MASTER

**GEOLOGY OF THE BIRMINGHAM,
GADSDEN, AND MONTGOMERY
1° × 2° NTMS QUADRANGLES, ALABAMA**

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AIKEN, SOUTH CAROLINA 29801**

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ABSTRACT

✓ This document is a facsimile edition (with accompanying maps) of geologic reports on the Birmingham, Gadsden, and Montgomery 1° x 2° NTMS quadrangles prepared for SRL by the Geological Survey of Alabama. The purpose of these reports is to provide background geologic information to aid in the interpretation of NURE geochemical reconnaissance data. Each report includes descriptions of economic mineral localities as well as a mineral locality map and a geologic map.

FOREWORD

The National Uranium Resource Evaluation (NURE) program was established to evaluate domestic uranium resources in the continental United States and to identify areas favorable for uranium exploration. The Grand Junction Office (GJ) of the Department of Energy (DOE) is responsible for administering and coordinating NURE program efforts. The Savannah River Laboratory (SRL) has responsibility for hydrogeochemical and stream sediment reconnaissance (HSSR) of 3.9 million square kilometers (1,500,000 square miles) in 37 eastern and western states. Other DOE laboratories are responsible for similar reconnaissance in the rest of the continental United States including Alaska. The significance of the distribution of uranium in natural waters and stream sediments will be assessed as an indicator of areas favorable for the location of uranium deposits.

The principal objectives of the NURE program are:

- Prepare, based on existing data, a preliminary evaluation of domestic uranium resources and favorable exploration areas.
- Assess the United States' uranium reserves.
- Improve the reliability of current uranium resource estimates.
- Identify new areas favorable for uranium exploration by industry.
- Apply new or improved uranium resource technology to support NURE. Provide improved exploration and production support for an expanding industry by technology transfer.

The Grand Junction (Colorado) Office of the Department of Energy (DOE-GJ) has completed the first objective.* DOE-GJ is responsible for administering and coordinating efforts to meet the other objectives including distribution of reports. Inputs to the NURE program come from DOE prime contractors, DOE-sponsored research and development, the uranium industry, U.S. Geological Survey, U.S. Bureau of Mines, other federal and state government agencies, and independent sources.

The NURE program consists of six parts:

1. Hydrogeochemical and Stream Sediment Reconnaissance Survey
2. Aerial Radiometric Survey
3. Intermediate Grade Resource Studies
4. World Class Geologic Studies
5. Subsurface Geologic Investigation
6. Technology Application

The Savannah River Laboratory (SRL) has conducted and is maintaining an extensive development program to support the regional geochemical reconnaissance in its area of responsibility. Sampling densities, sampling equipment and techniques, analytical techniques (including the types of analyses required), and results obtained from sampling of different media have been evaluated. Orientation or pilot studies have been conducted in model areas of known uranium mineral occurrences or where geologic conditions seem favorable for the accumulation of uranium. Results of these studies have been useful in designing and conducting the regional reconnaissance.

This document is being issued separately in order to disseminate its content to potential users on a timely basis. Abbreviated versions of the individual reports and slightly modified geologic maps will be issued as part of SRL's reports on results of NURE reconnaissance sampling in the Birmingham, Gadsden, and Montgomery 1° x 2° NTMS quadrangles.

* Document GJO-111(76). Available from Manager, DOE-GJ, P.O. Box 2567, Grand Junction, CO 81501.

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DESCRIPTION OF THE BIRMINGHAM QUADRANGLE

Prepared for E I Du Pont De Nemours & Co., Inc.
Savannah River Plant
As Requested by Purchase Order No. AX458897L

By

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February 12, 1979

DESCRIPTION OF THE BIRMINGHAM QUADRANGLE

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ABSTRACT

The Birmingham Quadrangle in northern Alabama includes from west to east parts of the East Gulf Coastal Plain, Appalachian Plateaus, Valley and Ridge and Piedmont physiographic provinces. In the western part of the quadrangle gently dipping fine and coarse siliciclastic sediments of Late Cretaceous age up to 1,000 feet (ft) or 305 meters (m) thick are present at the surface. They overlap Paleozoic strata near the boundaries of the province. The Appalachian Plateaus segment in the central part of the quadrangle is mainly characterized by gently dipping sedimentary rocks of Pennsylvanian age, however, rocks ranging from Late Cambrian and Early Ordovician to Mississippian are exposed along the flanks of major anticlinal folds that occur near the eastern edge of the plateaus region. The Valley and Ridge segment in the eastern part of the quadrangle is an area of highly folded and faulted sedimentary rocks characterized by northeast-southwest trending ridges separated by narrow valleys. Rocks exposed in the Valley and Ridge range in age from Early Cambrian to Pennsylvanian. The Piedmont area in the southeastern part of the quadrangle includes low-rank and high-rank metamorphic rocks and igneous rocks that are intensely folded and faulted. Dominant trends of the Piedmont units parallel those of the Valley and Ridge. The ages of the Piedmont units are uncertain but they are considered to be correlative with parts of the early and late Paleozoic.

The geologic history of the Valley and Ridge and Appalachian Plateaus region is dominated by elements of the Taconic orogeny including volcanic ash falls in the Middle Ordovician, undefined periods of uplift and erosion during the Silurian and Devonian periods and the Alleghany orogeny near the close of the Paleozoic Era.

The history of the Piedmont region is mainly deduced from apparent relationships existing between the plutonic and volcanic rocks and the metasediments in the area and scattered radiometric age dates. The schist and gneiss of the Hatchet Creek Group are believed to be the oldest metasedimentary rocks of the Piedmont. The Hatchet Creek appears to grade southwestward into the Elkahatchee Quartz Diorite Gneiss which may be a paligenetic equivalent of the Hatchet Creek. The age of the Elkahatchee as determined by radiometric age dating methods is approximately 500 m.y. The Wedowee Group is infolded into the Hatchet Creek and appears to be younger. Unity Group rocks are interpreted to be a metavolcanic clastic sequence in the upper part of the Talladega Group. The Rockford Granite and associated pegmatites seem to be the youngest intrusives in the Piedmont and have been dated by radiometric methods at approximately 300 m.y.

The Mesozoic rocks in the western part of the quadrangle overlap eroded Paleozoic structures and sequences and compose the northeastern flank of a broad downwarp known as the Mississippi Embayment. The initial marine transgression reflected in the lower part of the Tuscaloosa Group (Late Cretaceous) was followed by the development of a large scale fluvial deltaic complex comprising the remainder of the Tuscaloosa Group. Another marine transgression is indicated by the marine and estuarine sediments of the overlying Eutaw Formation (Late Cretaceous). Gaps in the stratigraphic record limit speculations related to the later geologic history of the region.

Formations of particular interest in the Appalachian Plateaus and Valley and Ridge regions are the Chattanooga Shale (Late Devonian) and Pottsville Formation (Pennsylvanian). The Chattanooga Shale contains dispersed uranium. It is exposed along the flanks of the major folds, occurs in the subsurface throughout the plateaus region, and is exposed sporadically along the Birmingham-Big Canoe Valley in the Valley and Ridge region. The Pottsville Formation is considered to have moderate to high uranium protore potential, particularly in the Coosa basin area of the Valley and Ridge region and, to a lesser extent, in the plateaus area. Suitable environments for uranium accumulation may exist along the paleo-oxidation-reduction interfaces, however, preliminary geochemical surveys in the Coosa basin have yielded inconclusive results.

Plutonic rocks of the Piedmont include the Elkahatchee Quartz Diorite Gneiss and the Rockford Granite. The pegmatites, quartz veins and greisens associated with the Rockford Granite contain mica, tin, beryl and rare earth minerals. Locally columbite, tantalite and possibly uraninite have been reported from the pegmatites.

Other units of particular interest in the Piedmont region are the Hatchet Creek, Wedowee and Talladega Groups. The Hatchet Creek Group includes mica pegmatites, greisens and granitic dikes that contain mica, tin, sparse beryllium and monazite mineralization. Uraninite and other radioactive minerals have been reported from the pegmatites. Scattered throughout the outcrop area of the Wedowee Group are small granite plutons and pegmatites containing mica, tin, beryl and radioactive minerals. Aeroradioactivity anomalies are associated with the graphitic schists of the Wedowee Group and the low-rank metamorphic rocks of the Talladega Group but the causes of the anomalies have not been determined.

LOCATION AND PHYSICAL GEOGRAPHY

The Birmingham 1° x 2° NTMS Quadrangle covers about 8,200 square miles (mi) (or 21,230 square kilometers (km)) in northern Alabama and, from west to east, includes parts of the East Gulf Coastal Plain, Appalachian Plateaus, Valley and Ridge and Piedmont physiographic provinces (plate 1). Elevations in the western part of the quadrangle range from 100 to 800 feet (ft) (or 30 to 244 meters (m)). The eastern part of the quadrangle includes many northeast-southwest trending ridges separated by narrow valleys and broad uplands. The elevations of the ridge crests range from 1,000 ft to 1,912 ft (305 to 583 m). Elevations of the valley floors range from about 500 to 600 ft (152 to 183 m) and elevations of the uplands in the southeastern part of the quadrangle range from 500 to 1,000 ft (152 to 305 m). Rainfall averages 57 inches (or 145 centimeters per year) at Birmingham. The climate is humid, subtropical, averaging 80°F (27°C) in January (Birmingham). Intensive weathering and dense vegetation limit outcrops in the area and exposures in roadcuts and stream valleys provide the control points for geologic mapping.

GENERAL GEOLOGY AND TECTONICS

The western part of the Birmingham Quadrangle is characterized by gently dipping Coastal Plain sediments of Late Cretaceous age that overlap Paleozoic strata near the boundaries of the province. In the Appalachian Plateaus segment in the central part of the quadrangle mainly gently dipping sedimentary rocks of Pennsylvanian age are present, however, rocks ranging from Late Cambrian and Early Ordovician to Mississippian are exposed along the flanks of major anticlinal folds that are exposed near the eastern edge of the region. The Valley and Ridge segment in the eastern part of the quadrangle is an area of highly folded and faulted rocks characterized by northeast-southwest trending ridges separated by narrow valleys. The anticlinal folds are mainly

asymmetrical, the northwest limbs are generally more steeply dipping and at places the folds are cut longitudinally by thrust faults of considerable displacement. Rocks exposed in the Valley and Ridge are mostly sedimentary and range in age from Early Cambrian to Pennsylvanian. The Piedmont area in the southeastern part of the quadrangle includes low- and high-rank metamorphic and igneous rocks that are intensively folded and faulted. The ages of the Piedmont rocks are uncertain but are considered to be correlative with parts of the early and late Paleozoic. Dominant trends of the Piedmont units parallel those of the Valley and Ridge.

The average thicknesses, where known, and the dominant lithologies of rock-stratigraphic units known to occur in the quadrangle are included in table 1. The geologic summary specifically emphasizes potential uranium source rocks such as alkalic plutons, and pegmatites and other rocks in the area that are potential host rocks for the accumulation of uranium.

EAST GULF COASTAL PLAIN REGION

The East Gulf Coastal Plain region is bounded on the east by the Appalachian Plateaus and the Valley and Ridge provinces. Mostly unconsolidated sediments of the Tuscaloosa Group and Eutaw Formation of Late Cretaceous age unconformably overlie indurated beds of the Pottsville Formation (Pennsylvanian) throughout most of the area. Alluvial deposits of Quaternary age occur in the flood plains and as terrace deposits in and near the streams and rivers.

The Tuscaloosa Group includes two formations, the Coker Formation at the base and the overlying Gordo Formation. The lower part of the Coker generally includes fluvial gravelly sands and sands overlain by brackish water lagoonal sediments up to 125 ft (38 m) thick that are characteristically in the form of alternating thin beds of carbonaceous clay, silt, and very fine- to fine-grained rippled sand. The upper part of the Coker is mainly a fluvial-deltaic sequence of lenticular beds of fine- to medium-grained, micaceous sand, varicolored micaceous clay and scattered thin beds of gravel. The maximum thickness of the Coker Formation in the southwestern part of the quadrangle is 500 ft (150 m).

Between the Gordo Formation and the overlying Coker there is an erosional disconformity of noticeable relief. The Gordo has a maximum thickness of 300 ft (90 m) in the southwestern corner of the quadrangle.

The Gordo was deposited in fluvial and deltaic environments. At its base, the formation contains irregular beds of gravelly crossbedded sand. The upper part of the formation consists of sands, crossbedded sands and varicolored clays.

The Eutaw Formation which unconformably overlies the Gordo, probably was deposited in marine and estuarine environments. The formation near the southern border of the quadrangle is about 200 ft (61 m) thick and is mostly evenly bedded alternations of fine- to medium-grained glauconitic sand, carbonaceous clay, and gray and greenish-gray laminated clays. Lignitized logs occur locally in the formation.

In the subsurface, formations of Late Cambrian and Early Ordovician ages have been penetrated by oil and gas test wells. Natural gas and limited amounts of crude oil are produced from sandstones in the Floyd Shale, Parkwood Formation (Mississippian) and the Pottsville Formation (Pennsylvanian). Faults in Lamar and Fayette Counties, located as a result of exploratory drilling for natural gas, are known to displace Mississippian units and parts of the Pottsville Formation but are not expressed at the surface in the overlying Cretaceous formations.

APPALACHIAN PLATEAUS REGION

The Appalachian Plateaus region in the central part of the quadrangle is bounded on the west and south by the East Gulf Coastal Plain and on the southeast by the Valley and Ridge. The

Table 1.-- Stratigraphic Units, Birmingham Quadrangle - Appalachian Plateaus, Valley and Ridge, and East Gulf Coastal Plain Province.

System	Rock-Stratigraphic Units		Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Quaternary	Alluvial and Low Terrace Deposits		40	12	Unconsolidated deposits of sand, gravel, and clay along major streams and rivers.
	High Terrace Deposits		25	8	Unconsolidated deposits of sand, gravel, and clay at higher elevations along major streams and rivers.
Cretaceous	Eutaw Formation		200	61	Sand, micaceous, fossiliferous and glauconitic in part; clay, micaceous, fossiliferous and carbonaceous in part.
	Tuscaloosa Group	Gordo Formation	150	46	Sand, chert gravel, and varicolored clay, irregularly bedded, sand and gravel more prevalent in lower part.
		Coker Formation	250	76	Sand, quartz and chert gravel, varicolored clay, and carbonaceous clay, lenticular bedding.
Pennsylvanian	Pottsville Formation		4500	1372	Sandstone, partly conglomeratic, thin-bedded to massive; shale, fissile to thin-bedded; coal and underclay; carbonaceous.
-----	Parkwood Formation		1750	533	Shale, siltstone, and argillaceous sandstone, partly carbonaceous.
Mississippian	Bangor Limestone		250	76	Limestone, bioclastic, oolitic, becomes argillaceous and shaly in southern part of Birmingham Quadrangle where present.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Mississippian	Hartselle Sandstone	75	23	Sandstone, light-colored, fine-grained, quartzose, thin-bedded to massive.
	Pride Mountain Formation	200	61	Fissile clay shale with lesser amounts of sandstone and limestone.
	Floyd Shale	800	244	Shale, dark gray, partly calcareous and carbonaceous, lesser amounts of siltstone, sandstone, and argillaceous limestone; geophysical logs indicate some zones are radioactive in subsurface; equivalent in part to Bangor, Hartselle, and Pride Mountain.
	Tuscumbia Limestone	100	30	Limestone, micrite and bioclastic, lesser amounts of oolitic limestone, chert, and dolomite.
	Fort Payne Chert	150	46	Fossiliferous bedded chert and siliceous limestone with lesser amounts of bioclastic limestone.
	Maury Formation	2	0.6	Green and maroon shale.
Devonian	Chattanooga Shale	20	6	Black fissile radioactive shale, lesser amounts of sandstone, partly phosphatic.
	Frog Mountain Sandstone	30	9	Sandstone, dusky-red and light- to dark-gray, coarse-grained, hematitic.
	Unnamed cherty limestone	300	91	Limestone, crystalline, glauconitic, cherty; chert, white to brownish-gray, mottled with limestone in part; (stratigraphic position relative to Frog Mountain Sandstone uncertain).

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Silurian	Red Mountain Formation and Silurian undifferentiated	400	122	Reddish to olive to gray sandstone, siltstone, shale, and limestone, hematitic in part, absent east of Helena fault.
Ordovician	<u>Western Facies - Valley and Ridge and Appalachian Plateaus Provinces</u>			
	Sequatchie Formation	100	30	Reddish-gray to yellowish-gray, fossiliferous limestone and reddish-gray siltstone.
	Chickamauga Limestone	600	183	Limestone, sublithographic to crystalline, partly phosphatic and argillaceous; thin beds of bentonitic shale occur locally.
	Attalla Chert Conglomerate Member of Chickamauga Limestone	20	6	Conglomerate composed of pebbles, cobbles, and boulders of chert and rarely dolomite and quartzite in a matrix of sand-sized chert and quartz; (restricted to Valley and Ridge province).
	<u>Eastern Facies - Valley and Ridge Province</u>			
	Sequatchie Formation	120	37	Calcareous siltstone, gray to grayish green, dolomite, and maroon and olive shale.
	Colvin Mountain Sandstone	70	21	Sandstone, orthoquartzitic, medium to coarse, some pebbles, thick- and thin-bedded; thin beds of sandy bentonite in upper part.
	Greensport Formation	235	72	Maroon and yellow-tan variegated siltstone, calcilutite, and shale; irregular lenses of sandstone.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Ordovician	Little Oak Limestone	250	76	Limestone, dark-gray, highly fossiliferous, slightly argillaceous, contains nodules and stringers of chert and bands of silty clay; bentonitic locally.
	Athens Shale	150	46	Black fissile shale; impure dark-gray to black limestone and thin beds of limestone.
	Lenoir Limestone	400	122	Limestone, very dark-gray, finely crystalline, medium to thick bedded, with thin irregular clay partings.
	Newala and Longview Limestones (of Knox Group)	750	229	Limestone, light- to very dark-gray, sublithographic to very coarse crystalline, fossiliferous and (or) cherty in part, lesser amounts of dolomite.
	Knox Group undifferentiated	200	610	Dolomite, medium- to light-gray, thick bedded, cherty; lesser amounts of limestone and dolomitic limestone; weathers to irregular boulders and fragments of chert and reddish clay.
Cambrian	Conasauga Formation	1500	457	Limestone, dark- to brownish-gray, sublithographic; shale, light-olive to medium-gray; lesser amounts of dolomite; (absent in Cahaba Valley).
	Bibb Dolomite	250	76	Dolomite, dark colored, coarsely crystalline, thick bedded, highly siliceous.
	Ketcha Dolomite	300	91	Dolomite, light- to light-brownish-gray, crystalline, pure, with lesser amounts of brownish-gray dolomite.

Table 1, contd.

System or Age	Rock-Stratigraphic Units	Average Thickness (feet)	Thickness (meters)	Dominant Lithologies and Remarks
Cambrian	Brierfield Dolomite	1500	457	Dolomite, coarsely grained, thick bedded, and highly siliceous in part.
	Rome Formation	1000+	305	Shale, red and green; sandstone, red to brown to gray, calcareous in part, lesser amounts of limestone and dolomite.
	Shady Dolomite	500	152	Dolomite, light- to dark-gray, fine- to medium-grained, locally siliceous and silty
	Weisner Quartzite	1500	457	Quartzite and sandstone, light-colored, fine- to coarse-grained, tough to friable, partly conglomeratic; lesser amounts of shale, dark gray, arenaceous, micaceous.
Late Paleozoic (?)	<u>Piedmont Province</u>			
	Stumps Creek Formation			Phyllite, silty laminae; local beds of calcareous siltstone and fine-grained sandstone.
	Brewer Phyllite			Phyllite, gray to green to red, clayey, silty, locally conglomeratic.
	Sawyer Limestone			Limestone and dolostone, gray, argillaceous, silty to siliceous, lithographic to medium-grained.

Table 1, contd.

System or Age	Rock-Stratigraphic Units		Dominant Lithologies and Remarks
Lower Paleozoic (?)	Unity Group	Hillabee Chlorite Schist	Chlorite schist, dense; may include ultramafic zones and streaks of chlorite phyllite.
		Chulafinnee Schist	Schist, green, fissile; may include chlorite phyllite and quartzose phyllite.
		Chloritic quartz schist	Chloritic quartz schist, light-gray to white, thinly laminated.
		Graphitic quartz schist	Graphitic quartz schist, dark-gray to black, thinly laminated, siliceous.
	Talladega Group	Abel Gap	Phyllite, siltstone and claystone; locally conglomeratic, arkose and (or) quartzite; calcareous siltstone and sandstone; arkose quartzite.
		Lay Dam Formation	Metaclastics, conglomeratic metagraywacke and quartzite.
		Lay Dam Quartzite	Quartzose to feldspathic quartzite, argillaceous and conglomeratic in part.

Table 1, contd.

System or Age	Rock-Stratigraphic Units		Dominant Lithologies and Remarks
Lower Paleozoic (?)	Wedowee Group	Wedowee Group undifferentiated	Phyllite, schist, and gneiss.
		Higgins Ferry Formation	Biotite-feldspathic schist and gneiss; graphite-sericite-feldspathic schist; granitic pegmatites.
		Poe Bridge Mountain Formation	Feldspathic graphite schist, roscoelite quartz schist, graphite quartzite, garnet muscovite biotite schist and gneiss and thin units of banded amphibolite.
		Hackneyville Schist	Graphite-sericite phyllite and schist, muscovite, porphyroblastic schist and phyllite.
		Wedowee Group graphitic units	Graphite-rich feldspathic mica schist.
	Hatchet Creek Group		Graphite-sericite phyllite and graphite-muscovite-garnet schist.
	Mitchell Dam Amphibolite		Homeblende-actinolite amphibolite, dark-green to black, thin layered to massive.

Table 1, contd.

System or Age	Rock-Stratigraphic Units	Dominant Lithologies and Remarks
Lower Paleozoic (?)	Ultramafics	Ultramafic pods and sheets, principally enstatite-hornblende-actinolite.
	Rockford Granite	Leucocratic muscovite-biotite quartz monzonite to granite, locally pegmatitic.
	Elkahatchee Quartz Diorite Gneiss	Biotite-quartz-diorite gneiss.

rocks in the region are characterized by the general absence of thrust faults and by the gentle, approximately symmetrical, surface folds (Colton, 1970, p. 15). The folds are steeper, more closely spaced, and more commonly parallel to the regional trend near the Appalachian structural front that forms the southeastern boundary of the region. Three major anticlines are exposed near the eastern boundary of the region and synclinal folds occur in the subsurface farther to the southwest (Semmes, 1929, map 2; and Kidd and Shannon, 1977, p. 4). Westward from the major folds, the rocks are gently folded into minor undulations. The regional dip of rocks in the northern part of the quadrangle is southwest about 45 ft per mi (8.5 m per km) and the dip steepens to the southeast to about 100 ft per mi (18.9 m per km).

Rocks of Middle Cambrian to Early Ordovician age are exposed along the axes of the major anticlines and rocks of Middle Ordovician to Mississippian age occur along the flanks. However, most of the area is underlain by fine and coarse siliciclastics of the Pottsville Formation (Pennsylvanian). Outliers of the Tuscaloosa Group (Late Cretaceous) cap hills in the western part of the area and Quaternary alluvium and remnants of terrace deposits occur in and near the major streams.

The sedimentary sequence in the region is at least 11,060 ft (3,371 m) thick, as reported from a deep oil test well in northern Tuscaloosa County.

CHATTANOOGA SHALE

The Chattanooga Shale (Late Devonian) contains dispersed uranium (Conant and Swanson, 1961, p. 71). It is exposed along the flanks of the major folds and occurs in the subsurface throughout the region. The Chattanooga Shale is mainly brownish-black to grayish-black, carbonaceous, silty, fissile shale with included thin discontinuous beds of fine-grained sandstone that may contain pyrite and phosphatic inclusions (Kidd, 1975, p. 36). The Chattanooga is generally less than 20 ft (6 m) thick.

POTTSVILLE FORMATION

The Pottsville Formation is considered by Dennison and Wheeler (1975, p. 191) to have moderate to high uranium protore potential and the report recommends additional investigation of the Pottsville in the Coosa basin located southeast of the plateaus region. The Pottsville in the plateaus region may also have uranium potential for reasons of partially similar lithologies and provenance of sediments.

The formation was deposited in mixed marine estuarine and deltaic environments as part of a vast delta complex prograding mainly from south to north; sediments were also contributed from sources in the southwest and southeast and, to a lesser extent, from the east and northeast. According to Ferm and Ehrlich (1967, p. 11) sediments from the south were derived from a presently buried Ouachita orogenic belt. Pebbles and cobbles in the conglomerate in the Cahaba and Coosa basins indicate that sediments from the southeast were derived from the Alabama Piedmont.

At the base, the formation includes thick beds of conglomeratic sandstone, mainly of the orthoquartzite variety. Above the base, the formation includes interbedded subgraywacke sandstone, micaceous, carbonaceous siltstone, and silty carbonaceous shale. Most of the beds are lenticular. The upper half of the formation contains interspersed coal seams and erratically occurring associated underclays. Thirty commercial coal seams comprising 8 coal groups are mined in the plateaus area. Natural gas is associated with the coal seams and is produced from sandstones in the formation in Fayette County.

Ferm and Ehrlich (1967, p. 11) describe the sandstones above the base of the Pottsville as mainly of the subgraywacke variety and consisting of varying proportions of strained and sheared (metamorphic) quartz, sodic feldspars, a great variety of low-grade micaceous, metamorphic rock fragments and some detrital volcanic fragments. The quartz content of the subgraywackes diminishes from north to south. Further details of the mineralogy and sedimentary environment are described by Ehrlich (1965) and Robinson, *ed.* (1976).

VALLEY AND RIDGE REGION

The Valley and Ridge region in the eastern part of the quadrangle is bounded on the northwest by the Appalachian Plateaus, on the southwest by the East Gulf Coastal Plain and on the southeast by the Piedmont. As stated by Colton (1970, p. 15) in characterizing the region, the axes of folds and the traces of faults closely parallel the long axis of the basin (northeast-southwest), and within the region the folds become progressively gentler and thrust faults become less numerous and more widely spaced toward the west. Many of the folds are oversteepened or are overturned to the west on their west flanks. Movement of the overthrust blocks along the thrust faults was toward the northwest. Sedimentary rocks in the region are more than 10,000 ft (3,048 m) thick.

Major structural and/or geomorphic subdivisions of the Valley and Ridge from the Appalachian Plateaus on the northwest to the Piedmont on the southeast are the Birmingham anticlinorium, Cahaba syncline, Helena thrust block, Coosa synclinorium, Coosa deformed belt of Thomas and Drahovzal (1974b) and the eastern Coosa Valley of Bearce (1978).

Rocks of Cambrian to Early Ordovician age are exposed along the eroded axis of the Birmingham anticlinorium and Middle Ordovician-Mississippian rocks are exposed along the flanks. Mississippian and Pennsylvanian rocks are exposed in the Cahaba syncline. The Helena thrust block to the southeast of the syncline is bounded on the northwest by the Helena thrust fault that juxtaposes Early Cambrian and Pennsylvanian rocks. Strata in the overthrust Helena block range in age from Early Cambrian to Early Ordovician. The Coosa synclinorium southeast of the Helena block includes Pennsylvanian rocks in the trough, and pre-Pottsville (pre-Pennsylvanian) rocks, including some as old as Cambrian, are exposed on the northwest limb.

The Coosa deformed belt described by Thomas and Drahovzal (1974b, p. 45-75) is located between the Coosa synclinorium and the eastern Coosa Valley. It is separated from the Coosa synclinorium on the northwest by the Coosa reverse fault that cuts the southeast limb of the synclinorium and from the eastern Coosa Valley on the southeast by the southeast dipping Pell City thrust fault. The Coosa deformed belt is a narrow linear zone of complex structures consisting of thin imbricate thrust slices that have been thrust northwestward toward the Coosa synclinorium. Most of the surface in the Coosa deformed belt is underlain by the Floyd-Parkwood (Mississippian and Mississippian-Pennsylvanian?) and older formations of the Ordovician, Devonian and Mississippian are exposed in narrow strips along thrust faults (Thomas and Drahovzal, 1974b, p. 45).

The eastern Coosa Valley as described by Bearce (1978, p. 461-476) is largely underlain on the northwest side by the Knox Group (Late Cambrian and Early Ordovician) and the southeast side includes Early-Middle Cambrian formations and the Knox Group. The southwestern part of the area also includes Late Mississippian rocks. The Coosa Valley strata have been deformed mainly by folding and thrust faulting (Bearce, 1978, p. 461).

CHATTANOOGA SHALE

Exposures of the Chattanooga Shale shown on plate 2 are mainly restricted to the Birmingham-Big Canoe Valley within the Valley and Ridge region. The formation, where present, contains dispersed uranium and is generally gray to black carbonaceous, pyritiferous, partly fossiliferous shale. The Chattanooga ranges in thickness from 20 to 35 ft (6.1 to 10.7 m) in Etowah and St. Clair Counties and thins rapidly to the south. In southeastern Jefferson County and northeastern Tuscaloosa County the formation is from 0 to 2.5 ft (0 to 0.8 m) thick.

POTTSVILLE FORMATION

The Pottsville Formation in the Cahaba coal field is the thickest succession of Pottsville strata in the state. It ranges in thickness from 5,100 ft (1,554 m) in the north to 9,000 ft (2,743 m) in the south. The sequence is mostly non-marine and includes only two known invertebrate fossil horizons (Dennison and Wheeler, 1975, p. 127). The formation in the Cahaba coal field or Cahaba syncline area is of Early and Middle Pennsylvanian age (Culbertson, 1964, p. B35). The lower part of the formation ranges in thickness from 600 ft (183 m) in the northern part to 1,100 ft (335 m) in the southern part and includes two thick conglomeratic orthoquartzite beds separated by from 200 to 500 ft (61 to 152 m) of shale and fine-grained sandstone. The middle part of the formation ranges in thickness from 3,000 to 4,700 ft (914 to 1,433 m) and is composed of mainly carbonaceous shaly siltstone and sandstone, with a few thin conglomerate beds and 12 to 15 commercial coal beds. The upper part is up to 3,000 ft (914 m) thick and is composed of fine to coarse, micaceous, carbonaceous sandstone, conglomerate and conglomeratic sandstone, carbonaceous shale, underclay and about 20 coal seams. The conglomerates consist of subrounded to well rounded pebbles and a few cobbles of quartzite, varicolored chert and metamorphic rocks in a matrix of fine to coarse grains of quartz and chert that occur in beds up to 100 ft (30 m) thick (Culbertson, 1964, p. B37). Sandstones in the middle and upper part of the formation are of the subgraywacke type.

The Pottsville in the Coosa basin has a maximum thickness of 5,500 ft (1,676 m) and is a non-marine succession according to Culbertson (1964, p. B46). The lower part includes two thick conglomeratic sandstone beds, a middle part 2,800 ft (853 m) thick essentially devoid of coal consisting of lenticular sandstone, siltstone, and shale beds and an upper coal-bearing part, 2,000 ft (610 m) thick consisting of fine to medium sandstone, carbonaceous shale and siltstone and about 14 beds of coal. According to Dennison and Wheeler (1975, p. 128) the Coosa basin is unusual in that it contains redbed strata (oxidizing facies) interbedded with reduzate facies sandstones containing carbonized wood and pyrite. Suitable environments for uranium accumulation may exist along the paleo-oxidation-reduction interfaces.

Reconnaissance radiometric and geochemical studies in the Coosa basin by Gilbert (1976) yielded inconclusive results that may be attributed to the general lack of accessibility to the region and the sparsely located sampling points. However, oxidized shale-reduced sandstone facies were located at several places in the basin. In a reconnaissance survey of the basin Schot and Penley (1977), found selected shale units which yielded 12 to 31 ppm uranium and sandstone units which yielded 0 to 22 ppm uranium. Roll-front type environments were not located.

PIEDMONT REGION

The Piedmont region in the Birmingham Quadrangle is a part of the northern Piedmont, which, as defined by Neathery and others (1974, p. 1) includes all the rocks between the southern edge of the Valley and Ridge province and the Brevard fault zone. The area is underlain predominantly by metasedimentary rocks that have undergone polyphase tectonism and syntectonic metamorphism. In a large part of the belt, the metasedimentary rocks have been intruded by minor mafic- and a wide variety of granitic igneous rocks. The northern Piedmont is divided into two major metamorphic belts: the low-rank Talladega belt, and the high-rank Wedowee belt. The terms high-rank and low-rank metamorphic belts are used in a relative sense by Neathery and others (1975, p. 1). Most of the rock in the low-rank belt is in the greenschist facies of regional metamorphism, but small areas of higher grade occur scattered throughout the belt. Similarly, the high-rank belt, which also contains broad exposures of greenschist facies rocks, is normally in the amphibolite facies of regional metamorphism.

PLUTONIC ROCKS

Elkahatchee Quartz Diorite Gneiss.—The Elkahatchee is exposed in large areas of Coosa County and makes up the largest part of the Pinckneyville Granite complex (Adams, 1926; Gault, 1945). The Elkahatchee generally is medium- to dark-gray rock of quartz-diorite composition with well defined gneissic banding. Locally, the gneissic banding ranges from a few inches to several feet (2.3 cm to 1 m) in thickness. Contacts between the Elkahatchee and the host rock (Hatchet Creek Group) are broadly concordant. Wedowee rocks show no evidence of alteration and lie non-conformably on the quartz-diorite. Elongate screen-like bodies of schist and hornblende gneiss are locally abundant. The Elkahatchee is dated to be 501 ± 51 m.y. by Rb/Sr whole rock analyses and 528 ± 10 m.y. by $\text{Pb}^{207}\text{-Pb}^{206}$ zircon methods (Russell, 1975, p. 91-92).

Rockford Granite.—A complex of dikes and small stocks of granitic rocks, known collectively as Rockford Granite, intrude the Hatchet Creek and Wedowee Group rocks west of the Elkahatchee outcrop in Coosa County. The Rockford ranges in composition from quartz monzonite to trondhjemite to granite. Internal foliations range from very faint to well developed and are generally concordant with the host rock. The contacts are concordant as well as discordant to the country rock, which is often feldspathized near the contact. The age of the Rockford as determined by K-Ar dating methods is 317 ± 10 m.y. (table 2; Wampler and others, 1970).

The pegmatites, quartz veins and greisens associated with the Rockford are rich in mica, tin and beryl, and contain rare earth minerals. Locally columbite, tantalite, and possibly uraninite have been reported from the pegmatites. Scintillometer traverses across many of the pegmatites denote anomalous radioactivity associated with the selvage zones.

VOLCANIC ROCKS

Mitchell Dam Amphibolite.—Exposed in the southeastern part of the Birmingham Quadrangle are thin outcrops of amphibolite. These amphibolites are considered correlative with the extensive amphibolite complex that outcrops at Mitchell Dam on the Coosa River and is termed

Table 2.--Radiometric age dates - Birmingham Quadrangle

<u>Map no.</u>	<u>Location</u>	<u>Rock type</u>	<u>Mineral analyzed</u>	<u>Dating method used</u>	<u>Apparent age (millions of years)</u>	<u>References</u>
1	N $\frac{1}{2}$ SW $\frac{1}{4}$ sec. 32, T. 24 N., R. 20 E. Coosa County	Rockford granite	Muscovite	K-Ar	317 $\pm$ 10	Wampler and others, 1970
2	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 17, T. 24 N., R. 18 E. Coosa County	Graphite-sericite phyllite Wedowee Group	Sericite	K-Ar	369 $\pm$ 18	Wampler and others, 1970
3	NE $\frac{1}{4}$ sec. 31, T. 24 N., R. 15 E. Chilton County	Phyllite Talladega Group	Sericite	K-Ar	389 $\pm$ 15	Kish and Harper, 1973 Harper, personal communication (1973).
4	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 6, T. 23 N., R. 15 E. Chilton County	Phyllite Talladega Group	Whole rock	K-Ar	410 $\pm$ 16	Kish and Harper, 1973 Harper, personal communication (1973).
5	NW $\frac{1}{4}$ sec. 1, T. 23 N., R. 14 E. Chilton County	Phyllite Talladega Group	Muscovite	K-Ar	374 $\pm$ 15	Kish and Harper, 1973 Harper, personal communication (1973).

Mitchell Dam Amphibolite. It is a dark-green layered amphibolite with a coarse to fine-grained texture. Both the mineralogy and texture are quite variable. Locally, the texture grades into a coarse-grained mafic rock suggestive of gabbro. North of Hanover, Coosa County, the amphibolite contains discrete bodies of ultramafic rock. The relationship of these various rock types to each other is not clear. Locally the fabric of the amphibolite is strongly lineated indicating possible tectonic involvement. Outcrop patterns suggest the amphibolite is a stratigraphic bounded unit complicated by complex folding.

Hillabee Chlorite Schist (Hillabee Greenstone).—Along the southeastern border of the Talladega Group is a narrow band of mafic rock consisting of chlorite-epidote schist, and quartz chlorite schist. This zone has been interpreted by Carrington and Wigley (1967, p. 19) as a mafic dike injected along the sole of a thrust fault. Neathery and Reynolds (1973, p. 725) suggest that the Hillabee represents a complex metavolcanic sequence which occurs at the top of the Talladega Group and is in normal but fault-bounded contact with the high-grade metamorphic rocks to the southeast. Tull and others (1978) interpret the Hillabee as a greenstone sequence, which may contain massive sulfide deposits locally along strike. Lamont and Hastings (1964) have discussed the copper-bearing pyrite ore in Pyriton, Clay County, Alabama, which lies a few miles east of the Birmingham Quadrangle.

OTHER CRYSTALLINE ROCK UNITS

Hatchet Creek Group.—The rocks of the Hatchet Creek Group are present southeast of the Wedowee belt in Coosa and Chilton Counties. These rocks are composed primarily of garnet-biotite schist and gneiss that have been interpreted to be a highly metamorphosed series of pelitic arenites and graywackes. Locally, infolded into the Hatchet Creek Group are thin graphitic units that appear to be remnants of the Wedowee Group. There are numerous mica pegmatites, greisens, alaskite veins and granitic dikes throughout the outcrop area. They contain mica, tin, and sparse beryllium, and monazite mineralization. Locally, uraninite and other radioactive minerals have been reported from the pegmatites.

Wedowee Group.—Southeast of the Hillabee Chlorite Schist is a belt of aluminous metasedimentary rocks of diverse character and lithology. These rocks belong to the Wedowee Group. The Wedowee exhibits a wide variation in lithology and metamorphic grade across the outcrop area. Along the northwest border of the Wedowee belt are sericite and sericite-graphite phyllites that represent the originally defined Wedowee Formation (Adams, 1926; 1933). The phyllite units grade southeastward into a coarsely crystalline kyanite-sillimanite mica schist and fine-grained gneiss. These have been named the Higgins Ferry Formation (Neathery and Reynolds, 1973; Neathery, 1975, p. 17). A porphyroblastic fine-grained andalusite bearing graphitic muscovite schist has been named Hackneyville Schist (Neathery, 1975, p. 24). The graphitic schists contain vanadium-bearing mica (roscoelite). Molybdenum mineralization in the graphitic schists has also been reported.

Intricately infolded with these metasedimentary rocks are numerous amphibolite units that are interpreted as mafic tuff. Some of the units are large enough to be recognized and mapped as separate units. Small granite plutons and pegmatites containing mica, tin, beryl, and radioactive minerals are scattered throughout the outcrop area. Locally, uraninite and other radioactive minerals have been reported.

Aeroradioactivity anomalies over the Wedowee graphitic schist regions have been recognized (Neathery, and others, 1976). The graphite schist may have provided a suitable environment for uranium mineralization.

Talladega Group.—Rocks of the Talladega Group consist of a thick sequence of gray and gray-green sandy and conglomeratic sericite phyllite, quartzite, chert, and irregular beds of quartz-graphite phyllite. All of these rocks are characteristic of a deltaic-lagoonal sequence. Over much of the outcrop area these rocks have been locally impregnated by quartz pods and veins during regional metamorphism and tectonism. These phyllites have been extensively folded, and locally faulted. Aeroradioactivity anomalies up to 625 counts per second (background less than 250 counts per second) have been recorded in northeast Chilton and southeast Shelby Counties (Neathery and others, 1976, p. 380). Locally, some of the phyllite sequences contain a high percentage of feldspar and granitic boulder-bearing graywacke which may be responsible for the anomalies. No field work has been done to ascertain the cause of the anomalies.

RADIOMETRIC AGE DATES

Age dates available for the Birmingham Quadrangle were all derived by the K-Ar method, which is an estimate of the last cooling event (last metamorphism), rather than the age of the rock. The dates are listed in table 2 and the locations of the collecting sites are shown in figure 1.

Samples of the Elkahatchee Quartz Diorite Gneiss from southern Coosa County, immediately south of the Birmingham Quadrangle were dated by Russell (1975, p. 91-92) by whole rock Rb/Sr and zircon Pb^{207}/Pb^{206} methods and the ages determined were 501 ± 51 m.y. and 528 ± 10 m.y. respectively.

GEOLOGIC HISTORY

The geologic history of the Valley and Ridge and Appalachian Plateaus regions in the Birmingham Quadrangle is dominated by elements of the Taconic orogeny, undefined periods of uplift and erosion that took place during the Silurian and Devonian, and the Alleghany orogeny near the close of the Paleozoic Era. The history of the Piedmont region is described from apparent relationships existing between the plutonic and volcanic rocks and the metasediments in the area and scattered radiometric age dates. The Mesozoic rocks in the western part of the quadrangle overlap eroded Paleozoic structures and sequences and compose the northeastern flank of a broad downwarp known as the Mississippi embayment.

The earliest event of the Taconic orogeny in the southern Appalachians as described by Gilbert (1971, p. 167) and Neathery and Drahovzal (1971, p. 185) was the uplift and erosion of Cambrian and Ordovician sediments near the close of the Early Ordovician. This uplift and erosion resulted in a pronounced disconformity between Lower and Middle Ordovician rocks. The result in the stratigraphic record is referred to as the Middle Ordovician unconformity or the post-Knox unconformity. A well-cemented conglomerate, derived from erosion of the underlying Knox Group and consisting of large boulders, cobbles and pebbles of chert cemented together in a matrix of finer-sized particles occurs at the base of the Middle Ordovician rocks in the Valley and Ridge province. A somewhat finer-grained facies occurs in exposures in Murphrees Valley and southern Wills Valley—two of the major folds located near the eastern margin of the Appalachian Plateaus province. Farther to the west in the Appalachian Plateaus province, Early Ordovician rocks of the Knox Group are overlain paraconformably by shale, limestone and dolomitic limestone of the Chickamauga (Middle Ordovician).

The Blountian phase of the Taconic orogeny of Rodgers (1953, p. 94, and 1971, p. 1165) that took place near the close of the Middle Ordovician was the next major event in the Appalachian region. In the eastern Valley and Ridge, epeirogenic uplift and subsequent erosion establish-

- K-Ar age dates from Wampler and others (1970)
- K-Ar age dates from Kish and Harper (1973)

Figure 1.—Locations of the samples used for radiometric age dating in northern Coosa and Chilton Counties, Alabama. (data in Table 2).

ed conditions for the formation of a delta complex of fine and coarse siliciclastics that include the Athens Shale, Greensport Formation and Colvin Mountain Sandstone which are equivalent to the Middle Ordovician Chickamauga Limestone of the western Valley and Ridge and the plateaus areas. The Blountian phase was concluded by volcanism. The ash falls resulting from the volcanic activity are widespread in the Chickamauga Limestone, the Athens Shale, Little Oak Limestone and Colvin Mountain Sandstone in the Valley and Ridge (Smith and others, 1971, p. 128-130). Ash falls have not been reported in the subsurface in the plateaus region of the quadrangle but are recorded in the Gadsden Quadrangle to the north.

During the Late Ordovician, existing Paleozoic sequences were uplifted and eroded as indicated by the wide variety of units upon which the Silurian sediments rest. The folding was most severe in the east and decreased westward. Uplift was greater in the south as the entire Ordovician sequence is beveled and thins greatly to the south. The absence of Silurian sediments in the Cahaba and Coosa Valleys to the south and southeast of Birmingham suggests a possible positive feature in that area or pronounced erosion prior to the deposition of Devonian formations.

The Silurian Red Mountain Formation rests unconformably on Ordovician rocks and outcrops of the Red Mountain in the Valley and Ridge and eastern Appalachian Plateaus are upper Llandovery in age (Berry and Boucot, 1970, p. 203). The Silurian strata in the subsurface in the plateaus region are partially equivalent to the Red Mountain Formation, and the undifferentiated Silurian sequences also includes younger siliciclastics and carbonates of Wenlock and Ludlow age (Berry and Boucot, 1970, p. 203); Lundin and Newton, 1970, p. 17). In the western Valley and Ridge, the Silurian rocks are overlain unconformably by the Frog Mountain Sandstone of Early and Middle Devonian age. In the eastern part of the Appalachian Plateaus province, the Red Mountain Formation is overlain by the Chattanooga Shale. In the western part of the province, undifferentiated Silurian formations are overlain unconformably by an unnamed cherty limestone considered to be of Devonian age. The sequences suggest uplift and erosion or non-deposition in the province during parts of the Silurian and Devonian, similar to that which occurred in the Interior Low Plateau province to the north.

Within the Valley and Ridge and Appalachian Plateaus provinces, the Devonian formations are overlain unconformably by the Maury Formation (Early Mississippian) and successively younger Mississippian formations. The stratigraphic relationships of the Mississippian units are mostly conformable even though the facies are diverse. Stratigraphic relationships of Upper Mississippian-Pennsylvanian units have been described by Thomas (1972, p. 90-94) and suggest continuous sedimentation across the systemic boundary rather than a major hiatus. The Mississippian-Pennsylvanian boundary has not been precisely defined but is considered to be within the Parkwood Formation by Butts (1926, p. 206) and may lie within the upper part of the shales that overlie the Bangor Limestone in areas where the Parkwood is absent. However, further work with fossil forms that are independent of facies control will be required to define the boundary.

The Alleghany orogeny, beginning near the close of the Paleozoic Era, was the last major event of deformation in the Appalachian Plateaus and the Valley and Ridge. The duration of the orogeny cannot be accurately determined because of large gaps in the stratigraphic record. No Paleozoic sediments younger than Early or early Middle Pennsylvanian age are known to occur and the Mesozoic Era is represented by only Late Cretaceous sediments. The large parallel folds occurring in the eastern part of the Appalachian Plateaus and the major structural features of the Valley and Ridge were formed during the Alleghany orogeny.

The Piedmont area of Alabama exhibits all the complexities of an old igneous-metamorphic terrain with multiple deformation. Insufficient data are available to establish a chronological order of rock formation and tectonic events. Tull, (1975; 1978) recognized four phases of deformation. All of the deformation phases apparently took place after the deposition of the youngest rocks. Whole rock Rb/Sr isochron age determinations have been made for the Kowaliga Gneiss and the Elkahatchee Quartz Diorite Gneiss (Russell, 1975, p. 91-92). Based on the cross-cutting relationships of granitic rocks and metamorphism, supplemented by meager radiometric age determinations, the following series of events emerge as the probable geologic historical sequence of the Alabama Piedmont region.

The schist and gneiss of the Hatchet Creek Group appear to be the oldest metasedimentary rocks of the Alabama Piedmont, resembling metamorphic equivalents of a thick flysch sequence. The Hatchet Creek Group appears to grade southwestward into the Elkahatchee Quartz Diorite Gneiss which may be a paligenetic equivalent of the Hatchet Creek. Chemically, the Elkahatchee strongly resembles graywacke, a common eugeosynclinal rock (Deininger, 1975, p. 59). The Elkahatchee has large inclusions of schists, probably skialiths, and is concordant with the Hatchet Creek Group.

The Wedowee Group forms a thick sequence of metavolcanic and pelitic graphitic phyllite and schist. It is infolded into the Hatchet Creek Group and appears to be younger than the Hatchet Creek schist and gneiss. The rocks of the Unity Group are interpreted as a metavolcanic siliciclastic sequence in the upper part of the Talladega Group.

Structurally, the Rockford Granite and associated pegmatites seem to be the youngest intrusives in the Alabama Piedmont. They and the pegmatites show intrusive cross-cutting relationships with the Elkahatchee, Hatchet Creek and Wedowee rocks, and an igneous origin for these rocks is indicated on the basis of map patterns, locally discordant contacts, inclusions, and composition. A K-Ar age date for the Rockford Granite of approximately 300 m.y. (table 2), indicates a late Paleozoic age for the time of uplift and cooling. However, the available K-Ar age dates for the other rocks in the northern Piedmont region including the Talladega Group show the same approximate age.

MINERAL OCCURRENCES

Lithium, beryllium, tin, niobium, tungsten, molybdenum, vanadium, uranium, thorium and rare-earth elements (monazite) occur in the crystalline rocks of the Birmingham Quadrangle. The description and distribution of mica pegmatites and possible massive sulfide prospects are described below, and shown on the accompanying map (plate 2). With the exception of sulfide deposits in the Hillabee Chlorite Schist of the Unity Group, most of the aforementioned elements occur in Coosa, Clay, and Talladega Counties in the southeast corner of the Birmingham Quadrangle. Dispersed uranium has been identified in the Chattanooga Shale in the northeastern part of the quadrangle.

MICA PEGMATITE

Pegmatites are very common in Coosa County. The locations shown on the map are compiled from Clark (1921), Heinrich and Olson (1953), and Neathery (1974). The pegmatites are variable in size and range from thin stringers to as much as 100 feet wide and 3,000 feet long.

They exhibit a general northeasterly strike and occur associated with the various granitic phases of Rockford plutons and as intrusives into the Wedowee and Hatchet Creek Groups and the Elkahatchee Quartz Diorite Gneiss. Most of the pegmatites contain muscovite and phlogopite, with biotite, and various phengite micas in trace amounts. In addition to mica they also contain other minerals, which are described in subsequent sections. The following is the most important pegmatite (Neathery, 1974, p. 16).

Map no.	Prospect name and location	Description
1	Bentley-Hertzfeld-Rawls W½ sec. 17, T. 24 N., R. 19 E.	Open cut about 30 feet long and a shaft 20 feet deep, both in pegmatite which strikes northeast and dips steeply to the southeast. Pegmatite composed of quartz, kaolinized feldspar, and ruby mica, sheets 4 x 4 inches; workings caved.

LITHIUM

Lithium reportedly occurs in spodumene ($\text{LiAl Si}_2\text{O}_6$) in mica- and tin-bearing pegmatites of Coosa County. No specific commercial location is known.

BERYLLIUM

Beryllium occurs in beryl ($\text{BeAl}_2\text{Si}_6\text{O}_{18}$) in pegmatites associated with or near the Rockford Granite (part of the Pinckneyville Granite complex) and in the associated host rocks of the Hatchet Creek and Wedowee Groups. Beryl has not been reported in northern Coosa County but may occur in traces and minor amounts in the selvage zone of some of the more complex pegmatites. Coosa County beryl is difficult to recognize as it is often yellow to milky in color and translucent resembling weathered potassium feldspar in outcrop.

TIN

Cassiterite (SnO_2) commonly occurs in greisens, pegmatites, and quartz veins in and around the Rockford plutons and in contact aureoles in the schists and gneisses of the Wedowee and Hatchet Creek Groups (Adams, 1930; Hunter, 1944; Reed, 1950; Neathery, 1974; and Cook, 1975). These pegmatites form part of the larger pegmatite belt described above. The tin-bearing belt extends from Goodwater in northeastern Coosa County southwestward into the Montgomery Quadrangle. The following is a list of known tin-bearing pegmatites with estimated tenor (Neathery, 1974, p. 18). Locations are shown on plate 2.

Map no.	Location	Type of deposit	Percent ¹ cassiterite
1	SW¼ sec. 31, T. 24 N., R. 20 E.	Pegmatite	2.3
2	SW¼ sec. 31, T. 24 N., R. 20 E.	Greisen	7.5
3	SW¼ sec. 31, T. 24 N., R. 20 E.	Greisen float	7.5
4	NW¼ sec. 6, T. 23 N., R. 20 E.	Pegmatite	7.5
5	SE¼ sec. 1, T. 23 N., R. 19 E.	Greisen float	3.0

¹Visual estimate by Hunter, 1944.

TUNGSTEN

Tungsten has been reported from several localities in the northern Alabama Piedmont, where it occurs as thin veins associated with late granite intrusives. It has not been reported in the Birmingham Quadrangle. Reconnaissance soil and stream geochemical sampling over and adjacent to the Rockford pluton in Coosa County have yielded negative results (Cook, 1975, p. 103).

NIOBIUM

Niobium in columbite occurs in small amounts along the western margin of the Rockford pluton in Coosa County and is associated with tantalite in cassiterite-bearing pegmatites and greisens. Samples obtained to date have been recovered from prospect pits west of the town of Rockford (Neathery, 1974, p. 10).

VANADIUM

A green mica (roscoelite) which contains a small amount of vanadium occurs with flake graphite deposits of the Wedowee graphite schist and phyllite in Coosa County (Pollister and Thoenen, 1948). The coarse graphite flakes occur mainly in the Higgins Ferry Formation of the Wedowee Group (Neathery, 1974). The following table gives the roscoelite analyses as V_2O_5 from some of the now-abandoned graphite mines (Neathery, 1974, p. 19).

Mine name	Location	Sample no.	Sample length (feet)	Mica in graphite tailings (percent)	Vanadium pentoxide in mica (percent)
Epps and Goodwater	SW¼SW¼ sec. 9, T. 24 N., R. 20 E.	A-11	8	13.5	0.13
		A-14	30	25.2	.13
		A-16	50	19.2	.07
		A-19	60	11.2	.13
		A-7	10	35.3	.06
Parkdale	NE¼NE¼ sec. 6, T. 24 N., R. 20 E.	A-13	-	35.5	.13
Ceylon Graphite	NW¼ sec. 16, T. 24 N., R. 19 E.	A-9	40	22.9	.04
			40	20.1	.20
			60	17.7	.16
Will	NE¼ sec. 20, T. 24 N., R. 19 E.	A-67	-	22.6	.24
Maxwell	T. 24 N., R. 19 E.	A-68	-	7.8	.12
Lewis	NW¼ sec. 29, T. 24 N., R. 19 E.	A-69	-	17.6	.27
Brown	T. 24 N., R. 19 E.	A-65	-	27.3	.14
Diamond	NW¼ sec. 31, T. 24 N., R. 19 E.				

MOLYBDENUM

Molybdenite is not a common mineral in the crystalline rocks in Alabama. However, minor traces of molybdenum mineralization have been noted in some of the higher-grade graphite schists of the Wedowee Group. Geochemical analyses of the graphitic schists have yielded values up to 100 ppm molybdenum. Recognizable molybdenite shows have not been reported from the granite plutons in the region.

MASSIVE SULFIDE

The Hillabee Chlorite Schist is exposed in parts of Coosa County and eastern Clay County. Occurrences of pyrite, chalcopyrite and some pyrrhotite in the Hillabee are quite common. Pyrite has been mined just to the east of the present area in Clay County near Pyriton (LaMont and Hastings, 1964).

MONAZITE AND RARE-EARTH ELEMENTS

Monazite is an orthophosphate of rare-earth elements, specifically containing thorium and cesium. No known occurrences of monazite have been reported from the northern part of Coosa County, which forms part of the Birmingham Quadrangle. However, several pegmatites are believed to be monazite-bearing due to high counts that were recorded during the scintillometer traverses (Neathery, 1974, p. 11).

URANIUM

There is a possibility that uranium mineralization occurs in the rich pegmatite district in Coosa County. The mineralization is probably associated with Rockford Granite and pegmatites intruding into the Hatchet Creek and Wedowee Groups. Scintillometer traverses in the vicinity of a number of pegmatites in western Coosa County indicate radiation levels of up to 0.05 milliroentgens per hour above background levels (Neathery, 1974, p. 11). Mineralization on the margins of pegmatites has also been reported. The areal extent of these occurrences has not been ascertained. Columbite, tantalite, and possible uraninite have been reported from some of the pegmatites.

Aeroradioactivity data over the Valley and Ridge and Piedmont regions of eastern Alabama by Neathery and others (1976, p. 380) show anomalous highs of up to 650 counts per second against a background of less than 250 counts per second in the Talladega slates and phyllites in northeast Chilton and southeast Shelby Counties and the pegmatite-bearing graphitic schists of the Wedowee Group in Coosa County. In the past 20 years, several companies have conducted reconnaissance surveys in this region but the results are not known. The anomalous areas are worth further exploration.

The uranium content of two samples of Chattanooga Shale collected and analyzed by the U.S. Geological Survey from exposures in the Appalachian Plateaus region in the northeastern part of the quadrangle contained 0.003 percent uranium (Glover, 1959, p. 151). One of the samples was collected along the northwest flank of the Murphrees Valley anticline about 0.5 mi (0.8 km) north of Oneonta, Blount County, and the other was collected near the southern terminus of the Wills Valley anticline in the SE cor. sec. 19, T. 12 S., R. 4 E., Etowah County.

GEOLOGIC LITERATURE AND CURRENT RESEARCH

GEOLOGIC LITERATURE

Citations, by author and date, of sources of information used in compiling the geologic map of the Birmingham Quadrangle (plate 1) are included on the map and the references, including those cited in the text, are included in the selected bibliography. The map overlay of mineral occurrences (plate 2) is a compilation of all available pertinent data on the selected elements, minerals, and rock types. Sources of information are cited in the text. Unpublished geologic maps and reports may be reviewed in the offices of the Geological Survey of Alabama, University, Alabama (Tuscaloosa).

CURRENT RESEARCH

The Geologic Division of the Geological Survey of Alabama is presently conducting a coal sampling and stratigraphic analysis program in the Warrior Coal Field through a contract with the Branch of Coal Resources of the U.S. Geological Survey (Reston). The study is primarily designed to collect coal samples for chemical analyses of coal quality and trace metal content and secondarily to provide detailed measurements of the enclosing strata. A better understanding of the environments of deposition of the Pottsville Formation will be a result of the study that is scheduled for completion September 30, 1979.

The Mineral Resources Division of the Geological Survey of Alabama is conducting a uranium resource assessment of the northern Alabama Piedmont through a contract with the Eastern Environmental Branch of the U.S. Geological Survey (Atlanta). Field examinations will be made of radioactive and magnetic anomalies described by Neathery and others (1976). Aeroradioactivity and aeromagnetic maps of the Piedmont region are being published by the U.S. Geological Survey. The uranium resource assessment study is scheduled for completion by September 30, 1979.

Dr. Stephen H. Stow of the Department of Geology and Geography at the University of Alabama is continuing research on the structure, geochemistry and mineralization of the Hillabee Chlorite Schist. Graduate students at Alabama, Pamela Bloss and Karen Rhearns, are completing theses on the geochemistry and structure and petrology of the Mitchell Dam Amphibolite.

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DESCRIPTION OF THE GADSDEN QUADRANGLE

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DESCRIPTION OF THE GADSDEN QUADRANGLE

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ABSTRACT

The Gadsden Quadrangle in northern Alabama mainly includes parts of the Appalachian Plateaus and Interior Low Plateau physiographic provinces. A small strip of the Valley and Ridge province is included in the southeast, and a small area of the East Gulf Coastal Plain province is included in the west. Exposures of indurated bedrock in the quadrangle are sedimentary and range in age from Middle Cambrian to Early Pennsylvanian. In the western part of the area, sediments of Late Cretaceous age occur as outliers, and alluvial deposits of Quaternary age occur near the streams and rivers. The geologic history of the Gadsden Quadrangle is dominated by elements of the Taconic orogeny, movement of the Nashville dome and the Alleghany orogeny.

In the Appalachian Plateaus region, Paleozoic formations about 8,200 ft (2,500 m) thick that range in age from Early Cambrian to Pennsylvanian overlie a crystalline basement complex assumed to be of Precambrian age. At the surface, most of the region is underlain by siliciclastics of the Pottsville Formation (Pennsylvanian). Three major anticlinal folds near the eastern edge of the region expose rocks ranging in age from Late Cambrian and Early Ordovician to Mississippian. Westward from the major folds the rocks are gently folded into minor undulations. Regionally the rocks dip southwest at a rate of approximately 45 ft per mi (8.5 m per km).

Formations of particular interest in the Appalachian Plateaus are the Chickamauga Limestone, the Chattanooga Shale and the Pottsville Formation. Volcanism during the Middle Ordovician is represented by bentonitic shales in the Chickamauga Limestone. The Chattanooga Shale (Late Devonian) with an average thickness of 20 ft (6 m) is known to contain trace amounts of uranium. The Pottsville Formation is a potential host rock for uranium and consists of quartzose sandstone with interbeds of silty carbonaceous shale, micaceous, carbonaceous siltstone and a few thin beds of coal.

In the Interior Low Plateau province in the northern part of the quadrangle, the Nashville dome is the dominant structural feature. Carbonate and siliciclastic rocks of Mississippian age are present at the surface, however, uplift and erosion have exposed pre-Mississippian rocks in the northern tier of counties. The regional dip in the area is generally south and southwest from 20 to 30 ft per mi (3.8 to 6.7 m per km).

Formations of particular interest in the low plateau are the Chickamauga Limestone, Chattanooga Shale and Hartselle Sandstone. Volcanism during the Middle Ordovician is represented by bentonitic shales in the Chickamauga. The Chattanooga Shale is known to contain trace amounts of uranium and ranges in thickness from 0 to 48 ft (0 to 10.4 m). The Hartselle Sandstone (Upper Mississippian) contains asphalt impregnated zones with an average thickness of 21.3 ft (6.5 m). Hydrogen sulfide that may be associated with petroleum residues and carbonaceous beds within the formation could create reducing environments resulting in uranium deposition.

In the East Gulf Coastal Plain region in the southwestern corner of the Gadsden Quadrangle, Coastal Plain sediments of the Tuscaloosa Group of Late Cretaceous age unconformably overlie Paleozoic rocks and occur as outliers capping hills and interfluvies. The Tuscaloosa Group sediments are about 200 ft (61 m) thick and dip southwest at 25 to 30 ft per mi (4.7 to 5.7 m per km).

LOCATION AND PHYSICAL GEOGRAPHY

The Gadsden 1° x 2° NTMS Quadrangle, as modified, covers about 8,100 square miles (mi) or 21,000 square kilometers (km) in northern Alabama and includes parts of the Appalachian Plateaus and Interior Low Plateau physiographic provinces (plate 1). A small strip of the Valley and Ridge province is included in the southeastern corner of the quadrangle and a small area of the East Gulf Coastal Plain province is included in the extreme western part. Elevations throughout most of the area range from about 500 to 1,000 ft (150 to 300 m). Crests of the mountains in the northeastern part of the area range in elevation from 1,500 to 1,860 ft (450 to 567 m). Rainfall averages 52 inches (132 centimeters) per year (Huntsville). The climate is humid, subtropical, averaging 80°F (27°C) in July and 41°F (5°C) in January (Huntsville). Intense weathering and dense vegetation limit outcrops in the area, and exposures in roadcuts and stream valleys provide the control points for geologic mapping.

GENERAL GEOLOGY AND TECTONICS

Indurated formations exposed in the quadrangle are of sedimentary origin and range in age from Middle Cambrian to Early Pennsylvanian. In the western part of the area unconsolidated sediments of Late Cretaceous age occur as outliers capping the hills. In the southwestern part of the area, unconsolidated alluvial deposits of Quaternary age overlie Pennsylvanian and Late Cretaceous bedrock in and near the streams and rivers in the area. At higher elevations, there are scattered terrace deposits formed when ancestral streams in the area occupied higher levels.

The average thickness and dominant lithologies of stratigraphic units known to occur in the Gadsden Quadrangle are reported in table 1. Only those units containing a record of volcanism or that are potential sources of uranium are discussed.

APPALACHIAN PLATEAUS REGION

The Appalachian Plateaus region is bounded on the north by the Interior Low Plateau province, on the southeast by the Valley and Ridge province, and to the south and west by the Coastal Plain province. The region is characterized by the general absence of thrust faults and by gentle, approximately symmetric surface folds (Colton, 1970, p. 15). The folds are steeper, more closely spaced, and more commonly parallel to the regional trend near the Appalachian structural front on the southeastern boundary of the region. Two anticlines near the front plunge to the southwest, one plunges to the northeast and is bounded on the southeast by a steeply NW dipping thrust fault. Westward from the major folds, the rocks are gently folded into only minor undulations and regionally the rocks dip southwest 45 ft per mi (8.5 m per km).

Rocks of Late Cambrian and Early Ordovician age are exposed along the axes of the major anticlines, and rocks of Middle Ordovician-Mississippian age occur along the flanks. At the surface, west of the major folds, most of the area is underlain by fine and coarse siliciclastics of the Pottsville Formation (Pennsylvanian). In the subsurface, the sedimentary sequence is about 8,200 ft (2,500 m) thick and includes formations ranging in age from Early Cambrian to Pennsylvanian that apparently overlie a crystalline basement complex assumed to be of Precambrian age. An oil test well in Cullman County penetrated hornblende diorite at a depth below surface of 8,189 ft (2,496 m) or 7,284 ft (2,221 m) below mean sea level (Kidd and Neathery, 1976, p. 767).

Table 1. Rock-Stratigraphic Units, Gadsden Quadrangle—Appalachian Plateaus, Valley and Ridge, and East Gulf Coastal Plain Provinces.

System	Rock-Stratigraphic Units		Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Quaternary	Alluvial and Low Terrace Deposits		15	5	Unconsolidated deposits of sand, gravel, and clay along major streams.
	High Terrace Deposits		20	6	Unconsolidated deposits of sand, gravel and clay at higher elevations along major streams.
Cretaceous	Tuscaloosa Group	Gordo Formation	100	30	Sand, gravel, and varicolored clay, irregularly bedded.
		Coker Formation	75	23	Sand, gravel, and varicolored clay; lenticular bedding dominant.
Pennsylvanian	Pottsville Formation		500	152	Sandstone, lower part conglomeratic, carbonaceous, thin bedded to massive; shale, fissile to thin bedded, carbonaceous; siltstone, micaceous, carbonaceous; coal and underclay.
Mississippian	Parkwood Formation — Pennington Formation		70	21	Silty clay shale, mudstone, siltstone, and argillaceous sandstone, partly carbonaceous; Parkwood restricted to SW and SE corners of Quad.; Pennington restricted to extreme eastern part of Quad.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Mississippian	Bangor Limestone	400	122	Limestone, bioclastic and oolitic; lesser amounts of micritic, shaly, argillaceous limestone, clay shale, dolomite, and chert.
	Hartselle Sandstone	100	30	Sandstone, light-colored, fine-grained, quartzose, thick-bedded to massive, locally asphaltic, with thin interbeds of carbonaceous clay shale and shaly sandstone.
	Floyd Shale	300	91	Shale, dark-gray, partly calcareous, lesser amounts of claystone, siderite nodules, and argillaceous limestone.
	Pride Mountain Formation	200	61	Clay shale, fissile, calcareous in part, carbonaceous in part, with thin interbeds of sandstone; shaly or oolitic limestone in lower part.
	Monteagle Limestone	200	61	Limestone, oolitic and bioclastic, with lesser amounts of dolomite and dolomitic limestone; restricted to NE part of Quad.
	Tuscumbia Limestone	200	61	Limestone, micritic and bioclastic, with lesser amounts of oolitic limestone, chert, and dolomite.
	Fort Payne Chert	180	55	Chert, bedded, fossiliferous, and siliceous limestone with lesser amounts of bioclastic limestone.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Mississippian	Maury Formation	2	0.6	Clay shale, green and maroon.
Devonian	Chattanooga Shale	20	6	Shale, black, fissile, carbonaceous, radioactive, lesser amounts of sandstone, partly phosphatic.
Silurian	Red Mountain — Silurian undifferentiated	200	61	Shale, grayish-red to greenish-gray, siltstone, and sandstone, and argillaceous to crystalline limestone; hematitic in part, particularly in eastern part of Quad.
Ordovician	Sequatchie Formation	100	30	Limestone, pinkish- to yellowish-gray, crystalline, and medium- to greenish-gray shale and sandstone.
	Chickamauga Limestone	1000	305	Limestone, sublithographic to crystalline, partly phosphatic and argillaceous; thin beds of bentonitic shale.
	Attalla Chert Conglomerate Member of Chickamauga Limestone	70	21	Conglomerate, composed of pebbles, cobbles, and boulders of chert and rarely dolomite and quartzite in a matrix of sand-sized chert and quartz, restricted to eastern part of Appalachian Plateaus area.
	Knox Group Undifferentiated	3240 (Plateau) 1100 (Valley and Ridge)	988 335	Dolomite, dolomitic limestone, limestone, and chert; upper part characteristically contains rounded frosted sand; weathers to irregular fragments of chert and reddish clay.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness		Dominant Lithologies and Remarks
		(feet)	(meters)	
Cambrian	Ketona Dolomite	760	232	Dolomite, very fine to coarsely crystalline, with partly recrystallized oolites, rare chert, and slightly argillaceous zones (known only from subsurface in Gadsden Quadrangle).
	Conasauga Formation	1400	427	Limestone, sublithographic to finely crystalline, partly argillaceous, contains recrystallized oolites; shale, partly calcareous and fossiliferous; rare chert.
	Rome Formation	290	88	Shale, medium dark- to greenish-gray, and grayish-red; lesser amounts of siltstone, limestone, and dolomite (known only from subsurface in Gadsden Quadrangle).
Precambrian (?)	Basement Complex			Hornblende diorite; (known only from subsurface in Cullman County).

CHICKAMAUGA LIMESTONE

North of the latitude of Gadsden, widespread occurrences of bentonite and bentonitic shale in the Chickamauga Limestone (Middle Ordovician) are the only records of volcanism in the area. The bentonites and bentonitic shales occur throughout a zone 30 or 40 ft (9 or 12 m) thick approximately 20 ft (6 m) below the top of that part of the Chickamauga Limestone that is equivalent to the Stones River Group of Tennessee (Drahovzal and Neathery, 1971, p. 13). In this area, two bentonite zones have been traced from Tennessee and correlate with the T-3 and T-4 bentonite horizons of Wilson (1949, p. 62-65). Drahovzal and Neathery (1971, p. 14) state that the lower T-3 bentonite is often 3 to 4 feet (1+m) thick in Alabama. The bed is underlain by chert from 3 to 8 inches (in) or 7.6 to 20.3 centimeters (cm) thick. The upper bentonite, T-4, may be as much as 2 ft (0.6 m) thick and is characterized by abundant biotite grains ranging from 0.5 to 2 mm in diameter. The best known surface exposure along Interstate Highway 59 north of Gadsden has been described by Neathery and Smith (1971, p. 217-223). The bentonite beds have also been identified in the subsurface in the northern one-half of the Warrior basin and in the Interior Low Plateau region (Kidd, 1975, p. 27).

CHATTANOOGA SHALE

The Chattanooga Shale (Late Devonian) contains minor amounts of uranium and is exposed along the flanks of the major folds and occurs in the subsurface throughout the region. The Chattanooga Shale is mainly brownish-black to grayish-black, carbonaceous, silty, fissile shale with thin discontinuous beds of fine-grained sandstone that may contain pyrite and phosphatic inclusions (Kidd, 1975, p. 36). The Chattanooga is generally less than 20 ft (6 m) thick.

POTTSVILLE FORMATION

The lower part of the Pottsville Formation is exposed in the Plateau region and consists mainly of fine- to coarse-grained, thin and thick-bedded quartzose sandstone, gravelly sandstone, and interbeds of silty, carbonaceous shale, micaceous siltstone and a few thin beds of coal. Sandstones which comprise most of the formation in the plateau area, are mostly of the orthoquartzite variety. Gravelly sandstones up to 160 ft (49 m) thick occur at the base of the Pottsville and contain abundant fine- to medium quartz-pebble gravels. The formation ranges in thickness from 0 to 50 ft (0 to 15 m) near the northern boundary of the province and from 800 to 1,000 ft (144 to 305 m) near the southern boundary.

The formation is considered to be a potential host rock for uranium. Further details of the mineralogy and sedimentary environments are described in the papers by Ferm and Ehrlich (1967, p. 11-13) and Robinson, *ed.*, and others (1976).

INTERIOR LOW PLATEAU REGION

The Interior Low Plateau region is bounded on the east, south and southwest by the Appalachian Plateaus province. The Nashville dome is the dominant structural feature in the region; only minor faults of slight displacement are presently known. Most of the area is underlain by carbonate and siliciclastic rocks of Mississippian age, however, uplift of the dome and subsequent erosion have exposed outcrops of pre-Mississippian rocks in the counties that border the state of Tennessee. Structural contour maps of the top of the Chattanooga Shale (Late Devonian) in

reports by Harris and others (1963), McMaster and Harris (1963), Jewell (1969), and Faust (1975, p. 24) show numerous small anticlines, synclines and domal areas. The regional dip in the area is generally south and southwest from 20 to 30 ft per mile (3.8 to 5.7 m per km).

In the western part of the province, outliers of the Gordo Formation of the Tuscaloosa Group (Late Cretaceous) overlie Mississippian beds. The elevations of the outliers are much lower than projected and apparently the Gordo sediments have been let down as a result of solution of the underlying carbonates.

CHICKAMAUGA LIMESTONE

Bentonitic shales near the top of the Stones River Group equivalent beds of the Chickamauga Limestone are the only record of volcanism in the area. Jewell (1969, p. 31-39) reports green and gray bentonitic shales near the top of the Stones River Group equivalent beds in Lawrence, Limestone, Madison and Morgan Counties. The bentonites apparently do not occur in the westernmost counties.

CHATTANOOGA SHALE

The Chattanooga Shale in the Interior Low Plateau region ranges in thickness from 0 to 48 ft (0 to 10.4 m). The Chattanooga contains minor amounts of uranium and, according to Jewell (1969, p. 21), is typically black, carbonaceous, fissile, indurated shale containing varying amounts of sandy shale, siltstone, and thin fine-grained sandstone. Thin beds of impure limestone and dolomite occur in the Chattanooga Shale in Limestone County. The formation is exposed in stream valleys in the northern tier of counties. Outcrops in Limestone and Madison Counties are petroliferous and freshly broken surfaces emit a petroliferous odor.

HARTSELLE SANDSTONE

The Hartselle Sandstone trends northwest-southeast and has the lithologic constituents and sedimentary structures typical of a barrier island complex. Local depositional environments include barrier-face sands, swash zones with fossil accumulations, intertidal barrier flats and offshore bars (Thomas, 1972, p. 43-44). Large accumulations of carbonized logs and other plant debris occur commonly in the formation (W. A. Thomas, personal communication, 1978). The Hartselle pinches out to the northeast into shallow marine carbonates of the Monteagle Limestone and to the southwest into clays of the Floyd Shale. The Hartselle is light-colored, fine-grained, well-sorted quartzose sandstone and locally is impregnated with asphalt. The sandstone is in part calcareous, but argillaceous, micaceous or carbonaceous sandstones occur rarely. The formation contains interbeds of clay shale as much as 15 ft (4.6 m) thick and intervals of very thin-bedded shaly sandstone with abundant clay partings that are as much as 40 ft (12 m) thick. The clay shale and shaly sandstone are in part carbonaceous and pyritic (Thomas, 1972, p. 39-41). Oil saturation in the impregnated interval of the Hartselle ranges from 1 to 60 percent and averages about 27 percent. The porosity of the saturated zone of the Hartselle ranges from 0.4 to 24.0 percent and averages about 13 percent. The impregnated interval ranges from 1 to 55 ft (0.3 to 16.7 m) thick with an average thickness of 21.3 ft (6.5 m) (Chaffin and others, 1975, p. 1). The average thickness of the formation in the Low Plateau region is 100 ft (30 m) and the formation is exposed south of the Tennessee River from the western boundary of the province to southwestern Morgan County. The Hartselle Sandstone (Upper Mississippian) in the Interior Low Plateau province is a

potential host rock for uranium but analyses are not available. Hydrogen sulfide that may be associated with the petroleum residues and carbonaceous beds within the formation could create reducing environments resulting in uranium deposition.

EAST GULF COASTAL PLAIN REGION

The East Gulf Coastal Plain region in the southwestern corner of the Gadsden Quadrangle is bounded on the east by the Appalachian Plateaus Province and on the north by the Interior Low Plateau Province. Coastal Plain sediments of the Tuscaloosa Group of Late Cretaceous age unconformably overlie Paleozoic rocks in the area and occur as outliers capping hills and interfluvies. Deeper stream valleys expose Paleozoic rocks of Mississippian and Pennsylvanian age.

The Tuscaloosa Group includes two formations, the Coker Formation at the base and the overlying Gordo Formation. Both formations in the area consist chiefly of sand, gravelly sand, and varicolored mottled clays. The Coker Formation is overlapped by the Gordo Formation in the northern part of Marion County and rests unconformably on the Pottsville (Causey and others, 1972, p. 4). To the north in Franklin County, the Tuscaloosa Group, herein interpreted to be the Gordo Formation, unconformably overlies outcrops of the Pottsville and the Bangor Limestone (Mississippian). The Coker and Gordo have a combined thickness of less than 200 ft (61 m) in the Gadsden Quadrangle but thicken rapidly to the south and west. The combined thickness, outside the quadrangle in the southwestern part of Marion County, is 350 ft (107 m). The Coker and Gordo dip southwest at 25 to 30 ft per mile (4.7 to 5.7 m per km).

GEOLOGIC HISTORY

The geologic history of the Gadsden Quadrangle is dominated by elements of the Taconic orogeny, fluctuations of the Nashville dome and Alleghany orogeny. The earliest events of the Taconic orogeny in the southern Appalachians as described by Gilbert (1971, p. 167) and Drahovzal and Neathery (1971, p. 185) were the uplift and erosion of Cambrian and Ordovician sediments near the close of the Early Ordovician that resulted in a pronounced disconformity between Lower and Middle Ordovician rocks. The result in the stratigraphic record is referred to as the Middle Ordovician unconformity or the post-Knox unconformity. A well-cemented conglomerate, derived from erosion of the underlying Knox Group and consisting of large boulders, cobbles and pebbles of chert cemented together in a matrix of finer-sized particles occurs at the base of the Middle Ordovician rocks in the Valley and Ridge province. A somewhat finer-grained facies occurs in exposures in Murphrees Valley and southern Wills Valley—two of the major folds located near the eastern margin of the Appalachian Plateaus province. Further to the west and north in the Appalachian Plateaus and Interior Low Plateau provinces, Early Ordovician rocks of the Knox Group are overlain paraconformably by shale, limestone and dolomitic limestone of the Chickamauga (Middle Ordovician).

The Blountian phase of the Taconic orogeny of Rodgers (1953, p. 94, and 1971, p. 1165) that took place near the close of the Middle Ordovician, was the next major event in the Appalachian region. In the eastern Valley and Ridge epeirogenic uplift and subsequent erosion established conditions for the formation of a delta complex. The Blountian phase was concluded by volcanism. The ash falls resulting from the volcanic activity are widespread in Stones River equivalents of the Middle Ordovician sequence in Alabama but have not been identified in the westernmost counties.

Additional uplift and widespread erosion occurred near the end of the Late Ordovician and is reflected in the stratigraphic record by widespread erosional unconformities between Ordovician and Silurian units in the Gadsden Quadrangle. Silurian outcrops in the Valley and Ridge are classically considered to be of Early or Middle Silurian age and to be of upper Llandovery age by Berry and Boucot (1970, p. 203 and pl. 2). The Silurian strata in the subsurface in the Appalachian Plateaus province are considered by Berry and Boucot (1970, pl. 2), following the work of Lundin and Newton (1970, p. 17), to be in part of Wenlock and Ludlow age. The Brassfield Limestone that occurs sporadically at the base of the Silurian section in the Interior Low Plateau area is considered to be of middle Llandovery age by Berry and Boucot (1970, pl. 2). The basal Silurian in the low plateau area unconformably overlies Ordovician rocks of different ages and in places overlies upper parts of the Chickamauga and the Sequatchie Formation.

Ordovician events of deformation in the Interior Low Plateau region have not been correlated directly with events of the Taconic orogeny in areas of the southeast; however, bentonitic shales are correlative between the regions and apparently represent synchronous events in all Appalachian provinces.

The stratigraphic irregularities of thickness and distribution in the Interior Low Plateau are assumed to be a result of periodic uplift and erosion of the Nashville dome. The dome was active at several times during the early Paleozoic, and examples of known occurrences are briefly described. The Chickamauga Limestone thins along a probable fold axis extending north-south approximately parallel to the Limestone-Madison County boundary (Jewell, 1969, p. 12-14, figs. 4 and 5). Silurian rocks in the same general area are thin to absent and the Chattanooga Shale (Late Devonian) rests unconformably on differing parts of the Chickamauga Limestone, Sequatchie Formation and undifferentiated formations of Silurian age. Pre-Chattanooga Devonian and Silurian formations thicken to the west and southwest of the western part of Limestone County (Jewell, 1969, p. 19, fig. 6). The relatively closely spaced folds that occur in the Chattanooga are not present in the overlying essentially flat lying Mississippian formations suggesting that most activity of the Nashville dome occurred in pre-Mississippian time.

In the eastern part of the Appalachian Plateaus province, the Red Mountain Formation is overlain unconformably by the Chattanooga Shale and in the western part of the province undifferentiated Silurian formations are overlain unconformably by an unnamed cherty limestone considered to be of Devonian age. The sequences suggest uplift and erosion, or non deposition, in the province during parts of the Silurian and Devonian similar to conditions in the Interior Low Plateau province to the north.

Within the Appalachian Plateaus province, the Devonian formations are overlain unconformably by the Maury Formation (Early Mississippian) and successively younger Mississippian formations. The stratigraphic relations of the Mississippian units are mostly conformable even though the facies are diverse. Stratigraphic relationships of Upper Mississippian-Pennsylvanian units have been described by Thomas (1972, p. 90-94) and suggest continuous sedimentation across the systemic boundary rather than a major hiatus. The Mississippian-Pennsylvanian boundary has not been precisely defined but is considered to be within the Parkwood Formation by Butts (1926, p. 206) and may lie within the upper part of the shales that overlie the Bangor Limestone in the central part of the area or in the upper part of the Pennington Formation in the eastern part. However, further work with fossil forms that are independent of facies control will be required to define the boundary.

The Alleghany orogeny beginning near the close of the Paleozoic Era was the last major event of deformation recorded in the Appalachian Plateaus. The duration of the orogeny cannot be accurately determined because of large gaps in the stratigraphic record. No Paleozoic sediments

younger than Early or early Middle Pennsylvanian age are known to be present and the Mesozoic Era is represented only by Late Cretaceous sediments. The large parallel folds occurring in the eastern part of the Appalachian Plateaus were formed during the Alleghany orogeny.

Martin (1965, p. 34-43) describes normal and reverse faults in the vicinity of Bear Creek in the southeastern part of Franklin County and the northeastern part of Marion County that mostly trend northwest-southeast and apparently displace unconsolidated sediments of the Tuscaloosa Group and bedrock of the Pottsville Formation. These are the only faults in the plateaus region known to involve Cretaceous beds and Martin (1965, p. 42) states that the faulting is of post-Tuscaloosa age and can be attributed to widespread warping and faulting near the margin of the Mississippi embayment related to subsidence of the embayment and crustal readjustment.

MINERAL OCCURRENCES

In the Gadsden Quadrangle there are no known occurrences of lithium, beryllium, niobium, tin, tungsten, molybdenum, vanadium, rare metals, massive sulfides, thorium and mica pegmatites. Uranium is known to occur in the Chattanooga Shale of Late Devonian age and exposures of the formation are shown on the overlay presented as plate 2 of the report.

URANIUM

The Chattanooga Shale contains minor amounts of uranium (Conant and Swanson, 1961, p. 71) and is exposed along the flanks of the major folds, in stream valleys in the northern tier of counties, and occurs in the subsurface throughout the quadrangle. The Chattanooga is mainly brownish-black to grayish-black, carbonaceous, fissile shale with thin discontinuous beds of fine-grained sandstone that may contain pyrite and phosphatic inclusions. The formation ranges in thickness from 0 to 48 ft (0 to 10.4 m) with an average thickness of 20 ft (6 m) or less.

The uranium content of two samples collected and analyzed by the U.S. Geological Survey from exposures located immediately south of the Gadsden Quadrangle contained 0.003 percent uranium (Glover, 1959, p. 151). One of the samples was collected along the northwest flank of the Murphrees Valley anticline about 0.5 mi (0.8 km) north of Onconta, Blount County, and the other was collected near the southern terminus of the Wills Valley anticline in the SE cor. sec. 19, T. 12 S., R. 4 E., Etowah County.

GEOLOGIC LITERATURE AND CURRENT RESEARCH

GEOLOGIC LITERATURE

Citations, by author and date, of sources of information used in compiling the geologic map of the Gadsden Quadrangle (plate 1) are included on the map and the references including those cited in the text are included in the selected bibliography. Unpublished geologic maps and reports may be reviewed in the offices of the Geological Survey of Alabama, University, Alabama (Tuscaloosa).

CURRENT RESEARCH

The Geologic Division of the Geological Survey of Alabama has a cooperative project with the U.S. Nuclear Regulatory Commission, Washington, D.C. entitled "Coordination of a Cooperative Seismotectonic Study of the New Madrid Area" that will provide additional information on tectonic events in northwest Alabama and the distribution and relative age of stratigraphic units. The geologic mapping phase of the investigation should be completed by September 30, 1979.

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DESCRIPTION OF THE MONTGOMERY QUADRANGLE

Prepared for E I Du Pont De Nemours & Co., Inc.
Savannah River Plant
As Requested by Purchase Order No. AX458897L

By

GEOLOGICAL SURVEY OF ALABAMA
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February 12, 1979

DESCRIPTION OF THE MONTGOMERY QUADRANGLE

By Charles W. Copeland
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Geological Survey of Alabama

ABSTRACT

The Montgomery Quadrangle in central Alabama is located mainly in the East Gulf Coastal Plain physiographic province. A narrow strip of the Valley and Ridge province is included along the northern boundary of the quadrangle and the northeastern corner includes a segment of the Piedmont province.

Mesozoic and Cenozoic sedimentary rocks in the Coastal Plain region dip gently to the south and southwest. The resistant beds form cuestas that slope southward forming a series of arcuate, southeasterly to easterly trending hilly belts across the state. Coastal Plain sediments exposed in the quadrangle range in age from Late Cretaceous to Paleocene. Late Cretaceous sediments overlap rocks of the Valley and Ridge in the north-central part of the quadrangle and Piedmont rocks in the northeastern part. The Coastal Plain sediments are only a few feet (1 meter or less) thick in the areas of overlap and thicken rapidly downdip to about 2,400 feet (ft) or 732 meters (m) in the southeastern part of the quadrangle and to about 9,000 ft (2,743 m) in the southwestern part. The occurrence in the subsurface of Jurassic and Early Cretaceous sediments adds to the rapid thickening of the Coastal Plain sediments. In the subsurface, the Mesozoic and Cenozoic rocks unconformably overlie sedimentary rocks of the Appalachian Plateaus and Valley and Ridge provinces and igneous and metamorphic rocks of the Piedmont.

Red beds of the Jurassic and Lower Cretaceous undifferentiated overlie the pre-Mesozoic surface in the Coastal Plain region. The initial marine transgression of the Late Cretaceous, reflected in the lower part of the Tuscaloosa Group, was followed by the development of a large-scale fluvial-deltaic complex that makes up the remainder of the Tuscaloosa Group. Another marine transgression is indicated by the marine and estuarine sediments of the overlying Eutaw Formation. Following the deposition of the Eutaw, the region was covered by a broad, shallow epicontinental sea in which chalk was widely deposited (Selma Group). Only minor amounts of terrigenous clastics were deposited in updip areas. At the close of Cretaceous time, the seas retreated southward from the western part of the area and became shallower in the eastern part. The exposed chalk beds in the west were eroded before the deposition of Tertiary sediments.

Volcanic activity in the Late Cretaceous is indicated by the occurrence of waterlain ash in the Demopolis Chalk in western Alabama and by waterlain ash and bentonite in the Ripley Formation in southeastern Alabama.

Paleocene sediments consisting initially of mixed siliciclastics and carbonates were deposited in shallow marine waters. Later Paleocene fine siliciclastics and thin interbedded shell marls were deposited in protected bays, lagoons or estuaries. Paleocene siliciclastics are thought to have been derived from the Rocky Mountains, northern Gulf basin regions and deeply weathered, nearly flat-lying Paleocene terranes.

Within the Coastal Plain region, the Tuscaloosa Group is considered to have moderate uranium protore potential, particularly in areas of eastern Alabama located south of the Piedmont region. Continental siliciclastics in the lower part of the Coker Formation were derived in part from the crystalline rocks of the Piedmont and may contain uranium leached from the crystallines. Reducing environments in proximity of carbonaceous beds in downdip areas may have been favorable for the concentration of uranium.

Trace amounts of thorium and uranium are reported from the ash of lignite occurring in the Oak Hill Member of the Naheola Formation. Reducing conditions in proximity of carbonaceous beds in the formation indicate that further examination of the uranium-bearing potential of the formation is desirable.

The geologic history of the Piedmont is mainly deduced from apparent relationships existing between the plutonic and volcanic rocks and the metasediments and from scattered radiometric age dates. The schist and gneiss of the Hatchet Creek Group and the Emuckfaw Schist seem to be the oldest metasedimentary rocks of the Alabama Piedmont. The Hatchet Creek Group apparently grades southeastward into the Elkahatchee Quartz Diorite Gneiss, and the two may be related palingenetically. A similar apparent relationship exists between the Emuckfaw Schist and the Kowaliga Gneiss. The age of both the Elkahatchee and the Kowaliga as determined by radiometric age dating methods is approximately 500 million years (m.y.). The Emuckfaw and Elkahatchee contain elongate bodies of granitic rock that apparently are later intrusions.

Stratigraphic relationships of the Wedowee Group undifferentiated and surrounding rocks are not known, but in the central part of the region, the Wedowee is infolded into the Hatchet Creek Group and appears to be younger. The Rockford Granite and associated pegmatites seem to be the youngest intrusives in the Piedmont and have been dated by radiometric methods at approximately 300 m. y. The Talladega Group in the Montgomery Quadrangle is considered to be of Devonian age. The rocks of the Unity Group are interpreted as a metavolcanic-siliciclastic sequence in the upper part of the Talladega Group and may be the youngest rocks in the Piedmont.

Plutonic rocks of the Piedmont include the Elkahatchee Quartz Diorite Gneiss, Kowaliga Gneiss, and the Hissop, Zana and Rockford Granites. The pegmatites, quartz veins, and greisens associated with the Rockford contain mica, tin, beryl and rare earth minerals. Locally columbite, tantalite and possibly uraninite have been reported from the pegmatites. Volcanic rocks of the Piedmont include the Mitchell Dam Amphibolites and the Hillabee Chlorite Schist. Locally, the Hillabee may contain massive sulfide deposits.

Other crystalline rock units of particular interest are the Hatchet Creek and Wedowee Groups. Scattered throughout the outcrop area of the Hatchet Creek are mica pegmatites, greisens, alaskite veins and granite dikes that contain mica, tin, sparse beryl, monazite, uraninite and other radioactive minerals. Wedowee Group graphitic units contain vanadium-bearing mica and evidences of molybdenum mineralization. Small granitic plutons and pegmatites containing mica, tin, beryl and radioactive minerals occur throughout the outcrop areas of the Wedowee Group. Aeroradioactivity surveys have detected anomalies over graphitic units and these anomalies should be investigated.

LOCATION AND PHYSICAL GEOGRAPHY

The Montgomery 1° x 2° NTMS Quadrangle covers about 8,250 square miles (mi) or 21,360 square kilometers (km) in central Alabama located mainly in the East Gulf Coastal Plain physiographic province (plate 1). A narrow strip of the Valley and Ridge physiographic province is included along the northern boundary of the quadrangle and the northeastern corner of the quadrangle includes a segment of the Piedmont province. Formations of the Appalachian Plateaus, Valley and Ridge, and Piedmont provinces underlie the East Gulf Coastal Plain in the region. Elevations of ridges in the northern part of the Coastal Plain range from 400 to 600 feet (ft) or from 122 to 183 meters (m). Elevations along the major rivers in the southern part of the Coastal Plain range from 50 to 100 ft (15 to 30 m), and the average elevation of the interfluvies is around 250 ft (76 m). The Piedmont region is a maturely dissected upland plateau ranging in elevation from 400 ft (122 m) in the south to 750 ft (229 m) in the north. A few topographic prominences near the northern boundary of the quadrangle exceed 1,000 ft (305 m) in elevation. Rainfall averages 50 inches or 127 centimeters per year (Montgomery). The climate is humid, subtropical, averaging 80°F (27°C) in January (Montgomery). Intensive weathering and dense vegetation limit outcrops in the area, and exposures in roadcuts and stream valleys provide the control points for geologic mapping.

GENERAL GEOLOGY AND TECTONICS

Mesozoic and Cenozoic sedimentary rocks in the East Gulf Coastal Plain dip gently to the south and southwest at 20 to 45 ft per mile (3.8 to 8.5 m per kilometer). The resistant beds form cuestas that slope southward forming a series of arcuate, southeasterly to easterly trending hilly belts across the state. Coastal Plain sediments exposed in the quadrangle range in age from Late Cretaceous to Paleocene. Late Cretaceous sediments overlap rocks of the Valley and Ridge in the north-central part of the Quadrangle and Piedmont rocks in the northeastern part. Alluvial deposits of Quaternary age occur in the flood plains and as terrace deposits in and near the streams and rivers. The Coastal Plain sediments are only a few feet (1 m or less) thick in the areas of overlap and thicken rapidly downdip to about 2,400 ft (732 m) in the southeastern part of the quadrangle and to approximately 9,000 ft (2,743 m) in the southwestern part. The occurrence of Jurassic and Early Cretaceous sediments in the subsurface adds to the rapid thickening of the Coastal Plain sediments. In the subsurface, the Mesozoic and Cenozoic rocks unconformably overlie older sedimentary rocks of the Appalachian Plateaus and Valley and Ridge provinces and igneous and metamorphic rocks of the Piedmont.

In the northern part of the quadrangle, Appalachian structures of the Valley and Ridge plunge beneath the Coastal Plain sediments. Small, highly folded and faulted areas of the Helena thrust block and Coosa synclinorium are exposed and include rocks ranging in age from Early Cambrian to Late Mississippian.

The Piedmont area in the northeastern part of the quadrangle, includes low-rank and high-rank metamorphic rocks and igneous rocks that have been intensively deformed. The ages of the Piedmont rocks are uncertain but are considered to be correlative with parts of the early and late Paleozoic. Dominant trends of the Piedmont units are northeast-southwest and essentially parallel to those of the Valley and Ridge.

The average thicknesses where known, and the dominant lithologies of rock-stratigraphic units occurring in the quadrangle are included in table 1. The geologic summary specifically emphasizes potential uranium source rocks such as alkalic plutons and pegmatites, rocks reflecting episodes of volcanic activity and other rocks in the area that are potential host rocks for the accumulation of uranium.

EAST GULF COASTAL PLAIN

STRUCTURAL FEATURES

Prominent structural features in the Coastal Plain part of the quadrangle are the Livingston fault zone in northwestern Marengo County and a cryptoexplosive structure in Elmore County. The Livingston fault zone, named for Livingston, in Sumter County is located 10 mi (16 km) west of the quadrangle. The zone has been described and mapped by Monroe and Hunt (1958). It extends for about 36 mi (58 km) as a long, narrow band of closely spaced faults from northwestern Sumter County southeastward into northwestern Marengo County. The zone is nearly continuous but is obscured at the Sumter-Marengo County boundary by flood-plain deposits of the Tombigbee River. Strata along the fault trend are broken into a series of parallel horsts and grabens separated by reverse faults that dip at angles of 8° to 70°, but average about 45° (Monroe and Hunt, 1958). In Marengo County, the faulting is separated at the surface by a series of narrow parallel blocks of Demopolis Chalk (Late Cretaceous) projecting upward into sands of the Ripley Formation (Late Cretaceous). The maximum measurable vertical displacement of the faults at the surface in Marengo County is about 75 ft (23 m) (Newton and others, 1961, p. 20 and pl. 2).

A structural feature interpreted as a cryptoexplosive structure and termed the "Wetumpka Astrobleme" by Neathery and others (1976a p. 576) occurs north of Wetumpka in south-central

Table 1. Rock-Stratigraphic Units, Montgomery Quadrangle.

East Gulf Coastal Plain, Appalachian Plateaus (Subsurface) and Valley and Ridge Provinces

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Quaternary	Alluvial and Low Terrace Deposits	15	5	Unconsolidated deposits of sand, gravel, and clay along major streams.
	High Terrace Deposits	20	6	Unconsolidated deposits of sand, gravel, and clay at higher elevations along major streams.
Tertiary	Tuscaloosa Sand	300	91	Sand, gray, fine-grained; clayey carbonaceous silt; fossiliferous glauconitic sand and marl zones in lower half; contains sporadic thin beds of lignite and lignitic sand.
	Nanafalia Formation	175	53	Clay, dark-gray, massive; sand, glauconitic, clayey, fossiliferous, glauconitic; sand, coarse-grained with quartz gravels and clay pebbles in lower part.
	Naheola Formation	140	43	Sandy silt, silty clay, fine-grained sand, glauconitic sand, and sandy marl; lignite occurs near middle of formation.
	Porters Creek Formation	300	91	Clay, dark-brown to black, carbonaceous, massive; glauconitic shell marl in upper part.
	Clayton Formation	75	23	Chalky marl and limestone, calcareous silt, sand, sandy limestone, and argillaceous sandy glauconitic chalk or granular limestone.

Table 1, contd.

System	Rock-Stratigraphic Units		Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Tertiary	Porters Creek and Clayton Formations undifferentiated		375	114	Clay, dark-brown to black, carbonaceous, massive with glauconitic sandy shell marl in upper part; lower part of unit is sandy chalk and calcareous glauconitic clayey sand.
Cretaceous	Selma Group	Providence Sand	225	69	Sand, very fine- to fine-grained; silty clay, micaceous and carbonaceous; grades into Prairie Bluff Chalk to the west.
		Prairie Bluff Chalk	10	3	Chalk, massive, white, compact, contains varying amounts of sand, fossiliferous; progressively sandy to the east.
		Ripley Formation	100	30	Sand, sandstone, sandy calcareous clay, calcareous silt; fossiliferous.
		Cusseta Sand Member of Ripley Formation	150	46	Calcareous sandstone, sandy chalk, and sand; consists of clay, sand, chalk, and thin beds of limestone and gravel to the east.
		Demopolis Chalk	450	137	Chalk, light-gray to white, marly to pure; chalky marl, clayey chalk, and calcareous clay in upper part; fossiliferous.

Table 1, contd.

System	Rock-Stratigraphic Units		Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Cretaceous	Selma Group	Mooreville Chalk	430	131	Clayey chalk, marl, and calcareous glauconitic clay; impure dense limestone in upper part; lower part sandy and phosphatic.
		Eutaw Formation	400	122	Sand, fine- to medium-grained, glauconitic, micaceous, fossiliferous, interbedded with gray, laminated, partly carbonaceous clay.
	Tuscaloosa Group	Gordo Formation	220	67	Gravel, sand, and clay; lenticular bedding; clays typically varicolored with characteristic purple mottling; lower part gravelly.
		Coker Formation	425	130	Gravel, sand, and varicolored clay, irregular bedding; glauconitic and carbonaceous in part.
Cretaceous and Jurassic	Lower Cretaceous and Jurassic undifferentiated (subsurface)		1500	457	Sandstone, sand and gravel, and shale; sandstone and sand, light-gray to light-red, medium- to very coarse-grained, poorly sorted, quartzose; gravels, varicolored, mostly chert and quartz; shale, dusky red, silty, fine sandy, micaceous; contains detrital limestone nodules, assorted mineral grains, and fragments of metamorphic rocks.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Pennsylvanian	Pottsville Formation (subsurface)	3000	914	Sandstone, carbonaceous, lower part conglomeratic; shale, carbonaceous; coal and underclay.
	Parkwood Formation	700	213	Shale, siltstone, and argillaceous sandstone, partly carbonaceous; lesser amounts of limestone.
Mississippian	Floyd Shale	550	168	Shale, dark-gray, partly calcareous and carbonaceous; lesser amounts of limestone and sandstone.
	Tuscumbia Limestone, Fort Payne Chert, and Maury Formation undifferentiated	100	30	Limestone, cherty limestone, chert and greenish- gray shale.
Devonian	Chattanooga Shale (subsurface)	30	9	Shale, grayish-black, silty, micaceous, radioactive.
	Devonian undifferentiated (subsurface)	400	122	Limestone, gray, dense to crystalline; chert, white to gray to brown, opaque to translucent, dolomitic in part.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Silurian	Silurian undifferentiated (subsurface)	250	76	Limestone, gray, green, and red, dense to crystalline, hematitic and argillaceous in part; shale and siltstone, grayish-red.
Ordovician	Ordovician undifferentiated (subsurface)	580	177	Limestone, gray to brown, dense to crystalline, argillaceous, siliceous, and cherty in part.
	Newala and Longview Limestones undifferentiated	1500	457	Limestone, light- to dark-gray, thick-bedded and cherty in part; lesser amounts of dolomite.
	Knox Group undifferentiated	2800	853	Dolomite, light-gray, fine- to coarse-grained, cherty; limestone, light-gray, dense; and chert, dense to soft and cavernous.
Cambrian	Bibb Dolomite	250	76	Dolomite, dark-gray, coarsely crystalline, thick-bedded, siliceous.
	Ketona Dolomite	250	76	Dolomite, light-gray, coarsely crystalline, thick-bedded, relatively pure and chert-free.

Table 1, contd.

System	Rock-Stratigraphic Units	Average Thickness (feet) (meters)		Dominant Lithologies and Remarks
Cambrian	Brierfield Dolomite	1500	457	Dolomite, bluish-gray, thick-bedded, highly siliceous in part; dense chert.
	Conasauga Formation	1000	305	Limestone, brownish-gray, thin-bedded; shale, olive to gray; dolomite, brownish-gray; lesser amounts of chert.
	Rome Formation	1000	305	Shale, greenish-gray to grayish-red; lesser amounts of argillaceous limestone, chert, and sandstone.

Piedmont Province

Age	Rock-Stratigraphic Units		Dominant Lithologies and Remarks
Upper Paleozoic (?)	Stumps Creek Formation		Phyllite; silty laminae; local beds of calcareous siltstone, and fine-grained sandstone.
Lower Paleozoic (?)	Unity Group	Hillabee Chlorite Schist	Chlorite schist, dense, may include ultramafic zones and streaks of chlorite phyllite.
		Chulafinnee Schist	Schist, green, fissile; may include chlorite phyllite and quartzose phyllite.
		Chloritic quartz schist	Chlorite-quartz schist, light-gray to white, fine-grained, thinly laminated.
		Graphitic quartz schist	Graphite-quartz schist, dark-gray to black, thinly laminated.

Table 1, contd.

Age	Rock-Stratigraphic Units		Dominant Lithologies and Remarks
Lower Paleozoic (?)	Talladega Group	Lay Dam Formation	Metaclastics, conglomeratic metagraywacke, and quartzite.
		Lay Dam Quartzite	Quartzite, quartzose to feldspathic, argillaceous and conglomeratic in part.
		Jumbo Dolomite	Dolomite, light-gray, fine- to medium-grained, locally silty and laminated.
		Jemison Chert	Siltstone, gray to purple-gray, siliceous, fine-grained, interlayered with siliceous phyllite; middle part contains dense tan, white, gray, or maroon chert.
	Wedowee Group	Wedowee Group undifferentiated	Phyllite, schist, and gneiss.
		Higgins Ferry Formation	Biotite-feldspathic schist and gneiss; graphite-sericite-feldspathic schist; kyanite-sillimanite mica schist; granitic pegmatites.
		Wedowee Group graphitic units	Graphite-rich feldspathic quartz mica schist.
	Hatchet Creek Group		Muscovite-garnet schist; staurolite-albite-biotite-muscovite-quartz schist and staurolite-biotite feldspathic gneiss.

Table 1, contd.

Age	Rock-Stratigraphic Units	Dominant Lithologies and Remarks
Lower Paleozoic (?)	Mitchell Dam Amphibolite	Hornblende-actinolite amphibolite, dark-green to black, thin-layered to massive.
	Ultramafics	Ultramafic pods and sheets, principally enstatite-hornblende-actinolite.
	Emuckfaw Schist	Muscovite-feldspar and quartz schist and gneiss; may contain kyanite and sillimanite.
	Rockford Granite	Leucocratic muscovite-biotite quartz monzonite to granite, locally pegmatitic.
	Zana Granite	Quartz monzonite to granite, gneissic texture due to shearing; cut by small pegmatites and aplitic dikes.
	Hissop Granite	Granodiorite to granite, leucocratic, strongly lineated.
	Elkahatchee Quartz Diorite Gneiss	Biotite-quartz-diorite gneiss.
	Kowaliga Gneiss	Gneiss ranging from granodiorite to quartz monzonite, coarse-grained, with augen of plagioclase and potassium feldspar up to 10 cm in diameter.

Elmore County. The feature is approximately circular in outline and is bordered by an arcuate ridge of schist that extends two-thirds of the way around the structure. The ridge stands 200 to 500 ft (61 to 152 m) above the adjacent Piedmont peneplain. Concentric marginal faults with an estimated displacement of 800 to 1,000 ft (244 to 305 m) are associated with the structure. The central portion is considered by Neathery and others (1976a, p. 567) to correspond to the central rebound area of the impact structure. Included in the central portion are non-oriented blocks or masses of metamorphic rocks and Late Cretaceous formations (the Coker, Gordo and Eutaw Formations and the Mooreville Chalk). The exposures of Mooreville preserved within the structure are approximately 10 miles (16 km) north of the present outcrop belt of the formation.

Only minor faults with displacement of less than 100 ft (30 m) and folds of limited areal extent are exposed elsewhere in the Coastal Plain segment of the quadrangle.

SIGNIFICANT STRATIGRAPHIC UNITS

TUSCALOOSA GROUP

In the eastern part of the quadrangle, the Coker Formation unconformably overlies eroded crystalline rocks of the Piedmont. The basal 150 ft (46 m) is mostly pale-yellowish-orange, medium- to coarse-grained arkosic sand that is interbedded with moderate-reddish-brown, pale-red-purple and pale-green sandy clay. Quartz gravels ranging in size from pebbles to boulders occur locally at the contact with the underlying crystalline rocks. The upper 350 to 450 ft (107 to 137 m) of the formation was deposited in shallow marine environments and consists of light-greenish-gray medium- to coarse-grained glauconitic, micaceous, quartzose sand containing thin interbeds of greenish-gray micaceous clay and medium-dark-gray carbonaceous clay. The formation also contains lignite and thin-shelled invertebrate fossils near the top (Knowles and others, 1963, p. 21-22).

In the western part of the quadrangle, the Coker Formation unconformably overlies Paleozoic rocks and limited updip extensions of deposits of probable Early Cretaceous age. In the outcrop and shallow subsurface, the Coker has a maximum thickness of about 500 ft (152 m). The basal part of the formation includes gravelly sands with quartz and chert pebbles and massive clays that are overlain by lagoonal or estuarine sediments that are characteristically in the form of alternating thin beds of carbonaceous clay, silt and very fine- to fine-grained glauconitic, quartzose sand. The upper part of the formation was deposited in fluvial and deltaic environments and consists of poorly consolidated beds of varicolored silty, micaceous, partly carbonaceous clay and fine- to coarse-grained very pale-orange and light-gray quartzose sand. Downdip the formation thickens to about 800 ft (244 m) and was deposited in combinations of fluvial-deltaic and marine environments. It consists of interbedded medium- to coarse-grained glauconitic, quartzose sand; greenish-gray and very dark-red clay; and medium-dark-gray carbonaceous clay. Lignite occurs abundantly in the formation in downdip areas.

The Gordo Formation unconformably overlies the Coker and has a maximum thickness of about 350 ft (107 m). The Gordo was deposited in fluvial-deltaic environments. It consists of gravelly crossbedded sands at the base that are overlain by pale-yellowish-orange medium- to coarse-grained quartzose sand interbedded with pale-red-purple sandy clay and scattered lenses of medium-dark-gray carbonaceous clay.

The Tuscaloosa Group is considered by Dennison and Wheeler (1975, p. 191) to have moderate uranium protore potential, particularly in areas of eastern Alabama located south of the Piedmont. Uranium ions may have been leached from granitic plutons in the Piedmont, transported southward, and deposited in sediments of the Tuscaloosa Group. A reconnaissance geochemical survey by Gilbert and Thompson (1976) of selected water wells located east of the Montgomery Quadrangle yielded inconclusive results as to uranium potential; however, further investigation is warranted.

DEMOPOLIS CHALK

Monroe and Hunt (1958) have reported a bed of volcanic ash in the Demopolis Chalk in the Epes vicinity (Sumter County), immediately west of the Montgomery Quadrangle. The bed is probably continuous throughout western Alabama but has not been reported elsewhere. The ash is represented by biotite flakes and other minerals, including angular quartz, secondary pyrite, feldspar and some angular sphene (titanite). The ash occurs in a bed of chalk 8 inches (20 centimeters) thick and approximately 270 ft (83 m) above the base of the Demopolis.

RIPLEY FORMATION

A thicker bed of volcanic ash, now altered to bentonite, occurs in the lower part of the Ripley Formation in the eastern part of Lowndes County and the southwestern corner of Montgomery County near the community of Devenport. Bentonite and bentonitic clays occur in beds from 2.5 to 18.4 ft (0.7 to 5.6 m) thick according to Monroe (1941, p. 112-114).

NAHEOLA FORMATION

The Naheola Formation of late Paleocene age is exposed in the southwestern part of the quadrangle. The formation is divided into two members, the Oak Hill Member at the bottom and the Coal Bluff Marl Member at the top. The Oak Hill Member generally is from 80 to 150 ft (24 to 46 m) thick in western Alabama and consists of brownish-gray to dark-gray thinly laminated sandy silt and silty carbonaceous clay and beds of greenish-gray fine-grained sand. One, and rarely two, beds of lignite occur in the upper few ft (1 m) of the Oak Hill. Where present, the upper bed averages about 0.5 foot (15 cm) in thickness and is separated from the lower bed by about 3 ft (1 m) of thinly laminated, carbonaceous, silt and sand (Newton and others, 1961, p. 75). The lower lignite bed ranges in thickness from 1 to 14 ft (0.3 to 4m) and is classified as Lignite A, nonagglomerating (Self and others, 1978, p. 22). The lignite ash contains trace amounts of thorium and uranium, and the results of six analyses are presented in table 7 in the "Mineral Occurrences" section of this report.

The overlying Coal Bluff Marl Member consists of glauconitic sand and sandy marl with thin-bedded silty clay. The Coal Bluff ranges in thickness from 30 to 60 ft (9 to 18 m).

PIEDMONT REGION

The Piedmont region in the Montgomery Quadrangle is a part of the northern Piedmont as defined by Neathery and others (1975, p. 1) to include all the rocks between the southern edge of the Valley and Ridge province and the Brevard fault zone. The area is underlain predominantly by metasedimentary rocks that have undergone polyphase tectonism and syntectonic metamorphism. In a large part of the area, the metasedimentary rocks have been intruded by small bodies of mafic rock and a wide variety of granitic igneous rocks. The northern Piedmont is divided into two major metamorphic belts, the low-rank Talladega belt and the high-rank Wedowee belt. The terms high-rank and low-rank metamorphic belts are used in a relative sense by Neathery and others (1975, p. 1). Generally, the low-rank and the high-rank belts correspond to the green schist and amphibiolite facies of regional metamorphism.

PLUTONIC ROCKS

Elkahatchee Quartz Diorite Gneiss.--The Elkahatchee, is part of the Pinckneyville Granite complex (Adams, 1926; Gault, 1945), and crops out over a broad area in southwestern Coosa County and northwestern Elmore County. Along most of the northwestern side of its outcrop,

the Elkahatchee is in fault contact with the Wedowee and Hatchet Creek Groups. Northeast of the fault, contacts of the Elkahatchee and the Hatchet Creek are gradational. To the southeast, the Elkahatchee is in fault contact with a southern segment of the Wedowee Group and to the southwest it is overlapped by the Coker Formation of the Tuscaloosa Group (Late Cretaceous).

The Elkahatchee generally is medium- to dark-gray quartz-diorite with well-defined foliation and lineation. Locally, the gneissic banding ranges from a few inches (centimeters) to several feet (meters) in thickness. Elongate screen-like bodies of schist and hornblende gneiss are locally abundant. The age of the Elkahatchee as determined by Russell (1975, p. 91-92) using Rb/Sr whole rock analyses is 501 ± 51 m.y. and by $\text{Pb}^{207}\text{-Pb}^{206}$ zircon analyses is 528 ± 10 m.y.

Rockford Granite.--A complex of dikes and small stocks of granitic rocks, known collectively as Rockford Granite, intruded the Hatchet Creek and Wedowee Group rocks west of the Elkahatchee outcrop in Coosa County. The Rockford ranges in composition from quartz monzonite to trondhjemite to granite. Internal foliations range from very faint to well developed and are generally concordant with the host rock. The contacts are concordant as well as discordant to the country rock, which is often feldspathized near the contact. K-Ar dates on the Rockford are 317 ± 10 m.y. (table 2) as determined by Wampler and others (1970).

Pegmatites, quartz veins and greisens associated with the Rockford are rich in mica, tin, and beryl and contain rare earth minerals. Locally, columbite, tantalite, and possibly uraninite have been reported from the pegmatites. Scintillometer traverses across many of the pegmatites denote anomalous radioactivity associated with the selvage zones.

Hissop Granite.--Granitic bodies known as Hissop Granite, ranging from 1 to 6 miles (1.6 to 10 km) in length and a few hundred feet (meters) to 1.4 miles (2 km) in width occur within the outcrop belt of the Elkahatchee Quartz Diorite Gneiss and appear to be later intrusions (Deininger, 1975, p. 54). The Hissop ranges in composition from quartz-diorite to trondhjemite to granite, but quartz monzonite may be the most abundant phase. The Hissop Granite bodies are elongate parallel to the regional strike. Internal foliations are generally concordant with those in the Elkahatchee. Granitic dikes similar to the Hissop in composition are widespread in the Elkahatchee. The dikes are commonly discordant with regional foliation, but most possess an internal foliation parallel with that in the host rock (Deininger, 1975, p. 55).

Zana Granite.--The Zana Granite intrusives in the Emuckfaw Schist occur as elongate bodies of granitic rock in north-central Elmore County and southeastern Coosa County. The Zana Granite ranges in composition from quartz-diorite to granite, however, most of it probably is quartz monzonite (Deininger, 1975, p. 50). Some of the Zana plutons have halos of potassium feldspar porphyroblasts not observed around other granites in the region (Deininger, 1975, p. 53). Exposed contacts between the Zana and the enclosing schists are limited, but the contacts appear to be generally concordant. The age of the Zana Granite as determined by Russell (1975, p. 93) from Rb/Sr whole rock analyses is approximately 520 m.y. A similar age is reported for the Kowaliga Gneiss exposed to the southeast (Russell, 1975, p. 92).

Kowaliga Gneiss.--The Kowaliga Gneiss is exposed in the southeastern corner of the Piedmont region in the quadrangle. Along the northwest side of the outcrop belt the Kowaliga is in contact with the Emuckfaw Schist. Observable contacts with the Emuckfaw are limited, but the contacts are generally sharp and concordant (Deininger, 1975, p. 50). Along the southeast and southwest sides, the Kowaliga is overlapped by the Coker Formation (Late Cretaceous).

The composition of the Kowaliga ranges from granodiorite to quartz monzonite. Augen of both plagioclase and potassium feldspar ranging in size from 1 to 4 inches (2 to 10 cm) are characteristic of the Kowaliga. The age of the Kowaliga Gneiss as determined from Rb/Sr whole rock analyses is 510 ± 10 m.y. and from $\text{Pb}^{206}\text{-Pb}^{207}$ zircon analyses is $518 \pm$ m.y. (Russell, 1975, p. 93-94).

Table 2.--Radiometric age dates - Montgomery Quadrangle

Map no.*	Location	Rock type	Material analyzed	Dating method used	Apparent age (millions of years)	References
1	NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 7, T. 23 N., R. 15 E. Chilton County	Phyllite Talladega Group	Whole rock	K-Ar	476 $\pm$ 19	Kish and Harper, 1973; Harper, personal communication (1973).
2	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, T. 23 N., R. 15 E. Chilton County	Phyllite Talladega Group	Sericite	K-Ar	371 $\pm$ 15	Kish and Harper, 1973; Harper, personal communication (1973).
3	NW $\frac{1}{4}$ sec. 31, T. 23 N., R. 15 E. Chilton County	Phyllite Talladega Group	Whole rock	K-Ar	407 $\pm$ 15	Kish and Harper, 1973; Harper, personal communication (1973).
4	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 7, T. 22 N., R. 15 E. Chilton County	Phyllite Talladega Group	Sericite	K-Ar	325 $\pm$ 13	Kish and Harper, 1973; Harper, personal communication (1973).
5	SW $\frac{1}{4}$ sec. 14, T. 21 N., R. 15 E. Chilton County	Mitchell Dam Amphibolite	Hornblende	K-Ar	348 $\pm$ 10	Wampler and others, 1970.
6	NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Garnet-mica schist Hatchet Creek Group	Biotite ?	K-Ar	296 $\pm$ 11	Alabama Power Company, 1974.
6a	NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Garnet-mica schist Hatchet Creek Group	Biotite ?	K-Ar	331 $\pm$ 12	Alabama Power Company, 1974.

7	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Granitic gneiss	Biotite ?	K-Ar	305 $\pm$ 11	Alabama Power Company, 1974.
8	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Granodioritic gneiss	Biotite ?	K-Ar	316 $\pm$ 11	Alabama Power Company, 1974.
9	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Biotite schist Hatchet Creek Group	Biotite ?	K-Ar	332 $\pm$ 12	Alabama Power Company, 1974.
10	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Granodioritic rock Hatchet Creek Group	Biotite ?	K-Ar	320 $\pm$ 11	Alabama Power Company, 1974.
11	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Biotite schist Hatchet Creek Group	Biotite ?	K-Ar	316 $\pm$ 11	Alabama Power Company, 1974.
11a	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 31, T. 21 N., R. 17 E. Chilton County	Granodioritic rock Hatchet Creek Group	Biotite ?	K-Ar	312 $\pm$ 11	Alabama Power Company, 1974.
12	NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 6, T. 20 N., R. 17 E. Elmore County	Biotite schist Hatchet Creek Group	Biotite ?	K-Ar	361 $\pm$ 13	Alabama Power Company, 1974.
13	NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 6, T. 20 N., R. 17 E. Elmore County	Biotite- muscovite schist Hatchet Creek Group	Biotite ?	K-Ar	314 $\pm$ 11	Alabama Power Company, 1974.
14	NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 6, T. 20 N., R. 17 E. Elmore County	Rockford Granite	Biotite ?	K-Ar	280 $\pm$ 10	Alabama Power Company, 1974.

15	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 15, T. 20 N., R. 17 E. Elmore County	Elkahatchee Quartz Diorite Gneiss	Biotite(?)	K-Ar	334 $\pm$ 12	Alabama Power Company, 1974.
16	N $\frac{1}{2}$ SE $\frac{1}{4}$ sec. 27, T. 22 N., R. 20 E. Coosa County	Elkahatchee Quartz Diorite Gneiss	Muscovite Biotite	K-Ar K-Ar	324 $\pm$ 1C 328 $\pm$ 1C	Wampler and others, 1970. Wampler and others, 1970.
17	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 32, T. 20 N., R. 18 E. Elmore County	Elkahatchee Quartz Diorite Gneiss	Zircon	Pb ²⁰⁷ - Pb ²⁰⁶	528 $\pm$ 10	Russell, 1975.
18	N $\frac{1}{2}$ sec. 26, T. 22 N., R. 20 E. Coosa County	Elkahatchee Quartz Diorite Gneiss	Whole rock	Rb-Sr	501 $\pm$ 51	Russell, 1975.
19a	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 19 N., R. 20 E. Elmore County	Kowaliga Gneiss and Zana Granite	Zircon Whole rock	Pb ²⁰⁷ - Pb ²⁰⁶ Rb-Sr	518 $\pm$ 10 520 $\pm$ 10	Russell, 1975. Russell, 1975.
19b	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 17, T. 19 N., R. 20 E. Elmore County	Kowaliga Gneiss and Zana Granite	Zircon Whole rock	Pb ²⁰⁷ - Pb ²⁰⁶ Rb-Sr	518 $\pm$ 10 520 $\pm$ 10	Russell, 1975. Russell, 1975.
19c	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 14, T. 20 N., R. 20 E. Elmore County	Kowaliga Gneiss and Zana Granite	Zircon Whole rock	Pb ²⁰⁷ - Pb ²⁰⁶ Rb-Sr	518 $\pm$ 10 520 $\pm$ 10	Russell, 1975. Russell, 1975.

*Map numbers refer to locations shown on figure 1.

VOLCANIC ROCKS

Mitchell Dam Amphibolite.--An extensive amphibolite complex, the Mitchell Dam Amphibolite, is exposed in the vicinity of Mitchell Dam on the Coosa River. This complex underlies a large part of Chilton County to the west of the Coosa River and has sporadic outcrops in Coosa County. It is a dark-green layered amphibolite with a coarse- to fine-grained texture. Both the mineralogy and texture are quite variable. Kalk (1972) divided the amphibolite complex into six lithologic groups on the basis of petrography and chemical composition. The outcrop in Coosa County is somewhat atypical of the total amphibolite body. Here a fault divides the amphibolite sequence into two distinctly different structural and petrographic domains. Both sequences consist of delicately banded amphibolite, however, the upper zone appears to contain abundant clinozoisite as a major accessory mineral, whereas garnet is the principal accessory mineral in the lower zone (Neathery, 1975, p. 40).

Hillabee Chlorite Schist.--Along the southeastern border of the Talladega Group is a narrow outcrop of mafic rock consisting of chlorite-epidote schist and quartz chlorite schist. This zone has been interpreted by Carrington and Wigley (1967, p. 19) as a mafic dike injected along the sole of a thrust fault. Neathery and Reynolds (1973, p. 725) suggest that the Hillabee is a complex metavolcanic sequence near the top of the Talladega Group and is in normal but fault-bounded contact with the high-grade metamorphic rocks to the southeast. Tull and others (1978, p. 95) interpret the Hillabee as a greenstone sequence that originated as extrusive basic and intermediate igneous rocks. The Hillabee may contain massive sulfide deposits locally along strike. LaMont and Hastings (1964) discuss the copper-bearing pyrite mineralization of the Hillabee near Pyriton, Clay County, Alabama, northeast of the Montgomery Quadrangle.

OTHER CRYSTALLINE ROCK UNITS

Hatchet Creek Group.--The Hatchet Creek Group is exposed in southwestern Coosa County. The group is bounded on the northwest by the Higgins Ferry Formation and along the southeast by a central segment of the Wedowee Group undifferentiated and the Elkahatchee Quartz Diorite Gneiss. The Hatchet Creek is probably the oldest rock in the northern Alabama Piedmont. It is intruded by the Rockford Granite and locally contains thin graphitic units considered to be infolded remnants of the Wedowee Group.

The Hatchet Creek is composed primarily of quartz-biotite schist and gneiss. Feldspathic and migmatitic biotite gneiss is included in the group near the Coosa River (Neathery, 1975, p. 27). Mica pegmatites, greisens, alaskite veins and granitic dikes are scattered throughout the outcrop area of the Hatchet Creek and contain mica, cassiterite, beryl and monazite. Locally, uraninite and other radioactive minerals have been reported from the pegmatites.

Wedowee Group.--The Wedowee Group undifferentiated (plate 1) occurs in the northwestern, central and southeastern parts of the Piedmont region. This group includes rocks of low to intermediate metamorphic grade. Rock types represented include the following: fine-grained graphite-chlorite-sericite schist and phyllite; garnet-sericite schist and phyllite; quartz-graphite sericite phyllite, and feldspathic biotite gneiss. Higher grade metamorphic rocks consisting mainly of coarse-grained kyanite-sillimanite mica schist and fine-grained gneiss are shown on the geologic map as the Higgins Ferry Formation (Neathery, 1975, p. 17). Schist units within the outcrop belt of the Higgins Ferry Formation that have a higher content of graphite are mapped as Wedowee Group graphitic units. The graphitic units are of particular interest because they contain vanadium-bearing mica (roscoelite) and molybdenum mineralization. Aeroradioactivity anomalies also have been detected (Neathery and others, 1976b), and the schists may have provided a suitable environment for uranium mineralization. Small granitic plutons and pegmatites containing mica, cassiterite, beryl, uraninite and other radioactive minerals are scattered throughout the outcrop area of the Wedowee Group.

RADIOMETRIC AGE DATES

Radiometric age dates determined from samples of igneous and metamorphic rock units in the Montgomery Quadrangle are listed in table 2, and the locations of the collecting sites for the samples used for dating are shown in figure 1.

GEOLOGIC HISTORY

The Piedmont area of Alabama exhibits the complexities of an old igneous-metamorphic terrain with multiple deformation, even though no Precambrian basement rocks have been recognized in the region. Insufficient data are available to establish a precise chronological order of rock formation and tectonic events; however, the results of research conducted during the past 15 years support limited speculation. Tull (1975; 1978) recognized four phases of deformation. All of the deformation phases apparently took place after the deposition of the youngest rocks. Based on the cross-cutting relationships of granitic rocks and metamorphism supplemented by scattered radiometric age determinations, the following may be geologic historical sequence of the Alabama Piedmont.

The schists and gneiss of the Hatchet Creek Group and the Emuckfaw Schist seem to be the oldest metasedimentary rocks of the Alabama Piedmont. These rocks appear to be a thick metamorphosed flysch sequence. The Hatchet Creek Group apparently grades into the Elkahatchee, and the Emuckfaw grades southeastward into the Kowaliga Gneiss, possibly indicating that the Elkahatchee and Kowaliga may be paligenetic equivalents of the Hatchet Creek and the Emuckfaw, respectively. The composition of the Elkahatchee strongly resembles that of graywacke, (Deininger, 1975, p. 59). The Elkahatchee has large inclusions of schists, probably skialiths, and is concordant with the Hatchet Creek Group. Similarly, the Kowaliga Gneiss is concordant with the Emuckfaw Schist and contains areas of schist interpreted as infolds of the Emuckfaw (Deininger, 1975, p. 50).

Hissop Granite occurs within the outcrop belt of the Elkahatchee and apparently was a later intrusion even though no contact alteration has been observed (Deininger, 1975, p. 55). The Hissop is possibly a granitic phase of the Elkahatchee resulting from anatexis.

The Emuckfaw Schist is also intruded by several elongate bodies of granitic rock known as the Zana Granite. Unlike other granites in the region, some of the Zana plutons have halos of potassium feldspar porphyroblasts developed in the marginal part of the pluton that extend for up to 300 ft (100 m) into the adjacent schist.

Stratigraphic relationships of the Wedowee Group undifferentiated are not known, but in the central part of the region, the Wedowee is infolded into the Hatchet Creek Group and appears to be younger than the Hatchet Creek. The northwestern outcrop of the Wedowee Group undifferentiated is in structural contact with the Hillabee Chlorite Schist and along the southeastern side, the Wedowee Group grades into higher grade metamorphic rocks of the Higgins Ferry Formation. The southeastern belt of the Wedowee Group undifferentiated is separated from adjoining units by thrust faults.

Structurally, the Rockford Granite and associated pegmatites seem to be the youngest intrusives in the Alabama Piedmont. These intrusives cut across the Elkahatchee, Hatchet Creek and Wedowee rocks. An igneous origin for these rocks is indicated on the basis of locally discordant contacts, inclusions, and composition. Potassium-Argon age dates for the Rockford Granite ranging from 280 to 317 m.y. indicate a late Paleozoic age for the time of uplift and cooling of this intrusion.

- K-Ar age dates from Wampler and others (1970)
- K-Ar age dates from Kish and Harper (1973)
- ☒ Pb-Pb and Rb-Sr age dates from Russell (1975)
- ▲ K-Ar age dates from Alabama Power Company (1974)

Figure 1.— Locations of the samples used for radiometric age dating in Coosa, Chilton and Elmore Counties, Alabama (data in Table 2).

The Talladega Group in the Montgomery Quadrangle is considered to be of Devonian age because of relationships of the units to the brachiopod-bearing Jemison Chert (Neathery, 1973b, p. 51-55). The rocks of the Unity Group are interpreted as a metavolcanic siliciclastic sequence occurring in the upper part of the Talladega Group.

The pre-Mesozoic surface upon which the Coastal Plain sediments were deposited can be divided into three geologic provinces by projecting the trends of exposed Valley and Ridge and Piedmont units to the southwest. Deep wells in the western part of the quadrangle penetrate Paleozoic rocks of the Appalachian Plateaus and the Valley and Ridge, and wells in the central and eastern parts of the quadrangle penetrate rocks typical of the Talladega Slate belt or higher grade metamorphic or igneous rocks (table 1 and plate 1). Pre-Mesozoic rocks in individual wells have been described by Neathery and Thomas (1976).

Redbeds, thought to be of Jurassic and Early Cretaceous age unconformably overlie the pre-Mesozoic surface. They consist of interbedded pale-red poorly sorted sand and gravel and dusky-red silty, fine-sandy, micaceous shale. The beds also contain varicolored detrital limestone nodules and assorted mineral and rock fragments typical of the Piedmont. The red bed sequence is about 800 ft (244 m) thick in the subsurface in the southeastern part of the quadrangle and thickens westward to more than 4,000 ft (1,219 m) in the subsurface in northern Choctaw County. The redbeds pinch out to the north, are not exposed and are overlapped by mixed marine and non-marine sediments of the Upper Cretaceous Series.

The initial marine transgression of the Late Cretaceous, reflected in the lower part of the Tuscaloosa Group, was followed by the development of a large-scale fluvial deltaic complex, and it is under these conditions that the remainder of the Tuscaloosa Group was deposited. Another marine transgression is indicated by the marine and estuarine sediments of the overlying Eutaw Formation.

After the deposition of the Eutaw Formation, the Mississippi Embayment and adjacent parts of the Coastal Plain continued to subside, and a shallow epicontinental sea covered the region. The area was covered by the shallow sea throughout the remainder of Late Cretaceous time. During much of this time span, very little terrigenous clastic material was transported into the sea, and there was widespread deposition of chalk (Selma Group). Sand and clay were eroded from adjacent land areas and were deposited in strandline and shallow marine nearshore environments (Ripley Formation) near the northern limit of deposition of the Selma Group (Rainwater, 1968, p. 128). From southern Lowndes County eastward the chalk formations of the Selma Group merge laterally into formations consisting mainly of sand and clay. The facies changes of the Selma Group have been described by Monroe (1941) and Eargle (1950).

Volcanic activity in the Late Cretaceous is indicated by the occurrence of waterlain ash in the Demopolis Chalk in western Alabama and bentonite in the Ripley Formation in the southeastern part of the quadrangle.

At the close of Cretaceous time, the sea retreated southward from the western part of the area, and the exposed beds were eroded during the interval that preceded the deposition of Tertiary sediments (LaMoreaux and Toulmin, 1959, p. 19). The sporadic distribution of the Prairie Bluff Chalk in Dallas and Wilcox Counties is considered evidence of Cretaceous surface erosion, resulting in a Cretaceous-Tertiary unconformity. This unconformity in the outcrop is indicated by differences in fauna and the occurrence of reworked Cretaceous fossils, coarse glauconite and phosphate in the basal beds of the overlying Clayton Formation (Paleocene). Cenozoic deposition in the southeastern part of the quadrangle possibly began without interruption although the seas possibly became shallower. Studies of planktonic foraminifera and calcareous nannofossils by Cepek and others, in Scott (1968, p. 27-41) indicate that in Lowndes County the Cretaceous-Tertiary unconformity does not represent an appreciable lapse of geologic time.

Deposition of calcareous silt and sandy limestone (Clayton Formation) in early Paleocene time was followed by deposition of massive marine clay of the Porters Creek Formation. Fine siliciclastics that make up the Midway and Wilcox Groups and younger units in the Coastal Plain are considered by MacNeil (1966, p. 2344) and Rainwater (1968, p. 129) to have been derived at least in part from the erosion of sediments from the Rocky Mountains, the northern Gulf basin regions, and deeply weathered peneplaned Paleozoic terranes. In late Paleocene time, streams carried detritus to the sea where it spread out in shallow water near the shore in protected bays, lagoons and estuaries. These thin-bedded deposits comprise the Oak Hill Member of the Naheola Formation. As evidenced by the occurrence of lignite and carbonaceous sediments, swamps developed on these extensive deposits of sand and mud as bays or estuaries became mostly filled.

Occasionally, the shoreline shifted, seas spread over the swamps, and calcareous and glauconitic sand and shells accumulated in the shallow water. The Coal Bluff Marl Member of the Naheola Formation was thus deposited on the lignite and stratified sand and silty clay of the Oak Hill Member. Similar estuarine and shallow marine sediments are characteristic of the later Paleocene formations; the Nanafalia Formation and the Tuscahoma Sand (LaMoreaux and Toulmin, 1959, p. 21).

MINERAL OCCURRENCES

Lithium, beryllium, tin, niobium, tungsten, molybdenum, vanadium, uranium, thorium, and rare earth minerals such as monazite occur in the crystalline rocks of Coosa County and possibly in Chilton and Elmore Counties. The distribution of elements, minerals, mica pegmatites and possible massive sulfide deposits are shown on plate 2 and are described below.

MICA PEGMATITE

Mica-bearing pegmatites are common in Coosa County and occur sporadically in Chilton and Elmore Counties. The locations shown on plate 2 are compiled from Clark (1921), Heinrich and Olson (1953), and Neathery (1974). The pegmatites are variable in size and range from thin stringers to 100 ft (30 m) in width and 3,000 ft (914 m) in length. They exhibit a generally northeasterly strike and occur associated with the various granitic phases of Rockford plutons and as intrusives into the Wedowee and Hatchet Creek Groups and the Elkahatchee Quartz Diorite Gneiss. Most of the pegmatites contain muscovite, phlogopite, and trace amounts of biotite and various phengite micas. In addition to mica, they also contain other minerals, which are described in subsequent sections. Mica prospects in Coosa County are listed in table 3 and located on plate 2.

LITHIUM

Lithium reportedly occurs in spodumene ($\text{Li Al Si}_2\text{O}_6$) in mica- and tin-bearing pegmatites of Coosa County. No specific commercial deposit is known.

BERYLLIUM

Beryllium occurs in beryl ($\text{Be Al}_2\text{Si}_6\text{O}_{18}$) in pegmatites associated with, or near, the Rockford Granite and in the associated host rocks of the Hatchet Creek and Wedowee Groups (U.S. Bureau of Mines, 1946; and Neathery, 1974). Two known beryl localities are shown on plate 2 and the mineral may also occur in trace and minor amounts in the selvage zone of some of the more complex pegmatites. Cook (1975) reports that beryl was produced from the Williams pegmatite (table 3). Coosa County beryl is difficult to recognize as it is often yellow to milky in color and translucent, resembling weathered potassium feldspar in outcrop.

Table 3.--Mica prospects, Coosa County, Alabama

Map no.*	Prospect name and location	Description
1	Thomas SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 11, T. 22 N., R. 19 E.	Open cut 30 feet long, 6 feet wide, 5 feet deep. Walls caved, pegmatite not usable, strike generally northeast. "A" mica on dumps. Beryl reported from locality.
2	E. E. Brown SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 11, T. 22 N., R. 18 E.	Shaft in soft sericite schist, 30 feet deep. Mica at bottom, flooded.
3	Pond Mine NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, T. 22 N., R. 18 E.	Inclined shaft, one vertical 50-foot shaft with connecting slopes. Pegmatite striking N 30° E., dip 70° SE, width about 5 feet. Massive quartz and kaolinized feldspar with ruby sheet mica. Workings flooded.
4a	Cowart Mines SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 21, T. 22 N., R. 18 E.	Shaft 20 feet with 10-foot entry to pegmatite at base. Pegmatite composed of quartz, kaolinized feldspar, and greenish-yellow mica; flooded.
4b	NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 22 N., R. 18 E.	Shaft 15 feet deep with drift following 2-foot wide pegmatite vein for 30 feet; "A" mica; caved.
4c	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 22, T. 22 N., R. 18 E.	Shaft 35 feet deep with 50-foot drift in soft kaolinized feldspar. Very little mica; flooded.
5	Dennis sec. 35, T. 23 N., R. 17 E.	Open cuts, Pegmatite containing quartz, feldspar, and small mica.
6	McMain secs. 15 and 16, T. 22 N., R. 17 E.	Open pits and shallow shafts, largest 10 feet square, 15 feet deep. Several small pegmatites composed of massive quartz, kaolinized feldspar, and colorless mica in large "A" blocks.
7	Katherine Williams W $\frac{1}{2}$ SE $\frac{1}{4}$ and eastern part of NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 10, T. 21 N., R. 18 E.	Open pits, shafts and cross cuts. Pegmatite strikes N 40° E and dips 30° to 40° NW. Pegmatite composed of massive quartz, feldspar, and large flat "A" sheets of clear mica. Pegmatite stripped for beryl. Old workings completely erased.

Table 3.--Mica prospects, Coosa County, Alabama - Continued

8	Penton-Anderson sec. 16, T. 21 N., R. 18 E.	Open cuts and shallow shafts. Cluster of three pegmatites both sides of small valley. Pegmatites composed of quartz, kaolinized feldspar, and small 3 x 3 inch ruby sheet mica.
9	O. F. Carlton SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 31, T. 23 N., R. 20 E.	Open pit. Small pegmatite containing small amount of flat mica.
10	Ivey Mine NE cor. NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 15, T. 22 N., R. 16 E.	Vertical shaft and open cut. Pegmatite strikes N 70°E and dips 60°SE. Composed of quartz, feldspar, and mica, 6 inches to 30 inches wide; dump material shows large sheet mica.
11	Meherg Mine SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 35, T. 23 N., R. 17 E.	Open cuts on both sides of road, shallow(?) shafts in floor of cuts. Host rock graphitic garnet schist and gneiss. Pegmatite irregular and discordant to foliation. Composed of quartz, kaolinized feldspar, and muscovite mica. Most mica "A" structure.

*Map numbers refer to locations shown on plate 2.

TIN

Cassiterite (SnO_2) commonly occurs in greisens, pegmatites, and quartz veins in and around the Rockford plutons and in contact aureoles in the schists and gneisses of the Wedowee and Hatch Creek Groups (Adams, 1930; Hunter, 1944; Reed, 1950; Neathery, 1974; and Cook, 1975). These pegmatites are a part of the larger mica pegmatite belt described above. The tin belt extends from south of Rockford northeastward to near Goodwater in the Birmingham Quadrangle. The tin-bearing pegmatites tend to be rich in a host of other minerals such as beryl, columbite, and tantalite and may also contain uraninite and monazite. Known tin-bearing pegmatites, greisens and quartz veins with estimated tenor have been compiled from Neathery (1974, p. 18) and are listed in table 4 and located on plate 2.

TUNGSTEN

Tungsten has been reported from several localities in the northern Alabama Piedmont where it occurs as thin veins associated with late granite intrusives. It has not been reported in the Montgomery Quadrangle. Reconnaissance geochemical studies of soils and streams over and adjacent to the Rockford pluton in Coosa County have yielded no evidence of tungsten (Cook, 1975, p. 103).

NIOBIUM

Niobium in columbite occurs in small amounts along the western margin of the Rockford pluton in Coosa County and is associated with tantalite in cassiterite-bearing pegmatites and greisens. Samples obtained to date have been recovered from prospect pits west of the town of Rockford (Neathery, 1974, p. 10).

VANADIUM

A green mica (roscoelite) which contains a small amount of vanadium occurs with flake graphite deposits of the Wedowee graphite schist and phyllite in Coosa County (Pallister and Thoenen, 1948). The coarse graphite flakes occur mainly in the Higgins Ferry Formation of the Wedowee Group (Neathery, 1974). Analyses for V_2O_5 of samples from some of the now-abandoned graphite mines are listed in table 5 and are compiled from Neathery (1974, p. 19).

MOLYBDENUM

Molybdenite is not a common mineral in the crystalline rocks in Alabama. However, minor traces of molybdenum mineralization have been noted in some of the higher-grade graphite schists of the Wedowee Group. Geochemical analyses of the graphitic schists indicate values up to 100 ppm molybdenum. Molybdenite has not been reported from the granite plutons in the region.

MASSIVE SULFIDE

The Hillabee Chlorite Schist is exposed in the northwestern part of Coosa County and the northeastern part of Chilton County. Occurrences of pyrite, chalcopyrite and some pyrrhotite in the Hillabee are common. Pyrite has been mined northeast of the Montgomery Quadrangle near Pyriton in Clay County (LaMont and Hastings, 1964).

Table 4.--List of known tin-bearing pegmatites and estimated tenor

<u>Map no.</u> ¹	<u>Location</u>	<u>Type of deposit</u>	<u>Percent cassiterite</u> ²
1	NW $\frac{1}{4}$ sec. 14, T. 23 N., R. 19 E.	Quartz vein	1 - 7.5
2	SE $\frac{1}{4}$ sec. 15, T. 23 N., R. 19 E.	Pegmatite	3.6 - 7.5
3	SW $\frac{1}{4}$ sec. 15, T. 23 N., R. 19 E.	Pegmatite	3.3
4	SE $\frac{1}{4}$ sec. 22, T. 22 N., R. 19 E.	Greisen	7.5
5	SE $\frac{1}{4}$ sec. 28, T. 23 N., R. 19 E.	Quartz vein	Worked out
6	SE $\frac{1}{4}$ sec. 28, T. 23 N., R. 19 E.	Quartz vein	7.5
7	NE $\frac{1}{4}$ sec. 8, T. 22 N., R. 19 E.	Greisen	1
8	Sec. 8, T. 23 N., R. 19 E.	Pegmatite	Worked out
9	Sec. 8, T. 23 N., R. 19 E.	Pegmatite	3 - 8
10	Sec. 8, T. 23 N., R. 19 E.	Pegmatite	7.5 Tantalite
11	Sec. 8, T. 23 N., R. 19 E.	Pegmatite	3 - 5
12	SW $\frac{1}{4}$ sec. 8, T. 22 N., R. 19 E.	Greisen	1
13	SE $\frac{1}{4}$ sec. 7, T. 22 N., R. 19 E.	Greisen	0.5
14	NE $\frac{1}{4}$ sec. 18, T. 22 N., R. 19 E.	Greisen	1
15	SE $\frac{1}{4}$ sec. 1, T. 22 N., R. 18 E.	Greisen	2

Table 4.--List of known tin-bearing pegmatites and estimated tenor - Continued

16	SE $\frac{1}{4}$ sec. 1, T. 22 N., R. 18 E.	Greisen	1
17	SE $\frac{1}{4}$ sec. 1, T. 22 N., R. 18 E.	Pegmatite	1
18	NE $\frac{1}{4}$ sec. 12, T. 22 N., R. 18 E.	Pegmatite	2
19	SW $\frac{1}{4}$ sec. 12, T. 22 N., R. 18 E.	Greisen	1 - 2
20	SE $\frac{1}{4}$ sec. 11, T. 22 N., R. 18 E.	Greisen float	3
21	SE $\frac{1}{4}$ sec. 11, T. 22 N., R. 18 E.	Greisen	2
22	NW $\frac{1}{4}$ sec. 23, T. 22 N., R. 18 E.	Greisen float block	0.5 - 1.0 Tantalite
23	NE $\frac{1}{4}$ sec. 22, T. 22 N., R. 18 E.	Pegmatite	2

¹Map numbers refer to locations shown on plate 2.

²Visual estimate by Hunter, 1944.

Table 5.--Vanadium pentoxide content of graphite schists, Coosa County, Alabama

Mine name	Location	Sample no.	Sample length (feet)	Mica in graphite tailings (percent)	Vanadium pentoxide in mica (percent)
Teel	SW $\frac{1}{4}$ sec. 12, T. 23 N., R. 17 E.	A-58	-	32.7	15.0 ¹
Duro-Flake	SE $\frac{1}{4}$ sec. 21, T. 23 N., R. 18 E.	A-66	-	28.3	.11
Jessie Little	NW $\frac{1}{4}$ sec. 32, T. 22 N., R. 18 E.	A-75 A-76	- -	33.3 22.4	.24 .42
Fixico	S. part sec. 8, T. 22 N., R. 17 E.	A-73 A-74	- -	8.3 8.8	.31 .08
Dean	S. part sec. 12, T. 21 N., R. 16 E.	A-71 A-72	- -	11.6 17.1	.62 .67

¹Abnormally high percentage of vanadium pentoxide reported, probably should read 0.15 percent.

MONAZITE AND RARE-EARTH ELEMENTS

Monazite is an orthophosphate of rare-earth elements, specifically thorium and cesium. It occurs as an accessory mineral in granitic rocks and often occurs in pegmatites. Scintillometer traverses located several zones of monazite-bearing pegmatites in schist units in the western part of Coosa County (Neathery, 1974, p. 11). The areal extent of these occurrences is not known. Mertie (1953, p. 23) includes a listing of seven localities of residual monazite in southern Coosa County. The locations are listed in table 6 and are shown on plate 2. Monazite also occurs in heavy mineral suites in the basal part of the Coker Formation (Late Cretaceous) that blankets the Piedmont rocks in Chilton and Elmore Counties.

URANIUM

There is a possibility that uranium mineralization occurs in the pegmatite district in Coosa County. The mineralization is probably associated with Rockford Granite and pegmatites intruding the Hatchet Creek and Wedowee Groups. Scintillometer traverses in the vicinity of a number of pegmatites in western Coosa County indicate levels of up to 0.05 milliroentgens per hour above background levels (Neathery, 1974, p. 11). Columbite, tantalite, and possible uraninite have been reported from some of the pegmatites.

Aeroradioactivity data collected from the Valley and Ridge and Piedmont regions of eastern Alabama by Neathery and others, (1976b, p. 380) show anomalous highs of up to 650 counts per second against a background of less than 250 counts per second in the Talladega slates and phyllites in northeast Chilton and southeast Shelby Counties and in the pegmatite-bearing graphitic schists of the Wedowee Group in Coosa County. In the past 20 years, several companies have conducted reconnaissance surveys in this region, but these results were not available for the present study. Exploration in these anomalous areas appears to be warranted.

The Tuscaloosa Group is considered by Dennison and Wheeler (1975, p. 191) to have moderate uranium protore potential, particularly in areas of eastern Alabama located south of the Piedmont. Favorable environments for roll-front-type mineralization may occur along oxidation-reduction interfaces in the Coker Formation at the base of the Tuscaloosa Group. Continental siliciclastics in the lower part of the Coker in the outcrop were derived in part from the crystalline rocks of the Piedmont and may contain uranium leached from the crystallines. Downdip the continental sediments grade into marine siliciclastics that contain carbonaceous and lignitic clays and lignite. Reducing conditions in the proximity of the carbonaceous beds may have created favorable environments for the concentration of uranium. A reconnaissance geochemical survey by Gilbert and Thompson (1976) referred to earlier in this report yielded inconclusive results. Success of the reconnaissance survey was limited by the numbers of water wells available for sampling and by an inability to sample selected zones within completed wells. However, further investigation of the uranium-bearing potential of the Tuscaloosa Group is warranted.

Lignite ash from the Oak Hill Member of the Naheola Formation contains trace amounts of thorium and uranium as reported by Self and others (1978, p. 22). The lignite samples were collected in Wilcox and Marengo Counties at locations shown on plate 2. The results of the analyses are listed in table 7.

GEOLOGIC LITERATURE AND CURRENT RESEARCH

GEOLOGIC LITERATURE

Citations, by author and date, and sources of information used in compiling the geologic map of the Montgomery Quadrangle (plate 1) are included on the map; the references, including

Table 6.--Residual monazite occurrences in Coosa County.

Map no.*	Location	Probable parent rock	Type of occurrence
1	NW $\frac{1}{4}$ sec. 24, T. 23 N., R. 20 E.	Granitic	Saprolite
2	SW $\frac{1}{4}$ sec. 27, T. 23 N., R. 20 E.	Granitic	Saprolite
3	SE $\frac{1}{4}$ sec. 8, T. 22 N., R. 20 E.	Granitic	Saprolite
4	NW $\frac{1}{4}$ sec. 13, T. 22 N., R. 20 E.	Granitic	Saprolite
5	SE $\frac{1}{4}$ sec. 13, T. 21 N., R. 19 E.	Granitic	Saprolite
6	SE $\frac{1}{4}$ sec. 23, T. 21 N., R. 18 E.	Granitic	Saprolite
7	NE $\frac{1}{4}$ sec. 23, T. 22 N., R. 19 E.	Pegmatitic	Saprolite

* Map numbers refer to locations shown on plate 2.

Table 7.--Uranium and thorium content of lignite ash from the Oak Hill Member of the Naheola Formation, Marengo and Wilcox Counties.

Map no.*	Location	Thorium in ash (ppm)	Uranium in ash (ppm)
1	SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 30, T. 13 N., R. 5 E.	<3	1.5
2	NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 24, T. 13 N., R. 4 E.	<3	0.5
3	SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 4, T. 13 N., R. 4 E.	3	1.4
4	SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 26, T. 14 N., R. 3 E.	<3	1.6
5	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 21, T. 14 N., R. 3 E.	6	3.2
6	SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 22, T. 14 N., R. 2 E.	<3	0.5

* Map numbers refer to locations shown on plate 2.

those cited in the text, are included in the selected bibliography. The map overlay of mineral occurrences (plate 2) is a compilation of all available pertinent data on the selected elements, minerals and rock types. Sources of information are cited in the text. Unpublished geologic maps and reports may be reviewed in the offices of the Geological Survey of Alabama, University, Alabama (Tuscaloosa).

CURRENT RESEARCH

The Mineral Resources Division of the Geological Survey of Alabama is conducting a uranium resource assessment of the northern Alabama Piedmont through a contract with the Eastern Environmental Branch of the U.S. Geological Survey (Atlanta). Field examinations will be made of radioactive and magnetic anomalies described by Neathery and others (1976b). Aeroradioactivity and aeromagnetic maps of the Piedmont region are being published by the U.S. Geological Survey. The uranium resource assessment study is scheduled for completion by September 30, 1979.

Dr. Stephen H. Stow of the Department of Geology and Geography at the University of Alabama is continuing research on the structure, geochemistry and mineralization of the Hillabee Chlorite Schist. Graduate students at Alabama, Pamela Bloss and Karen Rheams, are completing theses on the geochemistry and structure and petrology of the Mitchell Dam Amphibolite.

The Mineral Resources Institute at the University of Alabama is presently conducting a study of surface and subsurface lignite resources in the Midway and Wilcox Groups of southwestern Alabama. The research is being conducted by Professor Thomas A. Simpson of the Department of Mineral Engineering and Dr. Ernest A. Mancini of the Department of Geology and Geography. The study will supplement the information compiled by Self and others (1978) and will provide additional information about the environments of deposition of the lignite beds.

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GEOLOGIC MAP OF THE MONTGOMERY, ALABAMA QUADRANGLE

EXPLANATION	
EAST GULF COASTAL PLAIN AND VALLEY AND RIDGE PROVINCES	
Qal	Alluvial and Low Terrace Deposits
Qh	High Terrace Deposits
Tu	Tuscaloosa Sand
Tn	Nantuxia Formation
Tr	Nantuxia Formation
Tr	Porters Creek Formation
Tr	Porters Creek and Clayton Formations undifferentiated
Kp	Providence Sand
Kp	Prairie Bluff Chalk
Kr	Ripley Formation
Kr	Cassata Sand Member of the Ripley Formation
CRETACEOUS	
Kd	Danville Chalk
Km	Mooreville Chalk
Ks	Eutaw Formation
Ks	Gardens Formation
Ks	Coker Formation
Mw	Parkwood Formation
Mw	Floyd Shale
Mw	Tusculum Limestone, Fort Payne Chert and Maury Formation undifferentiated
Cl	Little Oak Limestone
Cl	Athens Shale
Cl	Lander Limestone
Cl	Norwell Limestone and Longview Limestone undifferentiated
Cl	Knox Group undifferentiated
Cl	Bibb Dolomite
Cl	Kerola Dolomite
Cl	Brierfield Dolomite
Cl	Coushatta Formation
Cl	Rome Formation
PIEDMONT PROVINCE	
Msc	Shulls Creek Formation
Ug	Hillabee Chlorite Schist
Ug	Chalatlum Schist
Ug	Chilistite quartz schist
Ug	Graphitic quartz schist
Ug	Jenkinson Chert (?)
Ug	Lay Dam Formation
Ug	Lay Dam Quartzite
Ug	Jumbo Dolomite
Ug	Wedowee Group undifferentiated
Ug	Higgins Ferry Formation
Ug	Wedowee Group graphitic units
Ug	Washers Creek Quartzite
Ug	Mitchell Dam Amphibolite
Ug	Ultramafics
Ug	Emucklaw Schist
Ug	Rockford Granite
Ug	Zeno Granite
Ug	Utopia Granite
Ug	Elkhardt Quartzite
Ug	Kowalew Granite

Base map modified from U. S. Army Topographic Command (A.F.E.), Washington, D. C., Montgomery 1:250,000 Quad, range N 16-11, 1953. Revised by the U. S. Geological Survey, 1969.

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1/ Prairie Bluff Chalk is mapped with the Ripley Formation in Montgomery, Dallas and Wilcox Counties. At places in Montgomery and Wilcox Counties the formation is absent locally, but generally is 11-15 ft (3.4-4.6 m) thick. C occurs as isolated exposures in Dallas County.

GEOLOGIC MAP OF THE GADSDEN, ALABAMA QUADRANGLE

EXPLANATION
INTERIOR LOW PLATEAU, APPALACHIAN PLATEAUS, VALLEY AND RIDGE, AND EAST GULF COASTAL PLAIN

Qal	Alluvial and Low Terrace Deposits
Qh	High Terrace Deposits
Kg	Gorda Formation
Kc	Coker Formation
Ppv	Patsville Formation
Mpw	Railwood Formation
Ma	Pennington Formation
Mf	Floyd Shale
Mb	Bangor Limestone
Mh	Hartselle Sandstone
Mym	Pride Mountain Formation and Monteagle Limestone undifferentiated
Mfp	Tusculum Limestone, Fort Payne Chert and Maury Formation undifferentiated
Mt	Tusculum Limestone
Mpa	Fort Payne Chert and Maury Formation undifferentiated
Dfm	Chattanooga Shale and Frog Mountain Sandstone undifferentiated
Dc	Chattanooga Shale
Sm	Red Mountain Formation
Su	Silurian undifferentiated
Os	Sequatchie Formation
Oc	Chickamauga Limestone
Oca	Attalla Chert Conglomerate Member of the Chickamauga Limestone
Ock	Knox Group undifferentiated
Cc	Consaga Formation

1/ Pride Mountain Formation is exposed in northwestern Alabama and grades into the Monteagle Limestone from Morgan County eastward.
2/ Silurian undifferentiated also occurs locally as discontinuous lenses in stream valleys in Limestone County.

SYMBOLS

- Formation contact
- Fault: U=Upthrown side, D=Downthrown side
- Thrust fault, sawtooth on upper plate

Base map modified from Army Map Service (SK), USGS, Washington, D. C., Gadsden 1:250,000 NTMS Quadrangle N 16 S, 1966. Limited revision by U. S. Geological Survey, 1966.

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GEOLOGIC MAP OF THE BIRMINGHAM, ALABAMA QUADRANGLE

EXPLANATION

APALACHIAN PLATEAU, VALLEY AND RIDGE, AND EAST GULF COASTAL PLAIN

Geological Formations and Symbols:

- Qal Alluvial and Low Terrace Deposits
- Qr High Terrace Deposits
- Ke Etowah Formation
- Ke Gordo Formation
- Ke Coler Formation
- Pp Partville Formation
- Ma Parkwood Formation
- MF Floyd Shale
- MB Bangor Limestone
- MH Marietta Sandstone
- AMM Arden Mountain Formation
- AMH Tusculum Limestone, Fort Payne Chert and Maury Formation undifferentiated
- Chm Chattanooga Shale and Frog Mountain Sandstone undifferentiated
- Sm Red Mountain Formation
- Chm Sequoyia Formation, Calves Mountain Sandstone and Greensport Formation undifferentiated
- Chm Chickamauga Limestone
- Chm Analla Chert Conglomerate Member of the Chickamauga Limestone
- Chm Little Oak Limestone
- Chm Athens Shale
- Chm Lincoln Limestone
- Chm Helena Limestone and Longview Limestone undifferentiated
- Chm Knox Group undifferentiated
- Chm Bibb Dolomite
- Chm Katoosa Dolomite
- Chm Briarfield Dolomite
- Chm Conasauga Formation
- Chm Rome Formation
- Chm Shady Dolomite
- Chm Weiser Quartzite

PIEDMONT PROVINCE

- Mac Straps Creek Formation
- Mac Brewer Rhyolite
- Mac Sawyer Limestone

Unit Group

- Push Hillabee Chlorite Schist
- Push Chulafin Schist
- Push Chloritic quartz schist
- Push Gisholt quartz schist

Talladega Group

- Push Abel Gap Formation
- Push Lay Dam Formation
- Push Lay Dam Quartzite

Wadsworth Group

- Push Wadsworth Group undifferentiated
- Push Hixson Ferry Formation
- Push Fox Bridge Mountain Formation
- Push Hackberryville Schist
- Push Wadsworth Group gneissic units

Other Symbols:

- Push March Creek Group
- Push Mitchell Dam Amphibolite
- Push Metamorphic
- Push Rocked Granite
- Push Elkhatchee Quartz Diorite Gneiss

SYMBOLS

- Formation contact
- U Fault: U=Upthrown side
- D Fault: D=Downthrown side
- Thrust fault, sawtooth on upper plate

Base map modified from U. S. Army Topographic Command (AJEE), Washington, D. C., Birmingham 1:50,000 NTMS Quadrangle N 105, 1953. Revised by the U. S. Geological Survey, 1969.

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LOCATIONS OF SELECTED ELEMENTS AND MINERALS IN THE GADSDEN QUADRANGLE

Explanation
/ Chattanooga shale (uranium)

PLATE 2

LOCATIONS OF SELECTED ELEMENTS AND MINERALS IN THE MONTGOMERY QUADRANGLE

- Explanation
(Descriptions of numbered locations included in report)
- Mica bearing pegmatite
 - ▲ Mica deposits
 - Beryl deposits
 - ◻ Tin deposits that may contain columbite and tantalite
 - ◻ Monazite occurrences
 - ◻ Graphite schist (Wedowee Group) containing vanadium bearing roscoelite mica and molybdenum
 - ◻ Hillabee chlorite schist (metavolcanic) containing massive sulfide deposits
 - Chattanooga shale (uranium)
 - Uranium in lignite

PLATE 2

LOCATIONS OF SELECTED ELEMENTS AND MINERALS IN THE BIRMINGHAM QUADRANGLE

- Explanation
(Descriptions of numbered locations included in report)
- Mica-bearing pegmatite
 - ▲ Mica deposits
 - Tin deposits that may contain columbite and tantalite
 - Ⓔ Graphite schist (Wedowee Group) containing vanadium bearing roscoelite mica and molybdenum
 - Ⓕ Hillabee chlorite schist (metavolcanic) containing massive sulfide deposits
 - Chattanooga shale (uranium)

INTERPRETIVE CROSS SECTION A-A'; BIRMINGHAM QUADRANGLE

Prepared by the Geological Survey of Alabama

INTERPRETIVE CROSS SECTION A-A'; GADSDEN QUADRANGLE

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INTERPRETIVE CROSS SECTION A-A'; MONTGOMERY QUADRANGLE

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