditure to heat an average insulated home, Laczniak's results demonstrate that the simple doublet system described above would support over 75 households. If pumped for only 6 months a year, the thermal life-span of the system would be at least 30 years.

CONCLUSIONS AND STATUS

Geothermal energy may be an important resource for the eastern United States. Three resource types (the radiogenic model, normal geothermal gradient resources, and hot springs) appear to be available for development. Pump testing at Crisfield, Maryland, indicated the presence of aquifers of potentially adequate production for many moderate-temperature applications. Predictions about the longevity of the resource are favorable. Several studies have been made to define the geothermal energy market on the Atlantic Coastal Plain and to investigate the cost of geothermal energy in this region (Toth, 1979; Weissbrod and Barron, 1979; Toth and Henderson, 1979; Barron, 1979; Leffel and Tillman, 1979; Paddison, 1979; Paddison and von Briesen, 1979). A major source of information concerning the development of geothermal energy in the East is now available in a handbook (Anderson and Lund, 1979) that serves as an introduction to the scientific, legal, institutional, environmental, and developmental aspects of geothermal energy in the eastern United States.

ACKNOWLEDMENTS

S. Dashevsky, W. McClung, and C. Rohrer did most of the geophysical logging of existing holes in the southeast U. S., W. C. Coulson supervised the drilling program. J. A. Speer, S. Farrar, and S. Becker studied the petrography and chemistry of heat-producing granite stocks and batholiths exposed in the Piedmont. P. Geiser (Univ. of Conn.) mapped the area near Hot Springs, Virginia. A. Cogbill and J. Dunbar acquired and interpreted gravity data in the Piedmont and the Atlantic Coastal Plain, J. Wonderley and R. Montgomery designed and assembled much of the geophysical electronic instrumentation. L. Perry supervised laboratory determinations of thermal conductivity and heat generation of rocks. J. A. Speer, S. Farrar, S. Becker, and R. Gleason described the basement rocks beneath the Atlantic Coastal Plain and Gleason made preliminary estimates of depth to basement beneath the Atlantic Coastal Plain. J. Lambiase supervised the sedimentology studies. B. Thoreson developed computer programs for the graphic display of results.

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NEW PUBLICATIONS

PUBLICATION 36

"Virginia Clay Material Resources," Publication 36, by P. C. Sweet, a 178 page illustrated report, is the seventh in a series of reports about clay materials. Potential uses for building bricks, drainage tiles, and chimney linings are indicated. The study includes location maps and fired test and lithologic data on 130 samples collected in 37 counties and 3 independent cities. It is available for $12.48 postpaid.

PUBLICATION 37

"Valley and Ridge Stratigraphic Correlations, Virginia," Publication 37, by E. K. Rader, is a 22 × 34 inch, descriptive chart depicting the relationships of rock units in Virginia west of the Blue Ridge. Different unit names from six portions of the Valley and Ridge indicate the variety of rocks in Virginia. Many of these names are from Virginia localities. The chart is useful for the student of Virginia geology as well as exploratory companies seeking mineral resources. These rocks were deposited from Late Precambrian through Pennsylvanian geologic time, a span of over 300 million years. It was during this time that the Appalachian Mountains were formed. Publication 37 is available for $3.12 postpaid.

LIST OF PUBLICATIONS

The Division's new 1982 List of Publications can be obtained without charge from the Division. It indicates maps and over 220 different publications which describe Virginia's rocks, minerals, and fossils.

SCHEDULED MEETINGS

May 21-23 Eastern Section of the National Association of Geology Teachers, Williamsburg, Va. (Dr. Bruce Goodwin, Geology Department, College of William and Mary, Williamsburg, Va. 23185).

October 3-6 Association of Earth Science Editors, ann. mtg., Williamsburg, Va. (Judy C. Holoviak, American Geophysical Union, 2000 Florida Ave., NW, Washington, D. C. 20009).

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COAL-BED METHANE TESTS

In January, the Department of Conservation and Economic Development, Division of Mineral Resources, began a test drilling program to determine the coal-bed methane potential in Montgomery County. The drilling phase of the program is being done under contract to Joy Manufacturing Company of LaPorte, Indiana.

The Division of Mineral Resources is conducting the tests to determine the potential for coal bed methane production in the Blacksburg-Radford area of Montgomery County. It has been apparent for many years that Mississippian-age coal-bearing strata extend from a short distance west of the Pulaski thrust sheet, eastward at shallow depth beneath the thrust for several miles, to where they are exposed in the Price Mountain window. Because of this potential, the Division has been actively studying the area by surface geologic mapping and by VIBROSEIS profiling. It is estimated, based on limited geological information, that there are 130,000,000 tons[1] of coal reserves in the Price Mountain and Brushy Mountain coal fields (Valley coal fields). This coal could contain an appreciative amount of methane in the Blacksburg-Radford area. Funding for the project was granted by the Department of Energy under its Unconventional Gas Program. In addition, the Division, in cooperation with the U.S. Geological Survey, Office of Energy Resources, Branch of Coal Resources, funded a VIBROSEIS survey in the area to aid in the research. The VIBROSEIS survey was done by the Department of Geological Sciences, Virginia Polytechnic Institute and State University.

The first test drill site was located at Prices Fork Research Center. The test hole was started in rocks of the Elbrook Formation (dolomite) of the Pulaski thrust sheet and was cored to a depth of 1773.5 feet. At this depth, because of unexpected thickness and difficulty in coring through the Pulaski thrust sheet, the drilling operation was moved from the hanging wall to a location in the footwall rocks (MacCrady Formation) approximately 1.5 miles northeast of Longshop, Montgomery County.

When the coal bed is encountered by drilling, methane gas analysis will be made on the retrieved core on site. The core will be "canned" and further tested in the laboratory. These analysis for the coal methane will be done by the U. S. Bureau of Mines. Further chemical analysis on the coal will be made by the U. S. Geological Survey. Upon completion of the drilling program, the Division will have the core holes logged by geophysical methods by the U. S. Geological Survey. The cores recovered from the test holes will be logged and studied for other geological information. The core will be stored at the Division's office in Charlottesville.

[1]Brown, Andrew and others, 1952, Coal Resources in Virginia: U.S. Geological Survey Circular 171 57 p.