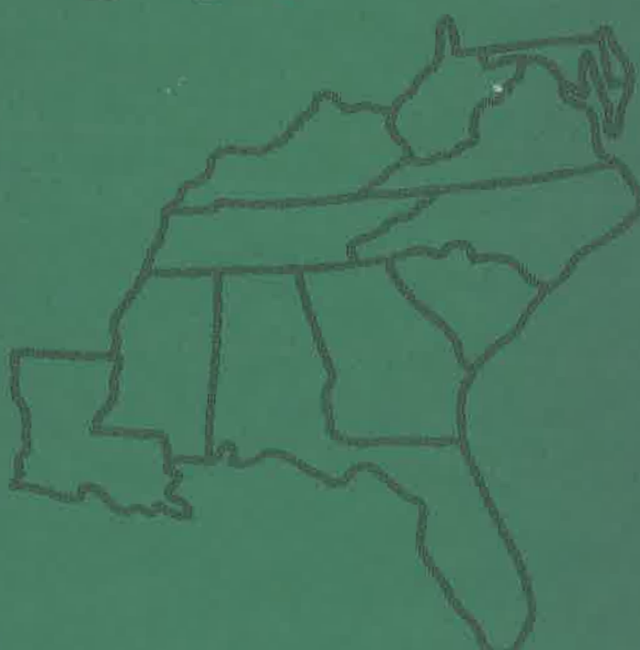
SOUTHEASTERN GEOLOGY



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HYDROGEOLOGIC FRAMEWORK OF THE GULF AND ATLANTIC COASTAL PLAIN*

by

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ABSTRACT

The Gulf and Atlantic Coastal Plain of the United States is underlain by an immense prism of Mesozoic and Cenozoic deposits that form a ground water system which is simple in general terms but complex in detail. Sand and limestone aquifers and alternating clay beds have a gentle coastward homoclinal dip and are ideally suited to the occurrence of artesian water.

The shallow subsurface part of the Coastal Plain contains in aggregate many thousands of cubic miles of fresh water in transient storage. A much greater volume of salty water in quasi-permanent storage underlies the fresh water as a wedge that thickens coastward. Except in southwest Texas, where the climate is not humid, most ground water recharge is short-circuited to effluent stream valleys through the water table and uppermost artesian aquifers.

By applying hydrologic principles to pertinent features of topography, geologic structure, lithology, and geologic history, it is possible to develop hydrogeologic classifications of the Coastal Plain that are useful. A new interest in systematics is leading to improved extrapolation and better understanding of the hydrology.

A water table aquifer and at least one artesian aquifer are present almost everywhere. The Coastal Plain has more immediate potential for ground water development than any other province of comparable size in the Western Hemisphere.

INTRODUCTION

The Atlantic and Gulf Coastal Plain is underlain by an immense hydrologic system which has more immediate potential for development of ground water resources than any other province of comparable size in the Western Hemisphere. Thousands of separate studies relating to the geology or to the ground water hydrology of local parts of the region have been made, but few attempts have been made to synthesize the results of separate studies. This paper is a brief summary of the

*Publication authorized by the Director, U. S. Geological Survey.

The plain slopes gently to the sea, extending beyond the coastline as the Continental Shelf. Beneath the plain, beds of sand, clay, and limestone of Cretaceous, Tertiary, and Quaternary age dip seaward. Figure 1 shows the general surface distribution of the Cretaceous, Tertiary, and Quaternary units. In gross terms the beds dip coastward at a rate only slightly greater than the slope of the land surface. Beds tend to thicken seaward. Many beds occurring at depth near the coast tend to wedge out before reaching the land surface at inland places. Figure 2 shows the altitude below sea level of the basement surface. Basement rocks are chiefly dense crystalline rocks and Paleozoic sedimentary rocks.

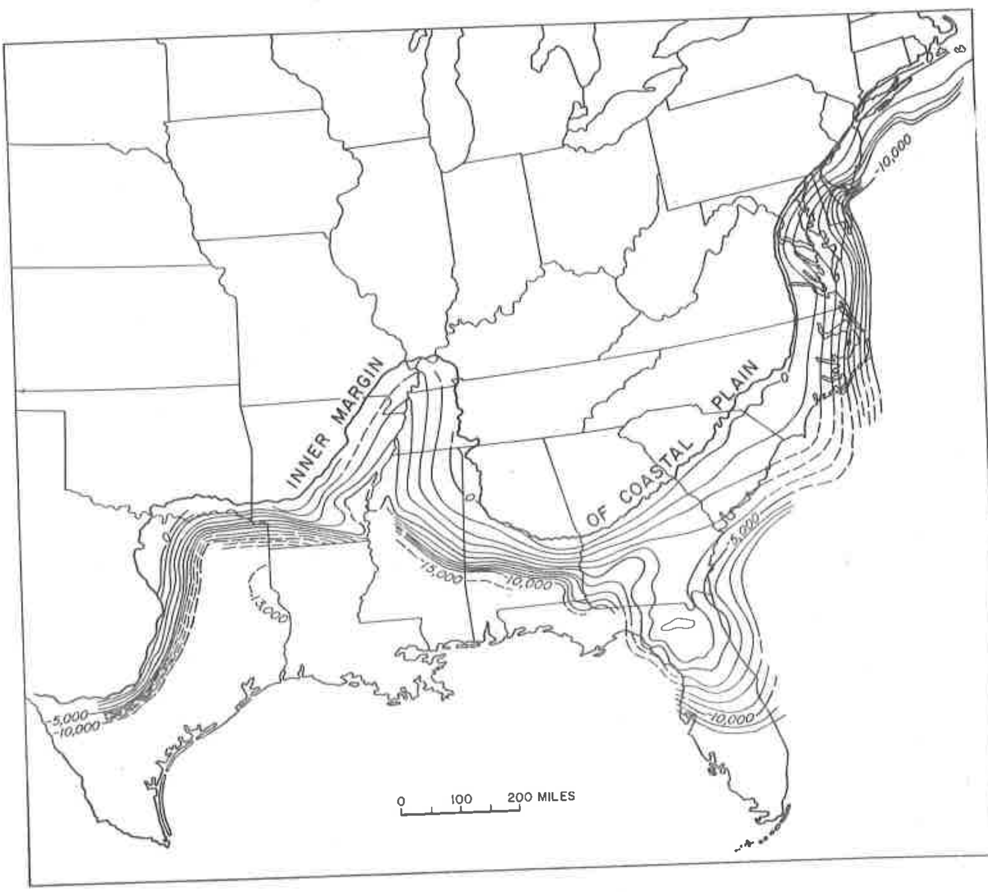

Figure 2. Approximate altitude in feet below sea level of the base of Coastal-Plain formations (Texas through South Carolina after Murray (1957) and North Carolina through New Jersey after Spangler and Peterson (1950).

Wide ranges in the porosity-permeability characteristics of calcareous materials occur within the Coastal Plain. Although some Pleistocene and Recent calcareous materials have remained unconsolidated, as have some older marls and chalks that have never been deeply buried, most of the calcareous materials have been consolidated into limestones and dolomites. Where these rocks have been elevated at some time in their history, so that meteoric water could circulate in them, solution has developed secondary permeability in the form of cavities. For example, parts of the Tertiary limestone unit of Florida, representing several formations, have been subjected to circulating ground water and to the enlargement of pore and channel openings during Pleistocene and Recent times (Stringfield, 1950, p. 221). Some deeply buried limestone formations of the Coastal Plain have never been above sea level and have never had meteoric water circulating through them; these rocks are still relatively dense and impermeable.

TOPOGRAPHY

Topography is a vital factor in the occurrence and movement of ground water because it controls recharge to and discharge from the underground water system. Moreover, features of topography provide differences in hydrostatic head between points of recharge and discharge and thus cause the movement of ground water.

From a broad view, the surface of the Coastal Plain appears nearly level, sloping only a few feet per mile toward the sea. Consequent streams have extended their courses seaward and represent the trunk streams toward which subsequent and insequent streams drain. Streams have cut their channels easily into the nearly flat-lying sand and clay beds. Bordering flood plains are common, but relief is generally significant between the flood plains and the upland areas. Along the coastal and central belts flat interstream areas are characteristic, and relief is appreciable only near stream valleys. Along the inner margin of the Coastal Plain the innerstream areas are more dissected, and slightly hilly topography is not uncommon there.

CLIMATE

The Coastal Plain east of the 95th meridian of longitude (in eastern Texas) receives an average of more than 40 inches of precipitation. In this humid region the precipitation is rather evenly distributed throughout the year, and in only a few months of the year is there less than 2 inches of rainfall. On the other hand, near the Mexican border in southern Texas, average precipitation is scarcely 20 inches a year; in that part of Texas, precipitation is about equal to the amount which, over the nation as a whole, is returned to the atmosphere annually by evapotranspiration.

ment may be extremely slow if impediments are in its path or if avenues for escape are poor. Ground water discharges naturally (1) as evapotranspiration in low areas,(2) as seeps and springs which tend to sustain the flow of streams in long periods of fair weather, and (3) as leakage into marginal seas.

The depth to the water table depends on the frequency and intensity of precipitation, on the ability of earth materials to transmit water, and on topography. Where a humid climate prevails, as in all of the Coastal Plain except the southern part of Texas, the frequency of periods of precipitation causes the water table to be near the land surface, especially in the low, flat areas (Fig. 3). In the humid part of the Coastal Plain the water table has a higher elevation beneath the upland, or interstream areas, than in the stream valleys; as a result, ground water moves toward the valleys and discharges into the streams. In the arid part of the Coastal Plain the scarcity of precipitation keeps the water table at a relatively low stage; water from parts of many streams seeps downward, adding water to the zone of saturation and building up the water table beneath the streams. Where poorly permeable materials, such as clay, sandy clay, or fine sand, and relatively flat topography exist, the water table is within a few feet of the land surface in the humid part of the Coastal Plain; this is a common condition. Where permeable materials such as coarse sand or limestone underlie the surface of hilly topography, the water table may lie 40 feet or more below the ground.

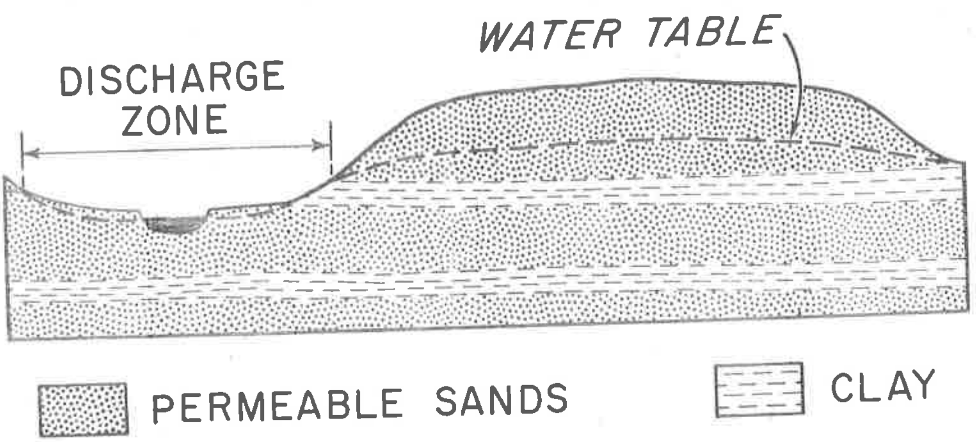

Figure 3. Diagram showing relative position of the water table beneath upland areas and in the discharge zone of a stream valley.

At some place below the water table a relatively impermeable bed occurs which retards the further downward movement of water. This impermeable bed, commonly clay, acts to confine under pressure the water that lies beneath it. The water enters the ground, reaches the water table, and flows water that infiltrates through surface materials is accepted by the aquifer, and the possible rate of recharge may be less than the rate at which the aquifer could accept the water and carry it away.

To some extent each artesian aquifer of the Coastal Plain acts as a pipe or conduit, transmitting water from a place of recharge at a high elevation to a place of discharge at a low elevation. The analogy soon breaks down because most aquifers in their downdip and coastward parts are less permeable than farther inland, are filled with dense mineralized water, and have extremely poor facilities for discharging water at great depths. Therefore, water in these aquifers tends to move upward, even through relatively impermeable aquicludes, into aquifers which have lower hydrostatic pressure. Some water discharges into the sea, and some moves upward through aquicludes and aquifers to reach a stream or the water-table aquifer. In places streams cut into artesian aquifers and bleed water from them; even where relatively impermeable beds separate the uppermost artesian aquifer from a stream, upward leakage to the stream valley may be considerable (Fig. 4). Recharge from the water-table aquifer to the uppermost artesian aquifer occurs when and where the water table is higher than the pressure surface of the artesian aquifer. In many parts of the Atlantic and Gulf Coastal Plain the water table and the pressure surface of the uppermost artesian aquifer have about the same elevation on the upland, or interstream, areas. As the water table aquifer is recharged the difference in head between the aquifers

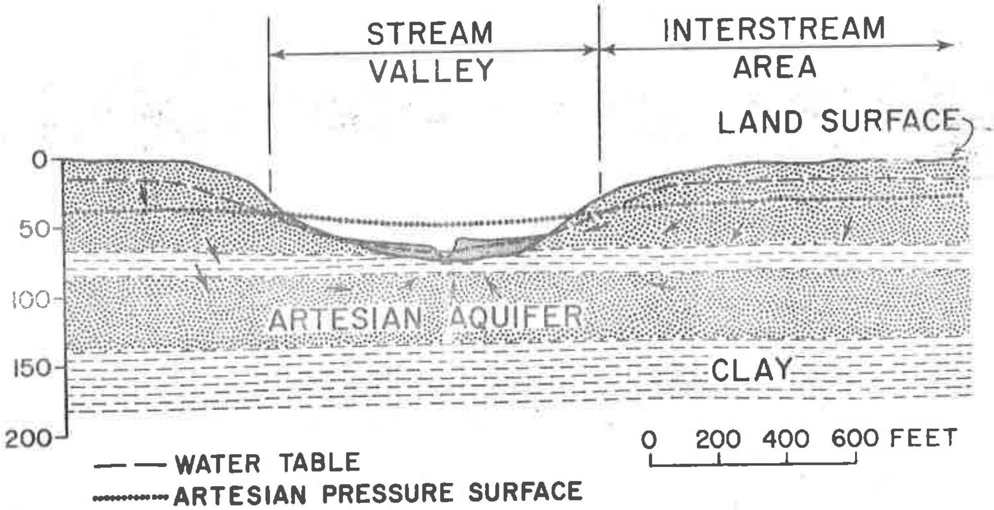

Figure 4. Diagram showing relative positions of the water table and piezometric surface of the uppermost artesian aquifer beneath stream valley and interstream area and the movement of water between these aquifers.

tinguish three zones in which water moves at different rates. In zone 1 of Figure 5 the water table and uppermost artesian aquifers are incised by streams, resulting in relatively rapid movement of water to the streams. The zone may be considered as extending 100 or 200 feet beneath the base of the streams, and the rate of movement may be considered in terms of feet per day to feet per year. The base of zone 2 is also arbitrary and may be considered to extend to a depth of several hundred feet or perhaps to a depth at which the water is salty; the water in zone 2 has no good discharge facilities and its rate of movement may be considered generally in terms of feet per year. Zone 3 contains only salty water and has extremely poor facilities for discharging water; the rate of movement may be considered in terms of feet per century. It must be realized that withdrawal of water from wells, or introduction of fluids through wells, would steepen the hydraulic gradient and would greatly quicken the flow in any of the zones.

CHEMICAL CHARACTER OF THE WATER

The chemical character of water in the Coastal Plain ranges from that of some near-surface water of low mineralization, containing less than 25 parts per million of total dissolved solids, to that of some deeply buried brines whose total dissolved mineral content is several times that of sea water. Sea water contains about 35,000 parts per million of total dissolved solids, of which slightly more than 19,000 parts are chloride ions and more than 10,000 are sodium ions.

Almost all of the sediments were deposited in sea water or had sea water introduced into them at some time in their history. Yet almost nowhere do the sediments now contain water chemically identical with that of the sea. Movement has been the cause of changes in the character of the water, for all the water has moved some distance and in doing so has been influenced by the character of sediments and by the character of contiguous water in its path. Water from precipitation has flushed out the salt water formerly present in most of the beds along the inner margin of the Coastal Plain and in the uppermost beds in most of the rest of the coastal areas. Thus, we must make a distinction between the water that is fresh and potable and water that is salty. Most of the saltiness is due to sodium and chloride ions. Two exceptions include some deeply buried brines that have more calcium than sodium and some water of intermediate depth in south Texas that is relatively low in chloride but high in calcium and magnesium sulfate. However, for the purposes of this report, water containing less than 500 parts per million of chloride is considered fresh.

As water moves through the Coastal-Plain sediments toward a place of discharge it changes in chemical character, in most cases becoming more mineralized with distance and time of travel. Some of the changes are evolutionary and may be traced in a general way. In all the Coastal Plain except south Texas, almost all of the water below south Texas the fresh ground water is somewhat more mineralized than in other parts of the Coastal Plain province; in this area many of the public and individual supplies deliver water containing 1000 parts per million of dissolved solids (Broadhurst and others, 1950, p. 2).

The zone of fresh water overlies the zone of salt water throughout the Coastal Plain province, but in a few places lenses of fresh water may be found below lenses of salty water. Generally the depth to salty water is greater beneath high inland places than beneath low coastal places (Fig. 6). Along the inner margin of the Coastal Plain all the beds may contain fresh water, whereas along the coast only the uppermost beds contain fresh water. South Carolina appears to be the only coastal State which contains a greater proportion of fresh water than salt water; Delaware contains nearly as much fresh as salty water. Florida and Louisiana contain large volumes of fresh water, but because the sediments in these States are extremely thick and extend far below sea level the volume of fresh water is much less than that of salt water. The surface of the salt-water body is very irregular, and information is not yet adequate in most States to map it with reasonable accuracy.

HYDROGEOLOGIC CLASSIFICATION OF THE COASTAL PLAIN

It is postulated that a hydrogeologic classification of the Coastal Plain is needed for us (1) to see and remember significant features of the hydrology, (2) to adequately synthesize our knowledge, (3) to see pertinent relationships, and (4) to develop predictions of hydrologic phenomena that will be useful in practices of water and waste management. It has been noted that hydrologic conditions result chiefly from the interaction of climate, topography, geologic structure, time, and certain actions of man; wherever these factors are similar, the hydrologic conditions are similar. Although hydrologic complexities and geologic heterogeneities are fairly common, especially in detailed analysis, one must admit that certain groups of hydrologic features showing similarities and differences can be synthesized into a harmonious whole. By fully developing a hydrogeologic classification of the Coastal Plain, he can construct hypothetical pictures of hydrologic conditions at any place in the Coastal-Plain framework. These hypothetical pictures without additional data will be sufficient for many purposes; for cases in which additional data are needed, one has the framework on which to hang details, and he can collect pertinent data without being blinded by a host of trivialities and by a superabundance of extraneous data. Specific geologic and hydrologic studies will continue to be necessary, but there is a need to improve techniques of developing the principle of successive approximation - getting the best possible answers today and improving or refining them tomorrow if necessary.

In a hydrogeologic classification of the Coastal Plain, certain groups of elements in the environment appear to be important. Per-

Plain. Such groups include vertical and areal zonations in the hydrogeologic system, lineation of natural discharge zones, topographic situations relating to recharge and discharge, and various discharge and recharge patterns.

The tendency for vertical zonation of ground water is shown in Figure 5. Areal zonation, such as (a) the inner margin of the Coastal Plain, (b) intermediate areas, and (c) the coastal margin, also seems useful. For example, relatively great topographic relief along the inner margin of the plain tends to cause relatively rapid movement of water in the water-table and uppermost artesian aquifer, and this freely circulating water is not saline. Along the coastal margin, in contrast, the aquifers generally have no good natural discharge facilities, resulting in sluggish movement and the entrapment of much salty water in the artesian aquifers.

Natural ground water discharge occurs from the water-table and the uppermost artesian aquifers. This discharge is predominantly from linear zones in consequent, subsequent, and insequent stream valleys. The gentle coastward dip of the formations in relation to the even more gentle coastward regional land slope results in discharge patterns from the uppermost artesian aquifers in the vicinity of consequent streams that are distinctly different from those near subsequent streams. Hypothetical piezometric surfaces can be constructed for the uppermost artesian aquifer that should have much potential value in the future water development and management in the region. A description of ground water discharge in consequent streams is now in preparation.

Although no attempt is made here to elaborate on the various means of ground water discharge in the region, the following categories of discharge give us insight into the great hydrologic system of the Coastal Plain:

1. Consequent streams into which the water-table and uppermost artesian aquifers discharge water and in the vicinity of which the piezometric surfaces of the two aquifers have special patterns. (Typical of inner parts of Coastal Plain. Since stream channel is in same direction as dip, balanced ground water discharge may be expected from both sides of stream. Outcrop of uppermost artesian aquifer in stream channel is lower in elevation and is nearer coast than on upland interstream area, resulting in much of the confined water beneath interstream area taking a downdip and coastward direction before taking a circuitous course updip and inland to discharge in stream where the overlying confining bed is cut away).

2. Subsequent streams into which the water-table and uppermost artesian aquifers discharge water and in the vicinity of which the piezometric surfaces of the two aquifers have special patterns. (Typical of inner parts of Coastal Plain. Since the stream channel is normal to dip, entrenchment of stream into artesian bed causes unbalanced artesian discharge beneath the surface drainage slopes and results in asymmetrical piezometric contours. Artesian leakage may

land and shallow counterparts. Thus, the permeability of the deep-lying beds almost invariably is less than that of beds near the surface.

Calcareous materials occur as limestone, marl, chalk, and finely dispersed materials in some sands and clays. North of North Carolina calcareous material is scarce. Limestone and other carbonate rocks compose the bulk of sediments of Florida. Limestone occurs elsewhere in scattered formations near the land surface, and the amount of limestone tends to increase toward the coast with depth. The Tertiary limestone unit of Florida and Georgia contains many permeable beds, and other limestone formations show a wide range of permeability. Marls and chalks of South Carolina, Alabama, Missisippi, and Texas are noteworthy because of their relatively low permeability.

The basal sediments in the coastal regions contain salty water. In considering the entire volume of Coastal Plain sediments, the volume containing salt water greatly exceeds that containing fresh water. The contact between the fresh-water zone and the underlying salt-water zone is erratic and is not amenable to brief accurate description. In general, the deepest fresh-water zones are in the hinterland. The freshwater zone is somewhat lens-shaped in cross-section. At many coastal points it is less than 100 feet thick; at places in the hinterland it is several hundred feet thick; and along the inner margin it thins as the sediments thin in a feather-edge.

The largest streams flow completely across the Coastal Plain to the sea. These streams and their tributaries form the bulk of the drainage. All streams, except perhaps those in extreme southern Texas, are effluent or "gaining" streams, typically, the water table beneath the interstream areas is higher than the stream level, and ground water moves toward the valleys to contribute water to the streams. Throughout most of the Coastal Plain the valleys are incised in loose sands and clays which tend to disperse ground water discharge as seepage or small springs into streams. Only where limestone is the near-surface aquifer, as in the northwestern peninsula of Florida, are large springs noteworthy.

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THE PUNGO RIVER FORMATION, A NEW NAME FOR MIDDLE MIOCENE PHOSPHORITES IN BEAUFORT COUNTY NORTH CAROLINA *

by

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ABSTRACT

This paper proposes the designation, Pungo River Formation, for a previously unnamed phosphorite unit of middle Miocene age that underlies more than 700 square miles of Beaufort County, North Carolina.

The Pungo River Formation is composed of interbedded phosphatic sands, silts and clays, diatomaceous clays, and phosphatic and non-phosphatic limestones. The formation dips gently to the east in Beaufort County; its thickness ranges from a featheredge, a few miles east of the city of Washington, to more than 110 feet in the southeastern part of the county.

INTRODUCTION

The Ground Water Branch of the U. S. Geological Survey began a geology and ground-water investigation in Beaufort County, North Carolina in March, 1962. The purpose of the investigation was to evaluate the ground water resources of the part of the county underlain by phosphorite deposits and to delineate the phosphorite unit. The investigation was made by the U. S. Geological Survey in financial cooperation with the North Carolina Division of Mineral Resources and the Beaufort County Board of Commissioners. The fieldwork was done under the immediate supervision of P. M. Brown, District Geologist, and under the general supervision of O. M. Hackett, Chief, Ground Water Branch, U. S. Geological Survey.

The phosphorite unit in Beaufort County, North Carolina, was first formally described by Brown (1958). He designated the unit as being of middle Miocene age on the basis of Foraminifera from the upper part of the unit that are correlative with Foraminifera from the Calvert Formation of middle Miocene age in Maryland.

* Publication authorized by the Director, U. S. Geological Survey.

Depth Interval	P_2O_5 Content (%)	Lithology
		grained angular to subangular clear quartz sand, fine-grained dark-brown to black phosphate. Black clay prominent. This interval contains thin layers of light greenish-gray fine sand. Foraminifera abundant.
224'8"-225'7"	1.54	Clay, dark olive-green; Same as 224'0"-224'8" interval with no sand layers. Foraminifera common.
225'7"-226'7"	0.76	Clay, dark olive-green; Same as 224'8"-225'7" interval with Foraminifera rare.
226'7"-227'7"	0.76	Clay, dark olive-green; Dark olive-green calcareous clay. Trace of fine subangular to subrounded clear quartz sand. Foraminifera common.
227'7"-228'4"	0.76	Clay, dark olive-green; Same as 226'7"-227'7" interval with Foraminifera very abundant.
228'4"-229'4"	0.43	Clay, light olive-green; Light olive-green light-weight slightly calcareous clay. Trace of fine subangular to subrounded clear quartz sand. Foraminifera abundant.
229'4"230'4"	0.43	Clay, light olive-green; Same as 228'4"-229'4" interval with 10 percent of sample composed of diatoms. Foraminifera abundant.
230'4"-231'5"	0.43	Clay, light olive-green; 90 percent light olive-green light-weight slightly calcareous clay, 10 percent fine angular to subangular clear quartz sand. Foraminifera very abundant, diatoms rare.
231'5"-232'0"	5.22	Clay, light olive-green; 75 percent light olive-green light-weight slightly calcareous clay, 20 percent fine subangular to angular clear quartz sand, 5 percent fine-grained dark-brown to black phosphate. Foraminifera very abundant,

Depth Interval	P_2O_5 Content (%)	Lithology
238'5"-239'4"	16.6	Phosphatic sand and clay, dark greenish-brown; Same as 237'5"-238'5" interval with no microfossils.
239'4"-240'4"	18.5	Phosphatic sand and clay, dark greenish-brown; Same as 238'5"-239'4" interval.
240'4"-241'4"	18.5	Phosphatic sand and clay, dark greenish-brown. Same as 239'4"-240'4" interval with 5 percent increase in fine to medium quartz sand and corresponding decrease in phosphate.
241'4"-242'4"	18.5	Phosphatic sand and clay, dark greenish-brown; Same as 240'4"-241'4" interval with trace of lignitized wood, amber.
242'4"-243'0"	19.8	Phosphatic sand, dark greenish-brown; 55 percent fine to medium angular to subangular clear quartz sand, 45 percent fine-grained light-brown to black phosphate. Light-gray weathered phosphate prominent. Trace of coarse-grained dark-brown to black phosphate, medium subrounded clear quartz sand, light- to dark-gray fragments of limestone. Foraminifera very rare.
243'0"-244'0"	19.8	Phosphatic sand, dark greenish-brow Same as 242'4"-243'0" interval with 10 percent increase in phosphate and corresponding decrease in fine to medium quartz sand. Foraminifera rare.
244'0"-245'8"	19.8	Phosphatic sand, dark greenish-brown; 45 percent fine- to medium-grained light-brown to black phosphate, 35 percent medium angular to subangular clear quartz sand, 20 percent fine angular to subangular clear quartz sand. Light-gray weathered phosphate and light-gray clay prominent. Trace of medium-grained dark-brown to black phosphate. Foraminifera very rare.

Depth Interval	P_2O_5 Content (%)	Lithology
263'8"-264'8"	10.6	Phosphatic clay and sand, light olive-green; Alternating irregular layers of light olive-green clay with layers of phosphatic sand. For entire interval; 55 percent light olive-green clay; 25 percent very fine- to fine angular to subangular clear quartz sand, 15 percent very fine- to fine-grained light-brown to black phosphate, 5 percent medium-grained light-brown to black phosphate. Trace of medium subrounded to rounded clear quartz sand. Small Foraminifera, diatoms, sponge spicules rare.
264'8"-265'8"	10.6	Phosphatic clay and sand, light olive-green; Same as 263'8"-264'8" interval with 5 percent increase in medium quartz sand and corresponding decrease in fine-grained phosphate. Diatoms and sponge spicules rare.
265'8"-266'8"	1.36	Phosphatic sandy clay, light olive-green; 75 percent light olive-green slightly calcareous clay, 15 percent very fine- to fine-grained angular to subangular clear quartz sand, 10 percent very fine- to fine-grained light-brown to black phosphate. Medium subangular to subrounded clear quartz sand and medium-grained dark-brown to black phosphate prominent. Trace of rose quartz, medium broken shell fragments. The sand and phosphate in this interval occur in thin layers. Diatoms rare.
266'8"-267'9"	1.36	Phosphatic sandy clay, light olive-green; Same as 265'8"-266'8" interval with diatoms and Foraminifera rare.
267'9"-268'9"	1.33	Clay, light olive-green; light olive-green slightly calcareous clay. Trace of medium-grained subrounded clear quartz sand, medium-grained dark-brown to

Depth Interval	P_2O_5 Content (%)	Lithology
		percent light olive-green calcareous clay occurring as "patches" in limestone, 10 percent medium subangular to subrounded clear quartz sand, 10 percent medium-grained dark-brown phosphate.
273'9"-276'2"		No sample.
		Eocene - Castle Hayne Limestone
276'2"-276'11"		Shell limestone, light to dark-gray, well indurated. Approximately 60 percent of this interval consists of fossil casts and molds. Trace of angular to subrounded clear quartz sand, fine-to coarse-grained dark-brown to black phosphate. Foraminifera and Ostracoda rare.

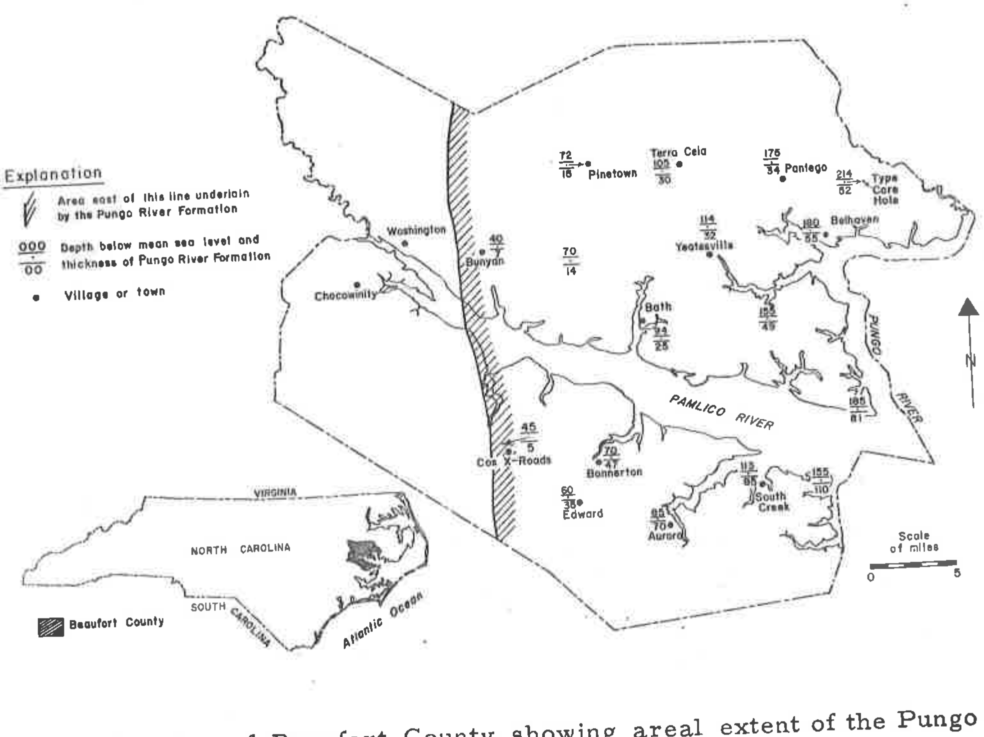

Figure 2. Map of Beaufort County showing areal extent of the Pungo River Formation.

The Pungo River Formation underlies more than 700 square miles of the eastern part of Beaufort County (Fig. 2). Its areal extent beyond the boundaries of Beaufort County is unknown. In Beaufort County, the formation is composed of interbedded phosphatic sands, silts and clays, diatomaceous clays, and phosphatic and non-phosphatic limestones. Lithologic horizons in the formation may be traced laterally across the county. Figure 3 is a typical isometric fence section of the Pungo River Formation in the northern part of Beaufort County.

The $P_2 O_3$ content of the phosphatic sands in the formation ranges up to a known maximum of about 21 percent of the raw core sample. They are comprised of fine- to medium-grained collophane and quartz with varying percentages of silt and clay sized material, small phosphatized fish teeth and bone fragments. The collophane grains are typically smooth, glossy, brown in color, and spheroidal to ovate in shape. Surfaces of individual grains commonly show concentric rings or bandings. The quartz occurs typically as clear, flat sided, angular to subrounded grains. Accessory minerals in the phosphatic sands include calcite and garnet. The more clayey phosphatic sands often contain weathered shell material.

The Pungo River Formation lies unconformably on the Castle Hayne Limestone of Eocene age and is unconformably overlain by the upper Miocene Yorktown Formation. The contact with the overlying Yorktown Formation, as observed in well cuttings and cores, is often gradational due to the reworked phosphatic material in the base of the Yorktown Formation.

The top of the formation dips generally to the east at a rate of about 5 to 10 feet per mile. The thickness of the formation in Beaufort County ranges from a featheredge in the western part of the county to more than 110 feet in the southeastern part of the country.

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AN UNUSUAL RADIOACTIVE, RARE EARTH-BEARING SULFIDE DEPOSIT IN CABARRUS COUNTY, NORTH CAROLINA*

by

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ABSTRACT

The Heglar prospect in Cabarrus County, North Carolina, contains disseminated pyrite and a significant amount of rare earth elements in an andradite-opal-chalcedony-quartz gangue. It is radioactive and occurs in an area of anomalous radioactivity. Opal commonly occurs as concentric colloform layers around fibrous chalcedony. Gold and tungsten have been mined in the area from quartz veins which have many features typical of gold-bearing quartz-pyrite lodes in the southern Piedmont. The prospect is near the boundary between pyroclastic and epiclastic rocks with interbedded volcanic flows characteristic of the Carolina slate belt to the east and plutonic rocks of the Charlotte belt to the west. It is a contact deposit associated with the intrusion of a pink microcline-bearing granite into a calcareous country rock now largely amphibolite.

INTRODUCTION

The Heglar prospect, Cabarrus County, N. C., is of interest because the associated minerals indicate a type of mineralization not previously reported in North Carolina. Disseminated pyrite in an andradite-opal-chalcedony-quartz gangue, a significant amount of cerium and other rare-earth elements, and radioactivity characterize the deposit. The prospect is in an area where gold and tungsten have been mined from quartz veins.

The Heglar prospect, near the northeast corner of the Concord SE. quadrangle (Fig. 1), is on a tributary of Hamby Branch approximately 750 feet south of the road through Cold Springs. The old Faggart gole mine, consisting of two abandoned shafts and some pits, is several hundred feet east of the prospect (Fig. 2).

*Publication authorized by the Director, U. S. Geological Survey.

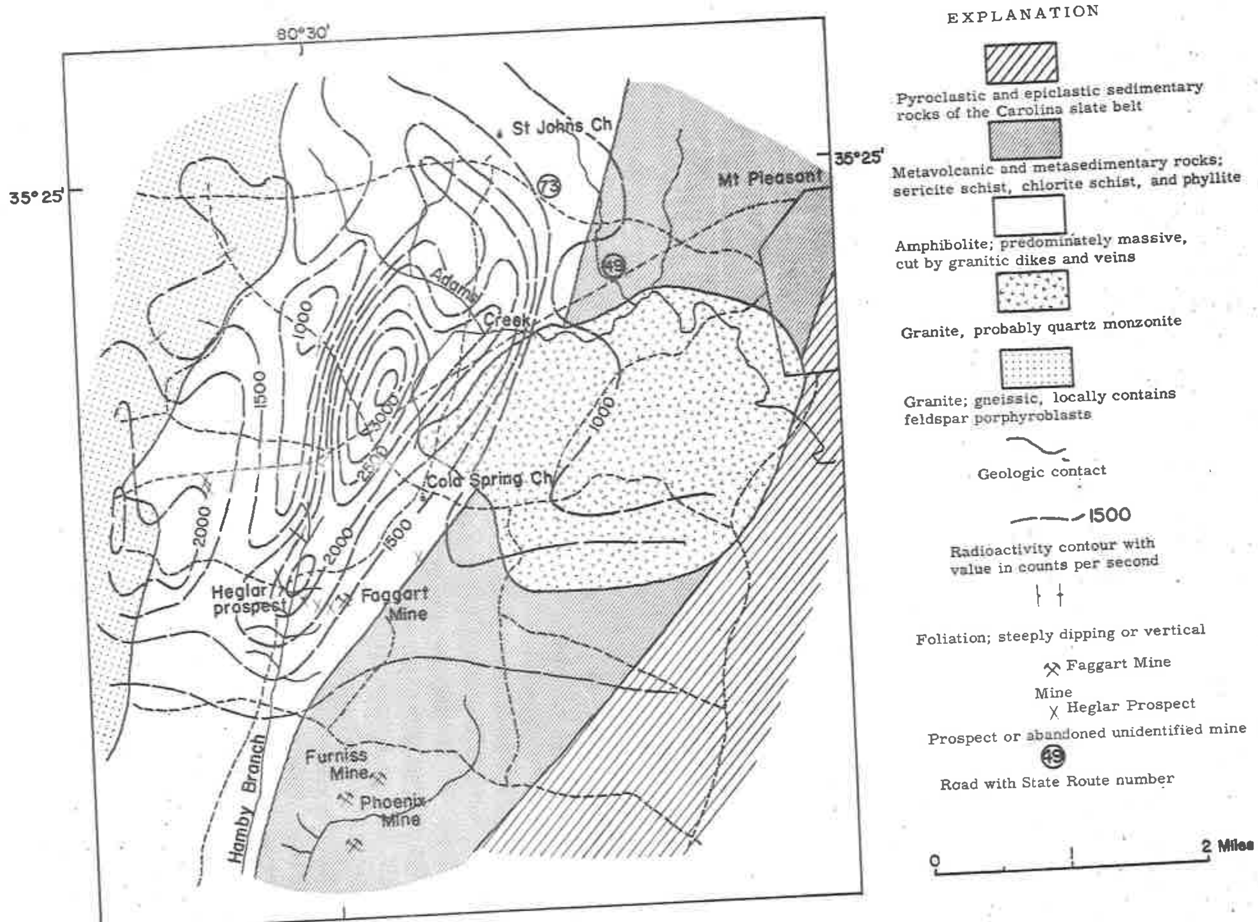

Figure 2. Geologic map showing radioactivity contours in the vicinity of the Heglar prospect. Radioactivity data contributed by R.W. Johnson and R.E. Bates.

subhedral, nearly equant grains that range in size from 0.1 to 5 mm. Some of the microcline is micro-perthitic, and film, vein, and patch perthite were noted. Much of the perthite is uniformly distributed in films and lenses parallel to the 010 twinning. Both replacement patch perthite and film perthite due to exsolution are recognized. Myrmekitic intergrowths of quartz and plagioclase are characteristically developed along microcline borders. Tiny quartz patches and veinlets and calcite veinlets occur in the microcline.

Plagioclase, in the sodic oligoclase range, occurs as subhedral to euhedral grains and laths that range in long dimension from 0.1 mm to 2 mm. Fine, uniform, evenly spaced albite twinning is well developed. Plagioclase is turbid and more altered than the microcline. Sericitization occurs along grain borders, cleavages, and along composition planes of albite twins. Tiny patches of veinlets of calcite are developed in some plagioclase grains.

Table 1. Modal analysis of pink granite (volume percent).

Quartz	29.9
Microcline	34.1
Plagioclase	28.2
Biotite	1.5
Sericite, chlorite	3.9
Calcite	1.5
Other	0.9

Quartz occurs as large anhedral grains that in places show undulatory extinction. In some cases, microcline is embayed by quartz. Biotite occurs in euhedral flakes interstitial to the quartz and feldspars, and, in places, biotite is intergrown with pennine chlorite. Apatite, zircon, sphene, clinozoisite, and black opaque grains occur as accessories.

The pink granite associated with the Heglar prospect may be an apophysis related to the crosscutting granite pluton located southwest of Mt. Pleasant (Fig. 2). This granite pluton is notable because of the shearing and abundance of pyrite in it. Details of the distribution of the granite and its contact with the country rocks are not known, however, and the pink granite at the Heglar prospect may have no connection with the granite southwest of Mt. Pleasant.

HEGLAR PROSPECT

The mineralized rock that constitutes the Heglar prospect consists dominantly of disseminated pyrite and andradite in a fine-grained to aphanitic siliceous matrix; other sulfides and allanite are present. In places, pyrite and andradite occur in 1- to 10-mm layers alternating with fine-grained siliceous material. In gross appearance, the

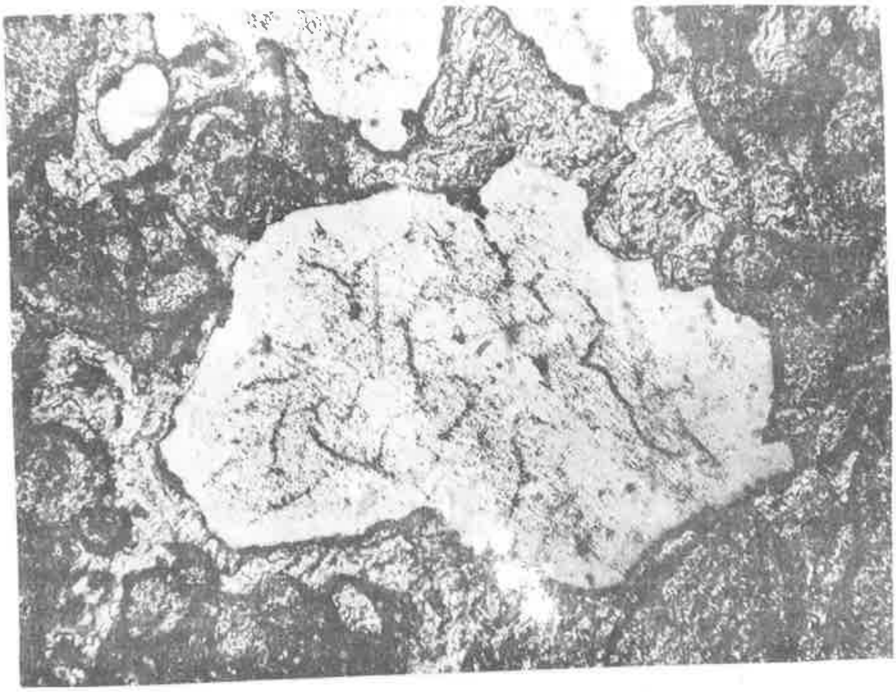

Figure 3. Photomicrograph of contraction cracks in chalcedony (white, low relief); opal (gray, high negative relief) borders chalcedony. Opal and chalcedony replace andradite (dark gray to black, high relief). Plane-polarized light.

According to Brian Skinner (written communication, 1964), x-ray diffraction patterns confirm that opal is a major phase of the groundmass and indicate that an ordered low-density phase occurs with the opal. The nature of this ordered phase has been referred to in the literature as beta-cristobalite, disordered low-cristobalite, and tridymite (Sato, 1962, p. 296-305; Sun, 1962, p. 1453-1456; Franks and Swineford, 1959, p. 186-196; Florke, 1955, p. 217-223). The diffraction pattern of the ordered phase of the Heglar material resembles that of beta-cristobalite, but it is not sufficiently definitive to be designated as beta-cristobalite, and is, perhaps, better called simply opal.

Chalcedony is developed as microcrystalline radiating fibrous or feathery aggregates. Upon rotation between crossed nicols much of

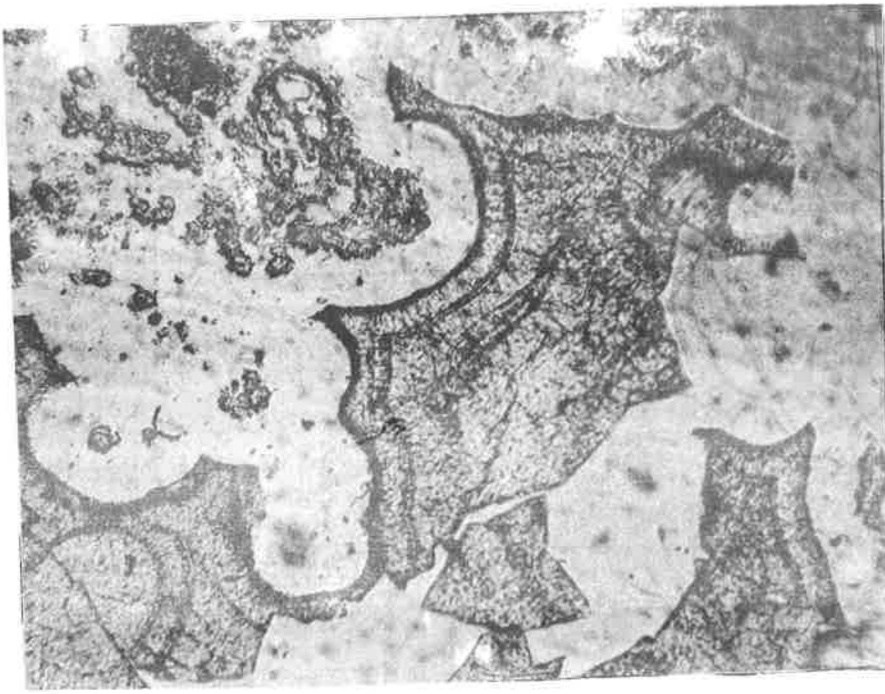

Figure 5. Photomicrograph showing colloform-banded opal (high negative relief, dark gray) and chalcedony (low relief, light gray) in silicified groundmass. Plane-polarized light.

epidote, and chlorite and is evidently the latest material to be deposited.

ALLANITE

Allanite occurs as, small black to smoky-brown, anhedral, birefringent to altered isotropic masses around epidote cores, as irregular patches replacing andradite along grain boundaries and fractures, as small remnants partially replaced by sulfides and as veinlets cutting andradite. Some of the allanite is pleochroic in shades of black, smoky brown, and dark red. Opal and microcrystalline silica veinlets cut allanite.

APATITE

Apatite occurs as small euhedral inclusions in andradite and also disseminated in the siliceous matrix. Apatite grains have apparently resisted replacement by sulfides and occur in places as remnants within pyrite grains that have partially replaced andradite. Some of the aparite presents a spongy appearance due to tiny opaque inclusions. A distinctive feature is the nearly ubiquitous narrow border

Survey. The analyses show noteworthy amounts of the rare-earth elements, also molybdenum, silver, copper, lead, zinc and bismuth.

The combined content of cerium, lanthanum, praseodymium, and neodymium ranges from 0.14 to 0.42 percent. The rare-earth elements probably occur in allanite, but a part may be incorporated in apatite. Pardee and Park (1948, p. 38, 43) report the occurrence of allanite in a gold placer and lode deposits in Georgia but not elsewhere in the gold-quartz deposits of the southern Piedmont. A large proportion of cerium earths (Ce, La, Nd) in relation to ytterium earths (Y, Yb) is characteristic of some rare earth deposits associated with alkalic rocks. Two large masses of syenite forming a ring structure and dikes of syenite and other alkalic rocks occur in the northwest corner of the Concord SE quadrangle and in the Concord quadrangle to the north (Bell and Overstreet, 1959). None of these rocks have been found near the Neglar prospect, however.

The molybdenum content of the samples is attributable to molybdenite which has been identified in polished surfaces and by X-ray powder pattern. It is also reported to occur at the Pioneer Mills mine nearby (Genth, 1891, p. 23).

The silver content of the samples cannot be attributed to an identified mineral. It may be associated with undetected gold. Gold occurs at the Faggart mine nearby and in gravel collected in Hamby Branch a short distance below the Heglar prospect and the Faggart mine.

Bismuch-bearing minerals have not been recognized in samples from the Heglar prospect. Genth, however, reports (1891, p. 22) bismuthinite at Gold Hil and tetradymite at a number of mines in the group associated with the Heglar prospect, including the Phoenix mine, Boger (Allan Boger ?), and Gold Hill mines. Very fine grained bismuthinite or a bismuth-bearing telluride may not have been detected in the samples. Tellurium concentrations below 0.01 percent would not ordinarily be detected by semiquantitative spectrographic analyses.

A heavy-mineral concentrate panned from gravel collected in Hamby Branch not far below the Heglar prospect contains abundant scheelite (Overstreet and Bell, 1960). Spectrographic analysis of this heavy-mineral concentrate from which magnetite was removed showed that the samples contained 0.015 percent tungsten. Neither scheelite nor ferberite, minerals which have been found in associated mines, were seen in the samples examined from the Heglar prospect, and tungsten is not reported in the spectrographic analyses shown in Table 3.

RADIOACTIVITY

The deposit is located within a northeast-trending radiometric anomaly charted by airborne methods (Johnson and Bates, 1960). The anomaly is developed along the western border of the granite body southwest of Mount Pleasant (Fig. 2). The anomaly ranges from 1,500 to 3,250 counts per second. The radioactivity of the deposit was verified on the ground with a scintillometer. No minerals with uranium or thorium as a major constituent have been recognized in the mineralized rock, and no uranium or thorium were reported in the semiquantitative spectrographic analyses. Allanite is reported to contain from 0.35 to 2.23 percent thorium (Deer, Howie, and Zussman, 1962, p. 213), and the radioactivity associated with the deposit may be due to residual weathering products of allanite. The cerium rare earths are commonly removed from allanite during weathering (Watson, 1917, p. 491-498), and the thorium content is increased relatively. Allanite develops a reddish brown earthy crust that contains ferric hydroxide and closely resembles other iron oxide weathering products in areas of deep weathering. In Georgia, Silver and Grunefelder, (1957, p. 1796) report that alteration products of allanite include bastnasite, huttonite (?), hematite and a pale yellow isotropic or nearly isotropic mineral. Further mapping and sampling will be necessary to discover the significance of the position of the deposit relative to the radiometric anomaly and to test for the weathering products of allanite.

SUMMARY AND CONCLUSIONS

The Heglar prospect is in a group of associated mines and prospects near the boundary between rocks of the Carolina slate belt in the greenschist metamorphic facies and higher grade metamorphic rocks in the Charlotte belt. The associated mines and prospects are on gold-quartz veins typical of deposits in the Gold Hill belt of the southern Appalachians. They have pyrite, chalcopyrite, barite, molybdenite, gold, and probably some bismuth mineral in common with the deposit at the Heglar prospect. The deposit at the Heglar prospect, however, has some unusual features not shared by the others. It is a replacement deposit at the contact of a pink microcline-bearing granitic rock and amphibolite. The mineral assemblage consists of the calc-silicates, andradite, epidote, and allanite, with magnetite and apatite, sulfides, mainly pyrite and chalcopyrite, and a late opal-chalcedony-quartz replacement gangue. The cerium rare earths are unusually abundant, and the deposit is radioactive.

Association of the low-temperature products of silicification such as opal and chalcedony at the Heglar prospect within a group of deposits generally characteristic of mesothermal deposition suggests that locally introduction of mineralizing solutions took place over a significant range of temperature. Preservation of delicate colloform structure and the generally undeformed character of the mineralized rock at the Heglar prospect indicates that mineralization post-dated pervasive regional metamorphism. The presence of strongly sheared rocks and a probable late crosscutting granite associated with radioactivity, gold-quartz-base metal and tungsten mineralization and a significant quantity of rare-earths suggests that the area merits careful search for other deposits with mineralogy atypical of this region.

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THE ELBERTON BATHOLITH

by

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ABSTRACT

The Elberton batholith constitutes over 900 square miles of the east-central Georgia Piedmont. It consists of fine-grained adamellite and porphyritic adamellite. The overall cross-cutting aspects, the presence of inclusions of metamorphic country rock, and the position with respect to metamorphic zones suggest a late- or post-tectonic origin. Mica age determinations give values of 250 m.y., while zircon results are on the order of 450 m.y. The Elberton batholith is asymmetrically placed to the southeast side of the belt of maximum metamorphic intensity. The rift and catacliastic eatures of the pluton, together with the discordance of the K-A ages and Pb-U ages, suggest that the batholith has been metamorphosed following emplacement into previously metamorphosed country rock.

INTRODUCTION

Granitic rocks constitute over 900 square miles of the Piedmont of east-central Georgia, underlying large parts of Elbert, Oglethorpe, Greene, Hancock, Wilkes, and Lincoln Counties. The town of Elberton is situated in the midst of this granitic rock mass and is the center of a large monument industry. At least forty quarries are locate near Elberton in Elbert and Oglethorpe Counties.

Much of what is shown on the Geologic Map of Georgia as granite is instead migmatite, or even gneiss and schist. However, bodies of granite which are now shown on the state map are known to exist.

Following Watson's study (1902) of the granites and gneisses of Georgia, scattered knowledge accumulated concerning Georgia granitic rocks. Much of this information is unpublished. As part of a study of the Elberton batholith (NSF grant GP-2143), all information known to the writer concerning the batholith was compiled and summarized in the following paper. Because much of this information is scattered or unpublished, this summary will be of some use while further knowledge accumulates.

PETROGRAPHY

The Elberton batholith is composed of a number of individual bodies of pink to gray, fine- to medium-grained, equigranular or porphyritic adamellite. (The term granitic rock is applied only in the general sense.) The color index ranges from 5 to 10.

Mineralogy

The major minerals are quartz, microcline, and oligoclase in roughly equal amounts. The characteristic varietal mineral is biotite but in many localities muscovite is well-developed. Magnetite, apatite, and zircon are ubiquitous. Allanite is a common accessory. Chlorite, hematite, and epidote are common secondary minerals.

Chayes (1951) showed 33 modes of specimens from quarries in Elbert and Oglethorpe Counties. Plagioclase, potash feldspar and quartz are nearly equal in amount, and the modes are closely grouped. Chayes found that the fine-grained Elberton rocks are distinctly lower in plagioclase than the coarse-grained Salisbury and Mt. Airy granitic rocks from North Carolina.

Unpublished modes by V. J. Hurst (Table 1) for 16 specimens from the Elberton area closely resemble Chayes' data. In only two of the modes is potash feldspar significantly in excess of plagioclase. All of the 49 modes of Chayes and Hurst fall in the adamellite (quartz monzonite) range.

An interesting study by Hurst (1953) of heavy mineral concentrates from Elberton granite-saprolite showed magnetite to be the characteristic heavy mineral. Also found were hematite, chlorite, epidote, garnet, sillimanite, staurolite, and altered ferromagnesian minerals.

Nearly all thin sections of the Elberton granitic rocks show quadrille twinning of the potash feldspar. Most of them also show simple (monoclinic) twinning. The degree of development of quadrille twinning is variable; in some specimens a majority of grains show it, in others only a scattered few.

Watson (1902) reported that microperthite commonly occurred in these rocks. In specimens examined by the writer from 13 localities, exsolved lamellae are rare, and the potash feldspar is probably microcline cryptoperthite.

Watson (1902, p. 214) noted an essentially one-feldspar (perthite) granite from the Oglesby area, but there are no other reports of one-feldspar rocks.

Texture

Both equigranular and porphyritic rocks are found in the Elberton batholith. The commonly quarried rock is fine to medium grained (0.5 to 2 mm), seriate, and xenomorphic granular. Irregular mutual penetration of the boundaries of mineral grains is common. Quartz commonly shows strain effects.

The regional orientation of the sub-vertical partings is non-uniform, although quarries in a local area have a uniform orientation. The writer is presently engaged in a study of this orientation. As far as can be told from preliminary observations, there is no relationship between lineation, foliation, schilieren, or even pegmatite veins and the directions of ease of parting. This is in accord with the conclusion reached by Balk (1937, p. 22) that the Appalachian granitic rocks furnish examples of the superposition of rift after development of mineral parallelism. Watson early recognized that "since the intrusion of the last granites, the region has suffered profound dynamometamorphism." (1902, p. 280).

The granitic rocks are commonly faulted. Amount of movement cannot be determined in most cases, but the direction of latest movement can be ascertained by the ridging on slickensided surfaces.

Slickensided fault surfaces are commonly mineralized. Locally, pegmatite veins are slickensided along one side.

Faulting must have been spread over a considerable time. Inclusions in the Acme Quarry have faults within the inclusions (Ramspott, 1964). In the Berkley Blue Quarry, Oglethorpe Co., a diabase dike which cuts through the quarry is offset by a fault. It is likely that movement along these faults was very slight; the offset of the diabase in the Berkley Quarry is about one foot.

AGE

Relative Age

The Elberton batholith has been regarded as Paleozoic by most workers. Diabase dikes, believed to correlate with the Triassic dikes of Connecticut and New Jersey (Lester and Allen, 1950), cut the batholith. The batholith cross-cuts all other Piedmont rocks. However, the Piedmont rocks have not been convincingly correlated with the relative geologic time scale.

Absolute Age

Absolute age determinations for Elberton granitic rocks are shown in Table 2. Age determinations on zircon concentrates by Uranium-lead methods yield ages on the order of 450 million years, whereas K/A and Rb/Sr determinations on micas yield ages on the order of 250 million years.

Grunenfelder and Silver (1958) attributed this difference to the occurrence of "two or more profound and distinct igneous or metamorphic episodes in the histories of these granite masses....". They attribute the older ages to a late Cambrian (?) plutonic episode previously unrecognized. According to this interpretation, the latest (250 m.y.) event would have affected the zircon only slightly while resetting the "atomic clock" for micas and feldspars.

these relationships are Hurst's unpublished data indicating that the batholith was not a center of the regional metamorphism; but lies well on southeast side of the "hot belt".

The known distribution of rock types does not preclude the possibility of several ages of rock within the batholith. In some quarries, two types of granitic rock have a well-defined contact. Detailed mapping may reveal temporally distinct units.

The relationship of the batholith to the second metamorphism is uncertain. Although the granitic rock shows signs of deformation in almost all thin sections, this strain may relate to the late stages of emplacement. The rift directions do not appear to coincide with primary structures in the batholith. Careful study of rift directions should reveal whether the rift was impressed on the granitic rock during consolidation or whether it is a regional effect of a late metamorphism.

Tectonic Relations

Buddington (1959) defined the zone of emplacement of plutons primarily on the basis of metamorphic facies of the surrounding rocks. By this criterion, the Elberton batholith would be a catazonal pluton, because the surrounding rocks are high grade sillimanite schist and gneiss.

However, catazonal plutons are usually interpreted as being of syntectonic origin. The general cross-cutting relationships, asymmetry with regard to the "hot belt" of metamorphism, and inclusion relations are features which suggest a post-tectonic origin for the Elberton batholith.

The writer's preliminary observations in the field indicate that the individual units of the batholith may be more concordant thar previously thought. Possibly there are both syntectonic and post-tectonic plutons in the batholith. Detailed mapping of the batholith may reveal its tectonic role.

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