MINERAL RESOURCES OF THE NORTHERN
ALABAMA PIEDMONT

Southeastern Geological Society
Guidebook No. 27

Edited by

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Marc J. Defant, Mark S. Drummond,
and David Allison

Published by
Southeastern Geological Society
P. O. Box 1634
Tallahassee, Florida 32302
April 18-20, 1986
Field Trip

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Guidebook

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SCHEDULE OF ACTIVITIES

April 18, 1986
4:00-11:00 p.m. Registration. Lobby of the Towne Inn Motel, Sylacauga, Alabama.

April 19, 1986
6:30-7:45 a.m. Breakfast. Huddle House Restaurant.
8:00 a.m. Load vans, depart from Towne Inn Motel. Those at the Campgrounds should make arrangements to meet at the motel by 8:00 a.m.
12:00 p.m. Lunch Stop - provided. Cheaha Mountain State Park.
5:30 p.m. Return to the Towne Inn.
8:00 p.m. SEG meeting in the Conference Room of the Towne Inn.

April 20, 1986
6:30-7:45 a.m. Breakfast. Huddle House Restaurant.
8:00 a.m. Load vans, depart from Towne Inn Motel. Be sure to check out of motel.
12:00 p.m. Lunch Stop.
1:00 p.m. Return to Towne Inn Motel and depart for Florida.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the support over the past years of the Geological Survey of Alabama. In addition, we would like to thank Mary Haney for her typing of this manuscript.
INTRODUCTION

The Northern Alabama Piedmont forms part of the southwesternmost surface exposure of the Appalachian orogen. Like many orogenic belts around the world the Appalachian orogen has formed through a variety of processes including both active and passive continental margin formation, crustal shortening and deformation, and metamorphism and plutonic activity. Because of the wide variety of processes which contribute to the formation of mountain belts, it should be expected that mineral deposits located in these regions of the earth's crust should reflect their varied background. As a result, several types of mineral deposits are recognized in the Northern Alabama Piedmont. These range from primary-type deposits that are the result of primary sedimentary or igneous activity, to secondary deposits related to metamorphism and hydrothermal alteration.

The purpose of this field trip is to briefly demonstrate the types of mineral deposits and their geologic settings which can be found along a transect of an orogenic belt using the Northern Alabama Piedmont as an example. It should be remembered that by no means do the examples presented here represent a complete suite of mineral deposits which can be found in orogenic belts. The Northern Alabama Piedmont forms only a portion of the orogen in Alabama. In other parts of the orogen, mineral deposits can be found in a wide variety of settings ranging from true sedimentary deposits in the foreland fold and thrust belt to primary and secondary deposits in the adjacent Inner and Southern Piedmonts. However, the Northern Alabama Piedmont contains the most extensively mined and explored metallic mineral deposits in the state as well as deposits which occur in their present state due to their active involvement in the orogenic process.

G. M. Guthrie

Stratigraphy, Metamorphism, and Deformation of the Northern Alabama Piedmont

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Introduction

The Northern Alabama Piedmont represents the southwesternmost extension of the crystalline Blue Ridge belt of the southern Appalachian orogen (Thomas and others, 1980). The Blue Ridge is bounded to the northwest by the Paleozoic foreland fold and thrust belt and to the southeast by the Inner Piedmont. Major regional fault systems form the boundaries in both instances. In the southern Appalachians of North Carolina and Georgia, the Blue Ridge has been subdivided into an eastern and western belt, separated by the Fries-Hayesville-Alatoona fault system (Rankin, 1975; Hatcher and others, 1979; McConnell and Costello, 1980). This two-fold subdivision is primarily based on the differences in lithostratigraphy between the two belts. Based on fossil evidence, the western Blue Ridge is believed to represent the southeastern extension of the Late Precambrian to Early Paleozoic continental margin (Walcott, 1870; Hatcher, 1972; Knoll and Keller, 1979). The relationship of the eastern Blue Ridge to the continental margin is subject to debate (Williams and Hatcher, 1982); however, most geologists consider it to represent rift-generated sediments and volcanics deposited during late Precambrian extension which lead to the development of the Iapetus Ocean basin (Rankin, 1975; Wehr and Glover, 1985).

In Alabama the same two-fold subdivision can be recognized in the northern Piedmont. This subdivision is marked by the Hollins Line -- Goodwater-Entichapopo fault system (HLGE; Fig. 1; Tull, 1978). To the northwest of this fault system, units comprising the Talladega lithotectonic block (Tull, 1978) have been equated with the western Blue Ridge and parts of the foreland fold and thrust belt (Tull and Guthrie, 1985). The Talladega block is separated from the foreland by the Talladega-Cartersville fault system (Fig. 1; Smith, 1988; Hayes, 1891). Southeast of the HLGE, units of the Coosa and Tallapoosa lithotectonic blocks (Tull, 1978) have been equated with the eastern Blue Ridge (Hurst, 1970). The Coosa and Tallapoosa blocks are separated by the Goodwater-Entichapopo fault (Tull, 1978). Units of the Inner Piedmont are juxtaposed to the southeast of the Tallapoosa block along the Brevard Zone fault system (Fig. 1; Jonas, 1932).

Like the Blue Ridge to the northeast, the Northern Alabama Piedmont is composed of polydeformed metamorphic rocks which vary in metamorphic grade from very low- to high-grade. Early estimates of the time of metamorphism in the Blue Ridge suggested that regional prograde metamorphism (M1) occurred during the Devonian in association with an Acadian orogenic event (Long and others, 1959; Carpenter, 1970). Later
estimates associated the time of metamorphism with Taconic orogenesis during the Ordovician (Butler, 1972; Kish and Harper, 1973; Odom and Fullager, 1973). In Alabama, problems arise with an Ordovician age due to the occurrence of Early Devonian fossils in the Talladega block. Recent correlations of the Talladega stratigraphy with that in the western Blue Ridge to the northeast have led Tull and Guthrie (1985) to propose that Devonian metamorphism was the primary prograde metamorphic event in that section of the Blue Ridge. Estimates on the time of deformation range from Devonian first generation structures (D1) to later Carboniferous deformation during the Alleghanian orogeny (Tull, 1980).

It is our intention here to present a brief outline of the evolution of the Northern Alabama Piedmont based on some established, as well as current research in the area. A more detailed examination of this area, as well as the Blue Ridge to the northeast, can be gleaned from the references cited.

Lithostratigraphy

Three distinct lithostratigraphic assemblages comprise the Northern Alabama Piedmont (Fig. 2). In addition to stratigraphic variation from block to block, lithostratigraphic variation is common within the same block, reflecting differences in protolith and depositional environment of the individual units. On the whole, units within the Coosa and Tallapoosa blocks appear to be the most homogeneous, possibly due to restricted times of deposition and environments. The Talladega block, on the other hand, contains an extremely heterogeneous lithostratigraphic assemblage representing a significant length of time in Appalachian basin history.

Talladega Block

Tull (1982) has outlined a four-fold stratigraphic subdivision for the Talladega block (Fig. 2) which includes, in ascending order: (1) the Kahatchee Mountain Group (KMG); (2) the Sylacauga Marble Group (SMG); (3) the Talladega Group (TG), and (4) the Hillabee Greenstone (HG). The stratigraphic and structural base is the KMG. This group is composed predominantly of fine-grained psammitic and pelitic rocks, with locally developed thin bedded marbles. Detrital biotite, muscovite, potassium feldspar, plagioclase, and zircon are common accessory minerals in the lowest units of the group with a tendency towards compositional maturity up section (Guthrie, 1985). The contact with the overlying SMG is gradational (Pendexter, 1982).

Dolomitic and calcitic marbles dominate the stratigraphy of the SMG. A significant thickness of chlorite, sericite phyllite is interlayered with dolomitic marble in the middle to lower part of the sequence (Tull, 1986). Marbles in the upper part of the group contain an Early Ordovician condont assemblage (Harriss and others, 1984). Unconformably overlying the SMG and the KMG along part of their length is the TG (Carrington, 1973; Shaw, 1970; Tull, 1982). Along most of
its trace, the contact between the TG and the underlying units is a fault (Prouty, 1916; Butts, 1926; Gilbert, 1937; Guthrie, in preparation).

The TG is the most heterogeneous and areally extensive unit in the Talladega block. Rhythmically-layered metapelite is the dominant lithology in the lowest part of the group. A shallow water marine conodont assemblage, ranging in age from Silurian through Permian, establish an age range for these metasediments (Harris and others, 1984). Metapelites are interlayered with a significant quantity of arkosic metasandstones and a considerable thickness of diamictite (Telle, 1983). Cobbles and boulders (up to three meters in diameter) in the diamictite vary in composition from lithologies found in the underlying units to granitoid boulders. Zircon separates from the granitoid lithologies have been dated using U-Pb techniques and have yielded ages of 1.1 b.y. (Telle and others, 1979). The upper units in the TG are composed of black, carbonaceous slate, arkose to quartz metarenite, and metachert (Tull, 1982). A shallow water marine biota constrains the age of the metachert at the top of the TG to Early Devonian. When combined with the faunal evidence from the lower part of the unit, the age for most of the TG is constrained between Silurian to Early Devonian. The upper contact of the TG is interlayered with units of the overlying HG (Tull and Stow, 1980).

The HG occurs at the stratigraphic and structural top of the Talladega block and can be characterized as a bimodal metavolcanic sequence composed of massive greenstone, greenschist, and minor metadacite (Tull and Stow, 1980). Along most of its outcrop trace, the HG and top of the TG below are imbricated in a regional duplex system (Moore and others, 1983).

Coosa Block

The Coosa block is subdivided into northeast and southwest salients in the Millerville area (Fig. 1) due to complex folding and faulting. The rocks in the northeast salient are known as the Poe Bridge Mountain Group (PMB) and Mad Indian Group (MI), whereas those in the southwest salient are known as the Higgins Ferry Group (HF) and Hatchet Creek Group (HC). The rock types in both salients are aligned similarly. The Poe Bridge Mountain/Higgins Ferry Groups and Mad Indian/Hatchet Creek Groups are considered correlative sequences (Tull, 1978).

The HF/PMB are medium to coarse-grained metasedimentary rocks consisting of rossocelite-bearing graphite, quartzite, feldspathic muscovite schist, quartz-muscovite schist, garnet quartzite, and garnetiferous biotite-muscovite schist. These lithologies are interlayered with metagneous rocks represented by amphibolite which is quite distinctive. The occurrence of granitoids within the HF/PMB sequence is minor. The major metasedimentary rock types of the HC/MI Groups consist of garnetiferous biotite-muscovite schist and paragneiss, with minor calc-silicate gneisses and garnet-biotite quartzites. Migmatites (anatectites), pegmatites, and small granitoid
bodies (usually <1km in diameter) are commonly scattered throughout the HC/MI Groups.

Tallapoosa Block

Two major metasedimentary units have been differentiated within the Tallapoosa block (Fig. 2): the Wedowee Group and the Emuckfaw Formation Group (Tull, 1978). The Wedowee Group is the most extensive unit in terms of areal extent with the Emuckfaw Formation comprising a relatively small region in the extreme southeastern portion of the Tallapoosa block. Voluminous granitoid bodies of various relative ages (pre-, syn, and post-MI-01) intrude the Tallapoosa block metasediments. A first order lithologic subdivision in the Wedowee Group can be made between phyllonites and schists. The phyllonites are texturally and mineralogically retrograded schists, which are due to cataclasis and recrystallization during a retrograde (D2-M2) metamorphism producing a very fine grained (generally <0.05mm) graphite-sericite phyllonite. The Wedowee Group schists retain their prograde Mi texture and mineralogy and are represented by garnetiferous biotite-muscovite schist and quartzo-muscovite schist. Muscovite-biotite paragenesis and biotite quartzites are commonly interlayered with the schists. The Emuckfaw Formation is made up of mineralogically variable schistose units with minor interlayered gneiss, amphibolite, and quartzite.

Depositional History

Interpreting the depositional setting of polydeformed metamorphic rocks is complicated by several factors. Among these are: the recrystallization of primary mineral assemblages; the destruction of primary sedimentary structures and concomitant lack of facing criteria; the lack of fossil material; and the existence of tectonic boundaries at formation contacts. Despite these problems, attempts have been made to interpret the sedimentary history of units in the northern Alabama Province and to incorporate these interpretations into current ideas on the formation of the Appalachian mountain system. In the Coosa and Tallapoosa blocks, many of the above listed problems become especially apparent due to the advanced stages of dynamothermal overprint. In some areas of the Talladega block, however, the low degree of penetrative strain and limited amount of recrystallization have allowed interpretations of the sedimentary and tectonic history to be made with some degree of confidence based on the constraints inherent in the control data.

Talladega Block

Units in the Talladega block have been correlated with units in the adjacent foreland fold and thrust belt and with units in the western Blue Ridge belt to the northeast using lithostratigraphic and paleontologic evidence (Tull and Guthrie, 1983, 1985). The MGK appears to represent a more distal part of the pre-Appalachian miogeoclinal shelf assemblage, believed to be upper Precambrian and lower Cambrian shallow water marine and transitional marine clastics deposited during the initial stages of continental margin stabilization (Tull, 1982; Guthrie, 1985). The overlying SMG has been interpreted as the metasedimentary equivalents of the early to middle Paleozoic carbonate bank sequence of the foreland fold and thrust belt. During post-Early Ordovician to pre-Silurian time, the margin became unstable and underwent rapid basin subsidence leading to deposition of the diamictites in the TG (Tolle, 1983; Tull, 1985).

The diamictites, which dominate the group near the coastal plain overlap in central Alabama, are interlayered with turbidite-like metapelites and are interpreted as submarine debris flows (Tolle, 1983). Similar lithologies have been reported from units in the Murphy belt of Georgia and North Carolina (Tull and Guthrie, 1985) and the Talladega belt in Georgia (Guthrie, 1986a). Near Cartersville, Georgia, lithologies that are compositionally similar but finer grained than the Alabama diamictites lie in close proximity to Greenville-age basements.

The uppermost part of the TG is composed of black slates, quartzites and cherts. An Early Devonian shallow water marine biota serves as the basis for correlating this portion of the section with a similar aged clastic unit, the Frog Mountain Formation, in the adjacent foreland (Butts, 1926; Sutley, 1977). The HG is interpreted as representing a portion of an Andean-type volcanic arc. This is based on its lithological makeup and its stratigraphic position overlying continental margin metasediments (Tull and Stow, 1980).

Coosa and Tallapoosa blocks

Unlike the interpretations made for the Talladega block, which can be categorized as a homoclinal, southeast dipping panel with commonly exposed formation contacts and well preserved primary features, interpretations of the Coosa and Tallapoosa blocks becomes complicated due to the previously mentioned problems. The distinct lithostratigraphic associations in these blocks, along with interpretations made in other parts of the eastern Blue Ridge, however, have allowed for interpretations to be made based on the available data.

The HF/PBM lithofacies assemblage of garnet and graphite quartzite interlayered with amphibolite has been interpreted to be a metamorphosed sequence of interlayered chert and submarine volcanics (Drummond, 1986). In addition, massive sulfide deposits at Stone Hill in the PMB, which have been interpreted as submarine exhalative deposits in a reducing environment (Whittington, 1982), and feldspathic mica schists, interpreted as marine shales, have led to the conclusion that these rocks were deposited in a restricted euxinic rift basin.

The feldspathic paragenesis and interlayered garnet, mica schist, calc-silicate gneiss and garnet-biotite quartzite which comprise the HC/MI Groups were interpreted as a distal turbidite sequence derived from a granitic terrane (Drummond, 1986).
The Wedowee/Emuchaw sequence composed of graphite schist, mica schist, biotite quartzites, metagraywacke, and minor amphibolite has been interpreted, along with the HC/MI Groups, as a continental slope-rise deposit (Thomas and others, 1980; Neathery and Thomas, 1980).

Metamorphism

Prograde regional metamorphism (MI) in the northern Alabama Piedmont can be categorized as an Acadian age (Devonian). Barrovian-type metamorphic event with metamorphic grade ranging from lower greenschist facies to upper amphibolite facies. Local migmatization and S-type granitoid intrusions are considered to be the result of crustal anatexis during the MI event. MI metamorphism is thought to represent the peak thermal event that controlled the prograde recrystallization of the sediments (Tull, 1975, 1978, and 1980). Metamorphic grade increases in a southwestward direction from the Talladega block (greenschist facies) to the Coosa and Tallapoosa blocks (middle to upper amphibolite facies).

Where developed, a pervasive retrograde (M2) episode mineralogically and texturally degrades the original MI mineralogical assemblage generally producing a fine-grained rock with various alteration assemblages depending on the MI protolith composition. The M2 event was followed by polyphase folding, uplift, and erosion associated with Alleghenian orogenesis. An average denudation rate (uplift and erosion rate) of 0.1 mm/yr has been calculated for the northern Alabama Piedmont (Drummond, 1986).

The MI mineralogical assemblage within metatlaschic units of the Talladega block is commonly quartz, white mica (probably phengite and/or paragonite), chlorite, epidote, and albite with accessory hematite, magnetite, pyrite, carbonate, and carbonaceous material. The relative abundance of chlorite, hematite, and carbonaceous material governs the color of the multi-hued slates and phyllites. Additional MI phases present in the dolomitic and calcite marbles include quartz, chlorite, white mica, apatite, and pyrite (Tull, 1988). The greenstones and greenschists of the HG have an MI assemblage of albite, epidote, actinolite, zoisite/clinozoisite, and chlorite (Tull and Stow, 1980, 1982). The Hillabee Greenstone metadacite units contain a metamorphic paragenesis of quartz, sericite, albite, epidote, actinolite, and K-feldspar with xenocrystic plagioclase, hornblende, and zircon (Tull and Stow, 1980, 1982).

The mineral assemblage with the HG indicates that it is in the albite-actinolite-chlorite metamorphic zone, which is indicative of the low-temperature portion of low-grade metamorphism, i.e., lower greenschist facies (350°-400°C; Winkler, 1976). No lawsonite, prehnite, or pumpellyite have been reported from the mafic Hillabee Greenstone indicating that metamorphic grade is higher than very low grade and is on the high temperature side of the lawsonite- or prehnite-out reactions where lawsonite and prehnite decomposition produces zoisite/clinozoisite and clinozoisite + actinolite, respectively.

Metapelites within the Talladega block are sub-biotite grade (Tull, 1985). Ferry (1984), in a comprehensive study of the biotite isograd in metapelites, found that biotite's lower temperature stability limit is approximately 400°C. This provides an upper temperature bracket recorded by the Talladega block metapelites. Plagioclase composition in the Talladega block is albite, which is consistent with lower greenschist facies conditions. At slightly higher metamorphic grades at or near the biotite isograd, two separate plagioclase populations (an 0-7 and an 20-30) can be produced due to the peristerite gap in the plagioclase solvus (Crawford, 1966; Ferry, 1984).

Two methods which have been used as a measure of changing metamorphic grade in the Talladega block are ililitr crystallinity and conodont color alteration. The conodont alteration index (CAI) is a semi-quantitative measure of the change in coloration of conodont elements. These changes are due to devolatilization reactions and recrystallization in the elements and is directly related to depth and duration of burial and geothermal gradient (Epstein and others, 1977). Conodonts from the Sylacauga Marble Group yield CAI values of 5.5-7 corresponding to a temperature range of 350°-400°C (Tull, 1985).

Ililitr crystallinity provides a qualitative measure of metamorphic grade variation in low-grade metamorphic rocks. This method is based on the observation that the shape of the 10° 2θ ililitr-mica peak changes with increasing metamorphic grade. The peak shape is determined by the relative amounts of chlorite, mica, and carbonaceous material (Kubler, 1968). Figure 3 illustrates how these three components are measured and Table 1 indicates the variation in values relative to metamorphic grade. Sharpness ratio values have been obtained from samples in three areas along the northwestern border of the Talladega block (Fig. 4). Values range from 4 to 12 in the Winterboro area (Blount and Nelson, in review); from 6-12 near Sylacauga; and from 4-7 near Shelby (Guthrie, in preparation), indicating very low to low-grade metamorphism. An evaluation of X-ray diffraction patterns of samples from the same unit in the Sylacauga Marble Group indicate that with increasing metamorphic grade clinoh charcoal increases in abundance and mixed-layer phengite/muscovite changes to 2:1 polytype muscovite (Guthrie, in preparation). A similar observation has been made by Robinson and Bevin (1986) in low-grade metamorphic rocks in Wales.

Tull (1985) reported coexisting calcite and dolomite from the marbles of the Sylacauga Marble Group. In the future, a quantitative geothermometer which could take advantage of this relationship in delineating metamorphic grade variations is the calcite-dolomite solvus thermometer (Bickle and Powell, 1977; Nesbitt and Essene, 1982).
Figure 3.--Method of measurement of the sharpness ratio (SR) and crystallinity index (CI).

\[ SR = \frac{A}{B} \]

\[ CI = \frac{\text{half width mica}}{\text{half width quartz}} \times 100 \]

Table 1.--Degree of metamorphism vs. sharpness ratio (after Weaver, 1960)

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<th>Degree of Metamorphism</th>
<th>Sharpness Ratio</th>
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<td>Low-grade metamorphism</td>
<td>12.1</td>
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<tr>
<td>Weak to very weak metamorphism</td>
<td>6.3</td>
</tr>
<tr>
<td>Incipient to weak metamorphism</td>
<td>4.5</td>
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<tr>
<td>Incipient metamorphism</td>
<td>2.3</td>
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</tbody>
</table>
Coosa Block

The M1 mineral assemblages within the metasomites of the HF/PBM Groups include quartz, muscovite, biotite, vanadium-bearing muscovite, crystalline graphite, plagioclase, garnet, kyanite, sillimanite, ilmenite, pyrrhotite, and staurolite. Hornblende, plagioclase, quartz, garnet, sphene, and zircon are common prograde phases in the amphibolites.

The major prograde (M1) mineral assemblage of the HC/M1 Groups' schist and gneiss is quartz, muscovite, biotite, and plagioclase. Accessory phases include garnet, sillimanite, kyanite, graphite, pyrrhotite, zircon, apatite, rutile, and ilmenite. Calc-silicate gneisses (metarals) contain a diverse mineralogy including hornblende, plagioclase, epidote, calcite, garnet, clinopyroxene, pyrrhotite, sphene and ilmenite. The metamorphic grade of the Coosa block is discussed in conjunction with the Tallapoosa block in the following section.

Tallapoosa Block

Quartz, sericite, chlorite, epidote, and hematite are associated with greenschist retrograde (M2) metamorphism in the graphite-sericite phyllicite of the Tallapoosa block. Recrystallization of the lower grade minerals has almost totally destroyed the prograde mineral assemblage. The only prograde minerals which have not been dynamically and/or chemically retrograded to any significant degree during M2-D2 are graphite, mechanically competent garnet and tourmaline porphyrablasts.

The predominant M1 mineral assemblage in the Wedowee Group schists and paragneisses include quartz, muscovite, biotite, and plagioclase (oligoclase) with accessory garnet, graphite, sillimanite, kyanite, tourmaline, ilmenite, pyrrhotite, zircon, apatite, and staurolite. Prograde mineralogy of schists within the Emuchaw Formation is muscovite, biotite, chlorite, plagioclase (albite and oligoclase), graphite, and quartz with minor kyanite, ilmenite, and magnetite (Neal and Denny, 1975).

Based on qualitative and quantitative mineral equilibria, the Coosa and Tallapoosa blocks are representative of middle to upper amphibolite facies metamorphism. A quantitative metamorphic petrologic study has been completed on the Higgins Ferry, Hatchet Creek, and Wedowee Groups and spatially related metamorphic S-type granitoids (Rockford Granite) in Coosa County, Alabama (Drummond and Allison, 1965; Drummond, 1986). The lowest grade M1 equilibria reactions found in these rocks coincides with the disappearance of staurolite. Staurolite in the Wedowee Group schists exhibits an important prograde reaction relationship with staurolite decomposing to almandine-sillimanite + biotite via the unbalanced reaction:

\[ \text{staurolite} + \text{muscovite} + \text{quartz} = \text{sillimanite} + \text{almandine} + \text{biotite} + H_2O (1) \]

Reaction 1 has been studied in detail by Thompson and Norton (1968) and Froese and Gasparrini (1975). At pressures of 4 to 6 K, the thermal boundary for reaction 1 lies in the temperature range of 610-644°C.

The temperature and pressure dependence of intercrystalline elemental exchange in equilibrium mineral equilibria, such as garnet + biotite = plagioclase + graphite, garnet + clinopyroxene = plagioclase + quartz, plagioclase + hornblende + epidote, was utilized to quantitatively determine the temperature and pressure of M1 metamorphism from various localities within the Higgins Ferry, Hatchet Creek, and Wedowee Group of Coosa County. Geothermobarometric estimates from the Hatchet Creek Group indicate that it has been subjected to an average T-P regime of 654±12°C and 5.50±0.46 K. Average temperature and pressure for the Wedowee Group is 603±9°C and 5.53±0.33 K, indicating an average temperature somewhat less than the Hatchet Creek Group. A single sample of amphibolite with migmatitic veiningls from the Higgins Ferry Group yielded a 665°C temperature and 4.36 Kb pressure estimate. The average temperature and pressure obtained from the Rockford Granite is 667°C±19°C (and 4.54±0.41 K.) and are interpreted to be related to the intrusion of the granitoids.

The average temperatures and pressures from the samples (Fig. 5) listed in Table 2 yield the array of points in P-T space which are shown in Figure 6. The resulting P-T path (arrowed line) interrelates the processes of regional metamorphism and anatexis. The P-T path is tightly constrained by sample points representing the average P-T of each sample except where the path decreases pressure at nearly constant temperature. If individual assemblages such as RS-2178(C2), RS-2178(C3), and RS-1260(C2) from Table 2 are plotted as well, then the entire length of the proposed path would be continuously constrained by P-T points. The points that align along the positively sloped portion of the P-T path display a Barrowan-type metamorphic grade and approximately 30°C/km. The best fit through these points closely coincides with kyanite-sillimanite facies series metamorphism. The arrows on the P-T path are indicative of the polychronous nature of progressive metamorphism where points at lower temperature reflect conditions earlier in the metamorphic development than those at higher temperatures (England and Richardson, 1977). Therefore, these types of graphs may be thought of as P-T-time paths with time being a relative quantity.

In the upper portion of Figure 6, some samples fall well on the high temperature side of the granite minimum melt curve (Thompson and Tracy, 1979; Thompson and England, 1984). The decrease of pressure at a nearly constant temperature, as indicated by the P-T path, is considered to be a function of crustal anatexis where migmatization allows crustal melts to accumulate and ascend through the crust. Thermal doming may have been accentuated by the diapirc rise of anacetic, S-type Rockford Granite intrusions, allowing the Barrowan gradient to be abruptly interrupted by nearly isothermal decompression. The samples that fall in the cusp between the muscovite-plagioclase stability curve (Chatterjee and Johannes, 1974) and the granite minimum
Figure 5. Distribution of samples used in geothermobarometric study. Geology from Drummond, 1986; Schrader and others, 1981; Allison, 1984, personal communication.

Table 2. Geothermobarometric estimates from the Hatchet Creek, Wedowee, Higgins Ferry Groups, and Rockford Granite.

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<th>PN</th>
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<td></td>
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<td></td>
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</table>

average temperature: 603±9°C
average pressure: 5.53±0.33Kb

Higgins Ferry Group

amphibolite RA-105* - - - - 665 4.36

Rockford Granite

RS-87b 686 4.94
RA-78* 648 4.13
average 567 4.54
±19 ±0.41

-TGS and PGS temperature and pressure determined utilizing Ghent and Stout's (1981) calibration
-TFS temperature determined using Ferry and Spear's (1978) garnet-biotite geothermometer
-TEG estimation of temperature by Ellis and Green's (1979) calibration
-TS temperature from hornblende-plagioclase, calibration of Spear (1980)
P pressure estimate from calibration of Plyusnina (1982)
* denotes samples of Allison (personal communication, 1985)
** temperature determined assuming average 5.53 Kb pressure of Wedowee Group

- deviations reported for the means are standard errors (std. deviation/ n).
melt curve represent either highly migmatitic metasediments or Rockford Granite samples.

Thompson and Tracy (1979) have stated that a P-T range of 4-6 kb. and 640°-720°C provides the optimum conditions for anatexitic melt generation in metapelitic rocks progressively metamorphosed in the kyanite-sillimanite facies series. In this T-P range, the maximum overlap between muscovite dehydration and initial melting reactions occurs. Therefore, nearly isothermal decompression along the P-T path is interpreted to be the result of uplift and doming associated with local migmatization and/or introduction of Rockford Granite plutons at the thermal peak of metamorphism thereby allowing temperature to remain constant while pressure decreases.

Quantitative metamorphic petrologic studies have not been carried out in other portions of the Coosa and Tallapoosa blocks, but the determination of equilibrium mineral assemblages does yield some information on their metamorphic grade. Neathery (1975) has stated that the MI assemblages in the PBM/MI are correlative to the sillimanite subfacies of the amphibolite facies. The MI is locally migmatitic as is the HC (Tull, 1978; Thomas and others, 1980). The occurrence of kyanite and staurolite is well documented in the Wedowee Group in Randolph County (Cornhouse Schist of Neathery and Reynolds, 1973; Neathery, 1975). The Wedowee Group in the northern portion of the Northern Alabama Piedmont probably experienced the staurolite-kyanite zone of regional metamorphism which is approximated at 525°-550°C and 4.2 to 4.8 kb. (Genty, 1975; Turner, 1982). The P-T regime of the staurolite-kyanite zone is a natural transition of the proposed regional metamorphic geotherm shown in Figure 6. The assemblage of chlorite + biotite + muscovite + garnet + albite/oligoclase for the Euchaff Formation (Neathery, 1975) is representative of lower amphibolite facies metamorphism or the andalusite + chlorite + muscovite zone. This assemblage is stable until the middle amphibolite facies is reached and then reacts to form biotite and staurolite via reaction 2 below:

\[
\text{chlorite+muscovite+andalusite = staurolite+biotite+quartz+H}_2\text{O} \quad (2)
\]

Deformation History

The Northern Alabama Piedmont has experienced a protracted history of polydeformation in both ductile and brittle deformation environments. At least seven distinct structural environments have been recognized in the region. For the purposes of this report, they have been designated D1 through D7. There is no absolute timing implied by this technique, which utilizes cross-cutting relationships as the basis to establish a relative structural sequence.

Five episodes of folding have been recognized in the Talladega block and four episodes in the Coosa and Tallapoosa blocks. First generation structures in the Talladega block are synsedimentary, exerting no apparent control on later structures or events. There will be no further consideration of these features.
First generation tectonic structures (D1) formed concomitant with prograde dynamothermal metamorphism (Tull, 1978). The dominant D1 structures can be recognized by the transposition of secondary layering into tight to isoclinal similar and flow folds. The metamorphic foliation is parallel to axial surfaces and a well-developed mineral lineation parallels the fold axes of D1 folds. D1 folds appear to be restricted to mesoscopic scale or smaller. Megascopic folds have not been recognized in the Talladega belt, although the occurrence of D1 folds becomes more pervasive to the northeast and southeast. The areal and outcrop expression of D1 increases to the east, across the northern Piedmont. In the Talladega belt this is especially true.

In the Coosa and Tallapoosa blocks, D1 folds are similar in style and characteristics to those in the Talladega belt. Recognition of mesoscopic scale D1 structures has also been difficult in this region despite the more pervasive nature of deformation. The difficulty in discerning D1 folds arises from several aspects: (1) poor outcrop exposure; (2) the polydeformed nature of the rocks; and (3) lack of detailed, lithologically oriented field mapping. In some areas, where mapping has been very detailed, the presence of megascopic structures has been reported (Allison, 1984, personal communication.)

Second generation structures (D2) are more highly localized and recognition of these has mainly been confined to the Coosa and Tallapoosa blocks (Jonas, 1932; Griffin, 1951; Neathery and Reynolds, 1975; Tull, 1978). In these areas, local transposition of metamorphic foliation (S1) along penetrative shear surfaces (S2) forms a "buttoned" or phylliclomatic texture. The formation of S2 accompanied the main retrograde metamorphic event (M2; Tull, 1978). Tight to isoclinal, microscopic and mesoscopic scale folds are the dominant D2 structures. Axial surfaces are parallel by S2. In the Coosa and Tallapoosa blocks, D2 fold axes are discordant to D1 fold axes, while in the Talladega block they are subparallel.

Recently, D2 structures have been recognized in the Talladega block (Guthrie, 1986b). D2 folds in this region share similar characteristics and style to those in the Coosa and Tallapoosa blocks. A detailed examination of these features indicates that they are associated with ductile deformation zones and mylonites. The areal extent of these features has not been completely delineated; however, preliminary data indicate that they are restricted to the proximity of the Talladega-Cartersville fault. A retrograde mineral assemblage of white mica + talc can be found along S2 surfaces. Talc has also been recognized in breccia zones that cross cut S1 in the marble quarries near Sylacauga. The possibility exists that zones of post-peak metamorphic hydrothermal fluid migration enhanced the ducitility of the rocks leading to the development of D2.

The Talladega-Cartersville fault system (TCFS; Fig. 1), which crosscuts D2 structures, involves multiple phases of movement which vary from syn-D2 ductile deformation zone to post-D2 brittle faulting (Guthrie, 1986b). This fault system contains units of the Talladega block in the hanging wall and units of the Paleozoic foreland and thrust belt in the footwall. Based on outcrop relationships, the fault system is discordant to stratigraphy of the hanging wall and footwall. In some areas, the footwall is composed of Cambro-Ordovician carbonates which were folded prior to fault emplacement.

Two types of fault zones are associated with the TCFS (Guthrie, 1986b). The first type is the ductile deformation zones described under D2 structures. The second type contains brittle cataclastic features such as limonite-cemented breccia. These two styles have been interpreted as two phases of fault development, one at or below the brittle-ductile transition zone and the other above the zone in the brittle regime (Guthrie, 1986b). The sinuous trace of the TCFS is partially attributed to D4 generation folding (Tull, 1984).

In all three blocks, D4 is expressed as flexural slip folding on a variety of scales. This is the Columbiana-Jemison phase of Tull (1984). Megascopic scale folds of this type "appear to form an "arrangement" of NE-SW structures which are asymmetric to the northwest. The folds are doubly plunging due to later refolding (Tull, 1984). A crenulation cleavage is associated with parasitic chevron folds on the limbs and in the hinge zones of megascopic and mesoscopic folds. In hinge zones, this cleavage is developed with such intensity that it locally transposes the earlier S-surfaces. D4 folding has been attributed to thrust sheet translation along foreland-directed thrust faults (Tull, 1984).

Megascopic D4 folds are cross cut by a major thrust system, the Hollins Line fault system (D5; Fig. 1; Tull, 1978). The existence of this structure has been known for a number of years but it has been variably interpreted (Adams, 1926; Griffin, 1951). The Hollins Line fault emplaces the Coosa block onto the Talladega block. A regional thrust duplex system is developed in the upper part of the stratigraphy of the Talladega block forming a braided outcrop pattern (Moore and others, 1983). In the hangingwall, megascopic folds are truncated along the fault (Tull, 1978).

The Hollins Line fault and all other earlier structures were cross folded during D6. These folds, denoted as the Millerville phase by Tull (1984), are characteristically open, upright flexural slip folds, with wavelengths on the order of several km. Occasionally crenulation folds occur in the hinge regions of the larger scale folds. Based on the style and oblique orientation of structures, Tull (1984) has interpreted this phase of deformation to be the result of oblique thrusting associated with the development of the Quachita orogen. Recently, Osborne and Guthrie (1986) have interpreted this event to be the result of movement of the crystalline and underlying thrust nappe stack over an irregular crystalline basement surface.

D6 structures are cross-cut by the Goodwater-Enntachopo fault system (GEFS; Neathery and Reynolds, 1975; Tull, 1978). The GEFS juxtaposes the Tallapoosa block against the Coosa block along most of its extent. However, northeast of Millerville the Tallapoosa block is juxtaposed with the Talladega block (Fig. 1). Zones of brecciation
4-50 meters thick are formed along the GEFS with a cataclastic foliation separating relatively undeformed blocks (Tull, 1978). The GEFS has been interpreted as a major regional high angle fault system, which continues to the northeast into Georgia forming the Alabama fault (Tull and others, 1985).

Timing of Metamorphism and Deformation

Stratigraphic, paleontologic, and isotopic evidence from the Talladega block indicate a Devonian age for metamorphism of the Northern Alabama Piedmont. The Jamison Chert, the uppermost unit of the Talladega Group (Tull and Stowe, 1980), contains an Early Devonian invertebrate fossil assemblage (Butts, 1926; Sutley, 1977) indicating that the low grade, regional metamorphic event that affected these rocks must have been post-Early Devonian (approximately 410 m.y. or younger). Isotopic age dating in the Talladega block has yielded a close number of determinations between 410-370 m.y. by conventional K-Ar whole rock and single mineral techniques (see Tull, 1982 for compilation). These are interpreted as cooling ages.

Radiometric age determinations from the Coosa and Tallapoosa blocks which may be used for estimating the time of prograde regional metamorphism include: (1) A Rb-Sr whole-rock age of 366 ± 18 m.y. from the symmetamorphic Bluff Springs Granite (Russell, 1978); (2) A 348 ± 10 m.y. K-Ar hornblende age from the Mitchell Dam Amphibolite (Hegel and others, 1970); and (3) A 366 ± 25 m.y. Rb-Sr whole-rock age from the Poe Bridge Mountain Group (Russell, 1978). Tull (1980) has suggested that these dates from the Coosa and Tallapoosa blocks may closely bracket the timing of metamorphism in the Northern Alabama Piedmont.

The approximately 60 m.y. age range (410-350 m.y.) listed above indicates that either the M1 event was a protracted Acadian orogenic event or that two or more separate metamorphic episodes occurred within that time segment. The former interpretation is favored based on the similarity in structural history of the three lithotectonic blocks as discussed above and on the general recognition of only one prograde metamorphic assemblage (Tull, 1978; Drummond and Allison, 1984; Drummond, 1986). Butler (1972) has suggested that conventional K-Ar mica ages obtained from the low-grade sections in the Appalachian orogen most closely date the time of metamorphism due to the shorter period of time required for these rocks to move through the argon blocking temperature. The younger ages determined for the Coosa and Tallapoosa blocks may reflect: (1) the longer period of time required for these rocks to move upwards in the crust concomitant with granitoid intrusion; or (2) continual heat input from the granitoid intrusions allowing these terrains to stay above the blocking temperatures of the various isotopic systems for a longer period of time.

Absolute timing of deformation events is a difficult task if the structures are not bracketed by tight age constraints. This is especially true in the Northern Alabama Piedmont where there is a dearth of these features throughout most of the area. In the Talladega block, constraints on the maximum age of deformation are provided by the Devonian fossils from the Jamison Chert discussed above.

Development of D1 structures was synchronous with prograde metamorphism (Tull, 1978). Although D2 is not as tightly constrained as D1, the mineral assemblages and ductile nature of deformation features dictate the time of deformation to be post D1 and associated with M2. The structural characteristics are indicative of progressive simple shear (Ramsay, 1980; Cuddob and Quinquis, 1980) so that D2 probably represents the waning stage of M1/D1, possibly terminating as the rocks moved above the argon blocking temperature of sericite and from a ductile to brittle deformation environment (Guthrie, 1986b, in preparation).

The movement of the TCFS probably initiated during this time facilitated by M2 fluids. Timing of the second phase of fault development (D3) is loosely constrained by the presence of the lower Mississippian marl in the focal area of the Floyd-Parkwood thrust system. Since the Talladega nappe was emplaced onto lithified Floyd-Parkwood, thrust development had to post date the Early Mississippian. The upper age limit of D3 and later events is not as tightly constrained. Subsurface Triassic-age basin sediments cross-cut the assembled and deformed nappe stack (Tull, 1980). These sediments in turn are unconformably overlain by Cretaceous coastal plain sediments.

The Wedowee/Emuchfaw Groups have been interpreted as lateral equivalents of the HCM/MI Groups (Thomas and Neatherly, 1980; Drummond, 1986), despite the occurrence of a tectonic boundary, the GEFS, separating the two blocks. Mylonites developed along the GEFS may be indicative of movement of this fault system synchronous with that along the TCFS. This would place the time of movement of the rocks at about 360 m.y. Folding (D4 and D6) share the same Carboniferous to Triassic time constraints as the Talladega block. This interpretation requires D7, development of the present GEFS, to be a reactivation event of the previous fault system since this deformation post dates D6 folding. The occurrence of cataclasites along the fault in addition to mylonites lends support to this interpretation.

Summary

Late Precambrian (?) to lower Devonian metamorphic rocks comprise the Northern Alabama Piedmont. The ages, lithostratigraphies, and depositional settings proposed for these rocks correlate to those in corresponding areas of the southern Appalachians, and span the period of continental margin development from early rift to margin stabilization to margin destabilization and basin contraction.

During the Devonian, the rocks were subjected to very low to high-grade metamorphism along a Barrovian-type metamorphic gradient. The thermal peak is believed to be associated with tectonic anatexis, S-type granitoid intrusion, and thermal doming. This has been interpreted as an Acadian dynamothermal regional metamorphic event. First and second
generation structures produced during the Acadian event mark the initiation of major crustal shortening and orogenesis.

Major uplift and denudation of the Northern Alabama Piedmont occurred during the Carboniferous in association with Alleghanian orogenesis (approximately 290-320 m.y. (Kamper and others, 1970). The uplift rate during the Alleghanian event has been estimated at 0.11 mm/year (Drummond, 1986). Foreland directed thrusting, accompanied by brittle folding and faulting, translated the northern Piedmont to the northwest into juxtaposition with the Paleozoic foreland fold and thrust belt at this time.

Metallogenesis and Tectonics:
Mineral Resources of the Northern Alabama Piedmont

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INTRODUCTION

Formation of a metallic deposit (metallogenesis) is predicated on the following factors: 1) there must be a source of the metal, 2) there must be a process by which the metal is concentrated which often coincides with the process by which the metal is transported (in the form of a saline brine, a silicate melt, etc.), and 3) there must be environmental conditions which are favorable to the formation and preservation of the deposit. Clearly, the possible variety of combinations of these three factors is very large. The theory of plate tectonics, however, provides a simple way in which these different settings may be organized.

In the previous paper, the geology of the crystalline rocks of Alabama was reviewed in a tectonic context. Beginning with rift related volcanic and sedimentary rocks and concluding with multiple episodes of metamorphism, deformation, and plutonism, the Alabama Piedmont documents the complex history of a continental margin from Precambrian to Paleozoic time. To the extent that mineral deposits reflect the tectonic settings of their formation, study of the mineral resources of the Alabama Piedmont augments the interpretation of that region's tectonic history. Such interpretation using metallic deposits is further advanced by the study of non-metallic resources so the scope of this discussion includes non-metallic mineral resources (e.g., marble, kyanite, talc).

The purpose of this discussion is to review the general settings that are proposed for each type of deposit described in the road log. Specific points referring to a particular deposit are discussed in the appropriate stop description so the present discussion is intended to interface between the previous paper and the stop descriptions that follow. Obviously, deposits that are older than episodes of deformation and metamorphism have been overprinted by that tectonism so some features of deposits formed at rift and passive margins have been subsequently obscured or obliterated.
RIFT MARGIN ENVIRONMENTS

Submarine Basaltic Volcanism
(Mitchell Dam Amphibolite)

Partial melting of mantle is commonly accepted as the source of basaltic volcanism at spreading centers. The enigma regarding Ashland Supergroup amphibolites of the Northern Alabama Piedmont consists of whether the spreading center environment was related to a rift margin (Thomas and others, 1980) or a back arc basin (Neatherly and Hollister, 1985). Both environments generate tholeiitic mafic melts. Unfortunately, the better elemental discriminators (e.g., potassium) are prone to symmetamorphic remobilization. The purpose of the present discussion is to address the issue of back arc versus rift margin environments of volcanism based on lithostratigraphic considerations. Implicit to the inclusion of this discussion under rift margin environments is that these ortho-amphibolites are believed to represent partial melting related to crustal rifting.

One feature that all active margins have in common is that they develop on what had previously been a rift/passive margin. Based on the example of the Atlantic Coastal Plain, the stratigraphy of a transitional rift-to-passive margin consists of early mafic tholeiitic volcanics interlayered with coarse to fine grain terrigenous clastic sediments (Daniels and others, 1983). This phase of volcanism and sedimentation grades into marine sedimentation and the cessation of volcanism corresponding to stabilization of the rift margin. If subduction was to begin along the present day Atlantic Coastal margin, it should be reflected in several ways. In brief, the stratigraphy of the active margin would develop (unconformably) on the pre-existing rift/passive margin stratigraphy. Thus, coarse grained clastics, volcanoclastics and bimodal volcanics would accumulate above the marine clastics and carbonates which, in turn, conformably overlie the rift margin stratigraphy. Such is the case for the stratigraphy within the low grade metamorphic rocks of the Talladega Slate Belt where the pre-Lower Paleozoic unconformity truncates Lower Paleozoic clastics and carbonates and underlies Middle Paleozoic diamictites and bimodal volcanics.

There is no similar association in the case of the orthoamphibolites of the Higgins Ferry Group or the correlative Poe Bridge Mountain Group (Mitchell Dam and Stone Hill stops, respectively). Felsic intercalations within these metabasalts are characteristically highly variable in their content of normative corundum and do not indicate an igneous protolith (see Stone Hill stop description). Moreover, the stratigraphic relationships proposed by Whittington (in press) indicate that the metabasalts of the Poe Bridge Mountain Group are stratigraphically lower than the metapelites of the Mad Indian Group. Such a sequence of primitive volcanics plus sediments beneath pelitic sediments is the reverse of what would be the stratigraphy of a back arc basin developing on an active margin.

In summary, basaltic volcanism during the late stages of crustal rifting seems to be a more feasible analogue for these amphibolites than the initiation of back arc spreading. This interpretation is further supported by an age of volcanism of 650 my (Lehray, 1983) if only because the earliest indications of active margin processes (plutonism in the Piedmont and unconformities in the Piedmont and Foreland Fold and Thrust Belt) are all Paleozoic in age.

Proximal Volcanogenic Massive Sulfides
(Stone Hill)

The most recent review of volcanogenic sulfide mineralization is that of Franklin and others (1981) and the interested reader is referred to that review from which this discussion was summarized. During an episode of submarine volcanism, seawater that penetrates along fractures is convectively circulated through the cooling volcanic pile as well as any associated clastic or volcanoclastic lithologies.

As the seawater is heated, it undergoes a series of reactions with the adjacent rock and is modified into a reduced, slightly acidic, saline solution enriched in base and/or precious metals. Associated with these changes in the fluid chemistry are compositional changes in the source rock that result in sericitic and/or chloritic footwall alteration. As the ore solution rises toward the seawater interface, sulfide and gangue phases which comprise stringer ore are precipitated as the fluid becomes saturated due to mixing with ambient seawater, boiling and/or wall rock reaction. Finally, the ore solution is exhaled from the sea floor at submarine vents.

The ore forming fluid exhaled at those vents produces the massive ore for which these deposits are named. Depending on the competing effects of temperature and density, the fluid will either rise as a buoyant plume out of which sulfide phases settle and accumulate around the vent, or a dense bottom brine will form and move down slope from the vent to collect in local depressions. In either scenario, massive ore is formed as lenses which are conformable to bedding. These deposits that form near the vent are recognized as proximal volcanogenic massive sulfides by the occurrence of stringer ore and/or alteration zones which form beneath the vent.

PASSIVE MARGIN ENVIRONMENTS

Carbonate Platforms
(Sylacauga Marble)

The development of modern shelf carbonates (and presumably ancient analogues) is largely the result of two environmental criteria -- the relative lack of clastic sedimentation and high rates of organic productivity (Seligman, 1979). In this view, the formation of a Paleozoic carbonate bank represents a profound transition in the tectonic development of the proto-North American continental margin. During this period, episodes of crustal rifting, abundant clastic sedimentation, volcanism and concomitant subsidence diminishes the suitability of those environ-
ments for significant accumulation of carbonates. The amelioration of the environment to enable formation of a carbonate bank signifies a stabilization of tectonism characteristic of passive continental margins.

Of the two varieties of carbonate shelves summarized by Sellwood (1979), the Cambro-Ordovician carbonates of proto-North America correspond more closely to a subtropical rather than a temperate environment. Following the correlation of units in the Sylacauga Marble Group with the Shady Dolomite, Rome Formation, Conasauga Formation and the Knox Group (Tull, 1985), a subtropical environment is proposed for the marbles of the Talladega Slate Belt. Although some subtropical carbonate banks develop on open, deeply submerged inclined shelves (e.g., the Yucatan), the shallow water facies proposed by Tull (1985) for the Sylacauga Marble Group are indicative of low energy environments typical of protected shelf lagoons (Sellwood, 1979).

ACTIVE MARGIN ENVIRONMENTS
Distal Volcanogenic Massive Sulfides
(Pyriton)

Similar to submarine volcanism associated with rift environments, volcanism related to active margins will also produce ore forming fluids through leaching of base and precious metals by convectively circulating seawater (see discussion for Stone Hill). If the exhaled ore solution is sufficiently dense, it may form a dense bottom brine and move considerable distances from its vent before finally accumulating in topographic depressions. It should be emphasized that the proximal versus distal aspect of the two sulfide localities on this field trip do not correspond to the rift versus active margins on which they formed. The same circumstances which are favorable for proximal volcanogenic massive sulfide mineralization may simultaneously produce distal volcanogenic mineralization regardless of the tectonic setting. The distinction between distal and proximal massive sulfide deposits is the lack of evidence regarding proximity to the submarine vent -- primarily the lack of stringer ore and footwall alteration zones.

Kyanite
(Turkey Heaven Mountain Kyanite)

The formation of kyanite during dynamothermal metamorphism may be divided into two questions -- first, which reactions produce the aluminosilicate phase and second, which polymorph (kyanite or sillimanite) constitutes that phase. The first question is relatively straightforward and involves reaction of phases which are common in pelitic material undergoing prograde metamorphism. Two such reactions are shown below (Winkler, 1976).

\[ \text{(I) muscovite + quartz + k-feldspar + A12Si05 + water} \]
\[ \text{= A12Si05 + liquid} \]
\[ \text{(for water pressure < 3.5 kb)} \]

Both of the reactions, above, involve the breakdown of muscovite in the presence of quartz. Application of these reactions to practical examples causes some paradoxes. For example, reaction I does not occur in pressure-temperature regime of kyanite and the aluminosilicate polymorph should be sillimanite. In contrast, reaction II does extend into the stability field of kyanite; however, the liquid generated by this reaction corresponds to anatetic melting of sediments which does not account for kyanite occurring in non-migmatitic metapelites (Winkler, 1976; Fig. 7-3).

The cause of this dilemma is probably related to the thermodynamic uncertainties of polymorphic transitions. Brown and Fyfe (1971) point out that entropies of these polymorphic transitions are less than 0.0004 k cal of their lattice energies. Therefore the slope of these reactions in pressure-temperature space, calculated by the Clausius-Clapeyron equation, are prone to very large errors. Such subtle energetic variations also enhance the effect that, otherwise, insignificant factors such as surface energy or impurities exert on the system.

In Granites and Related Pegmatites
(Two-Bit Tin Prospect -- Pegmatite Quarry)

During the peak of thermal metamorphism, partial melting of pelitic sedimentary material generates peraluminous silicic melts which are emplaced to form S-type granites. Incompatible elements (those which do not readily substitute into common silicate minerals) which are present in the sedimentary protolith may be incorporated into the melt either at the source of melting or they may be scavenged from the country rock as the melts rise. Intrusives (tin granites) that form from such melts will tend to be enriched in those elements, however, the incompatibility which enriched these elements in the initial melt also favors their further enrichment in the fractionating melt during crystallization. The eventual release of that residual water-rich liquid produces pegmatites characterized by unusual mineralogy.

The incompatible elements (e.g., Sn, Cl, F, Be, and Li) concentrated in the pegmatitic fluid are incorporated into minerals such as cassiterite, topaz, beryl, and lithium-bearing mica as the fluid cools and becomes saturated. Thus the formation of rare and semi-rare silicates and oxide minerals within these pegmatites requires special conditions to concentrate the incompatible elements into hydrothermal ore-forming fluids. In this case, the process of concentrating the incompatible elements proceeds in two stages. The elements are first extracted from their metasedimentary source by the formation and mobilization of granitic melts; then further concentrated by fractionation of the granitic magma and release of aqueous liquids to form the pegmatite bodies.
Talc (Winterboro Talc Deposit)

Talc is a hydrous magnesium silicate produced by alteration. It may be associated with serpentinization of peridotites provided the bulk composition of the peridotite is more silicic than serpentinite (Winkler, 1976). Those reactions are particularly sensitive to the availability of water and carbon dioxide to the system as illustrated in the reaction below:

(I) forsterite + water + carbon dioxide = talc + magnesite

From this reaction, it is reasonable to expect that talc may also result from alteration of siliceous dolomitic limestones as shown below (Winkler, 1976).

(II) dolomite + quartz + water + talc + calcite + carbon dioxide

Interestingly, the presence of carbon dioxide on the same side as talc in the second reaction means that abundant carbon dioxide inhibits the formation of talc from dolomitic limestones even though it favors the formation of talc during alteration of ferromagnesian silicates. In the case of sufficiently high carbon dioxide partial pressure, tremolite is produced rather than talc.

Usually, the first metamorphic mineral recognized for dolomitic limestone protoliths is tremolite. Although this could be attributed to excessive carbon dioxide (such that tremolite substitutes for talc in equation (II), above); Winkler (1976) suggests that metamorphic assemblages of talc + calcite + quartz and/or dolomite may be more common than usually realized due to petrographic misidentification of talc as white mica.

SUMMARY

The relevance of tectonics to metallogenesis is well accepted today even if the exact nature of that relationship is not always clear. Fortunately, the practical importance of mineral resources continue to stimulate study necessary for refinement of this knowledge. Very few topics in geology enjoy the scrutiny addressed to economic and sub-economic mineral deposits. Therefore, the preceding discussion should be viewed as an update of our understanding rather than a definitive conclusion. As further work justifies, the origin of these deposits (and criteria for locating more deposits) shall continue to be reviewed. Corresponding to those developments will be refinements in our understanding of the tectonic processes related to the origin and destruction of the Paleozoic continental margin represented by the crystalline rocks of Alabama.

ROAD LOG

<table>
<thead>
<tr>
<th>Mileage</th>
<th>Cumulative Interval</th>
<th>Day 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
<td>Start out from Towne Inn going north on U.S. 280</td>
</tr>
<tr>
<td>0.4</td>
<td>&quot;0.4</td>
<td>Turn left to go south on Talladega Co 29</td>
</tr>
<tr>
<td>1.5</td>
<td>1.1</td>
<td>Continue straight through 3-way stop sign</td>
</tr>
<tr>
<td>2.1</td>
<td>0.6</td>
<td>SYLACAUGA MARBLE STOP - gate 9 to Thompson Weimann marble quarry - turn around and go back north on Talladega Co 29</td>
</tr>
</tbody>
</table>

Stop 1. The Sylacauga Marble Deposits at Gantt's Quarry

G. M. Guthrie
Alabama Geological Survey
P. O. Drawer 0
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The marble deposits in the Sylacauga area represent one of the most important sources for relatively pure calcium carbonate marble in the country. Marble has been mined at Gantt's Quarry, Alabama since 1904 (Prouty, 1916). Early mining operations exploited the marble for use in the building and statuary stone industries (Prouty, 1916). During the last few decades, the emphasis on mining has changed from black marble to crushed stone. This forms a more diversified market for the rock types available in the region. The crushed stone is used in a variety of products, such as paints, plastics, fertilizer, building aggregate, and food. At the Moretti-Harrah quarries some stone is still mined in blocks for building/monument stone and cut into floor tile. The marble deposits are contained in the Gantt's Quarry Formation of the Sylacauga Marble Group (SMG).

The SMG is one of four groups which comprise the Talladega slate belt (Tull, 1982). The lower contact of the SMG with the Kahatchee Mountain Group (KMG) is interlayered and gradational while the upper contact with the Talladega Group (TG) is an unconformity (see Drummond and Guthrie, this volume; Tull, 1982). Five formations have been recognized in the SMG (Tull, 1985), in ascending order: (1) the Jumbo Dolomite; (2) the Fayetteville Phyllite; (3) the Shelvin Rock Church Formation; (4) the Gooch Branch Chert, and (5) the Gantt's Quarry Formation. The age of the SMG has long been debated due to a lack of fossils. Recently, Early Ordovician conodont elements were obtained from the Gants Quarry Formation along strike to the northeast (Harris and others, 1984). The age of the rest of the group is still based on lithostratigraphic similarities with units in the adjacent foreland fold and thrust belt. These units range in age from lower Cambrian to lower Ordovician and are thought to represent a distal extension of the Paleozoic carbonate bank sequence (Tull and Guthrie, 1985).
In the Sylacauga area, the SMG is exposed in a window beneath a crystalline thrust sheet containing the upper part of the KMG and the lower part of the TG (Guthrie, in preparation). At Gantt's Quarry, outcrop distribution and drill core data indicate that the SMG is folded into a megascopical D1 (Drummond and Guthrie, this volume), tight to isoclinal syncline with a faulted out overturned southeast limb. Dolomite and calcite marble in the Gantt's Quarry Formation define the structure. The white marble layer is located in the axial surface region of the syncline. An axial plane foliation is formed by chlorite and sericite layers. The maximum thickness of the marble appears to be found in Gantt's Quarry, with thickness thinning to the northeast and southwest. This thickness variation appears to be a result of ductile flow of the marble in the interior high strain area of the fold. Examples of ductile flow phenomena can be recognized in the walls of the Moretti-Marrah quarries. Dolomite marbles in the formation maintain a constant thickness throughout the fold due to their brittle behavior during deformation.

3.8 1.7 Turn left to go north on U.S. 280
5.5 1.7 Cross Kehatchee Mountain
6.0 0.5 Cross Talladega thrust fault into Foreland Fold and Thrust Belt
9.9 3.9 Enter Childersburg
11.7 1.8 Turn right to go east on Ala 76 going straight through 2 traffic lights and exit Childersburg
20.8 9.1 Continue past intersection with Talladega Co 139 on the right
20.9 0.1 WINTERBORO TALC MINE - turn off and park on first dirt road on the right past intersection with Talladega Co 139 - continue going east on Ala 76

Stop 2. Talc Deposits at Winterboro

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Alabama Geological Survey
P. O. Drawer O
University, Alabama 35486

At this stop, we will examine one of the abandoned surface mines in the Winterboro talc district. Talc mining began in this area in the early 1900's and continued sporadically until 1975 (Blount and Helbig, in review). At this time, there is no production from the mines, however, talc is still processed at nearby Alpine, Alabama. The Winterboro talc deposits were composed of talc with trace amounts of quartz + calcite + dolomite + pyrite. Because of the low mineral
impurity content of the deposits, they were especially suitable for use in the cosmetic and pharmaceutical industries (Blount and Helbig, in review).

The Winterboro talc deposits are located along the boundary between the foreland fold and thrust belt and the Talladega belt. Host rock for the deposit is a gray, crystalline dolomite which has been mapped as the lower Cambrian Shady Colomite (Shaw, 1970). The hills surrounding the dolomite and talc deposits are formed on phyllite and quartzite of the lower Cambrian Weisner and Middle Cambrian Rome Formations (Shaw, 1970). Tall and Guthrie (1986) have equated these three units with the Wash Creek Formation (of the Kahatchee Mountain Group), the Jumbo Dolomite and the Fayetteville Phyllite (both of the Sylacauga Marble Group).

Drill records from the old mining operations and geologic mapping indicate that the talc deposits are contained in zones oblique to bedding and some regional structure. A number of high angle reverse faults which repeat the stratigraphy have also been recognized in the area, but the deposits are localized along the frontal discontinuity separating the Weisner, Shady, Rome triplet from the adjacent foreland Ordovician carbonates. Mineral paragenetic sequences and textures are indicative of a reaction between the host dolomite and silica-rich hydrothermal fluids (Blount and Helbig, in review). The style, orientation, and associated mineralization of these zones indicate that they may have been related to the D2/M2 event which affected the Northern Alabama Piedmont (Drummond and Guthrie, this volume). The high angle faults which also affect the area appear to be related to a later deformation event.

- **Figure 8.** Location map to the Talc Deposits at Winterboro (Winterboro 7 1/2 minute quadrangle).

<table>
<thead>
<tr>
<th>Mile</th>
<th>Turn</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.0</td>
<td>1.1</td>
<td>Turn left to go north on Ala 21 at flashing red light</td>
</tr>
<tr>
<td>28.0</td>
<td>6.0</td>
<td>Sleeping Giants on left (held up by lower Cambrian Weisner Fm)</td>
</tr>
<tr>
<td>33.1</td>
<td>5.1</td>
<td>Turn left at light in Talladega and continue north on Ala 21</td>
</tr>
<tr>
<td>34.2</td>
<td>1.1</td>
<td>Turn right at stop sign</td>
</tr>
<tr>
<td>39.5</td>
<td>5.3</td>
<td>Turn right onto Talladega Co 96 toward Cheaha</td>
</tr>
<tr>
<td>43.6</td>
<td>4.1</td>
<td>Sign to Mt. Cheaha on right, turn right onto unnamed paved road toward Cheaha</td>
</tr>
<tr>
<td>57.6</td>
<td>14.0</td>
<td>Turn left at ranger station toward picnic area # 1</td>
</tr>
<tr>
<td>58.2</td>
<td>0.6</td>
<td>Turn left on to loop toward picnic area</td>
</tr>
</tbody>
</table>

LUNCH - after lunch, drive back to loop
Stop 3 - Stone Hill Copper Mine

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Department of Geology
Florida State University

The Stone Hill Copper Mine is a proximal volcanogenic massive sulfide deposit (Whittington 1982). The deposit is the only example of volcanogenic mineralization in Alabama to be profitably developed for copper. The other example of volcanogenic sulfide mineralization, Pyriton (discussed below) contains less copper and was developed for its sulfur potential. First opened in 1876, the operation at Stone Hill consisted of trenching along a trend indicated by a trace of cinder-like rhyolitic tuff, a residuum of sulfide ore ("gossan"). A supergene enriched ore called "black oxide" was recovered from the interval between the surface and the water table during this phase of activity. Based on descriptions by the miners and comparison with similar settings, the black oxide ore was probably chalcopyrite (reported assays of up to 30 wt % copper). This high-grade ore was exhausted within a few years and the operations at Stone Hill were abandoned until new owners installed water pumps in 1896 to enable recovery of the hypogene ore below the water table. Although of lower tenor than the black oxide ore recovered in the 1870's, the known reserves of "higher" grade hypogene ore (Cu > 1.0 wt %) exceed 193,000 tons (U.S. Bureau of Mines, 1945). Known reserves of lower grade ore (between 0.64 and 1.0 wt % Cu) are 583,000 tons (U.S. Bureau of Mines, 1946). The operations were abandoned a second time in 1899 and the mine has remained inactive ever since.

The ore zone is represented by an interval of hornblende-bearing felsic schist that is approximately 10 to 15 meters in thickness. Within that zone, are two distinct varieties of sulfide mineralization although both varieties contain the same sulfide mineralogy (pyrrhotite plus minor chalcopyrite and trace abundances of sphalerite). The first variety of ore is massive ore -- after which this category of sulfide deposits are named. This ore type is dominated by sulfide phases such that most samples are well over 90% sulfides and exhibit a distinct maroon color on weathered surfaces. The second variety of ore, called stringer ore, is felsic schist containing disseminated sulfides. Although the stringer ore is lower in total sulfide content than massive ore, its greater chalcopyrite content favored it as the copper ore recovered during the 1890's.

The most easily recognized tectonic fabrics in hand specimens is foliation in the stringer ore related to the first episode of metamorphism/deformation and the flattening of foliation around sulfide grains related to a second episode of metamorphism/deformation. On a regional scale, the structure of the deposit is dominated by large post-metamorphic east-southeast oriented recumbent synform causing the ore zone and the enclosing country rock to dip to the southeast. Based on the higher content of copper, relative to Zn, near the hanging wall, the occurrence of footwall alteration (represented by chlorite/tremolite schist) in the hanging wall, and regionally persistent trends of Ni and Cr, Whittington (1985, in press) concluded that the deposit is presently overturned.

The felsic zone of sulfide mineralization comprising the deposit at Stone Hill is peneconformable to the enclosing orthoamphibolite. Although the country rock is interpreted as a metamorphosed basalt of mid-ocean ridge chemical affinities (Whittington, 1982), the felsic schist comprising the ore zone does not indicate a felsic igneous protolith. Based on variable content of normative corundum or diopside among intimately associated core samples, this unit probably represents intensive metamictic/metamorphic basalt by the ore forming fluid during syngenetic mineralization.

A tectonic setting for mineralization of a back arc basin was proposed by Neathery and Hollister (1985), however, Whittington (1982, in press) found no indication of an arc setting for either the volcanic or sedimentary protoliths. Instead, a late stage of cratonic rifting was proposed by Whittington (1982) which resulted in superficial similarities between the deposit at Stone Hill and those formed in arc environments (Hutchinson, personal communication). Consistent with this earlier setting of mineralization proposed for a stabilizing continental margin was the isotopic data reported by LeHuray (1986) for the Stone Hill deposit indicative of Precambrian basaltic volcanism (650 Ma) associated with disturbance of the Pb systematics by a source of Grenville age (900 Ma).
91.7 0.3  Turn left on to unnamed paved road
91.9 0.2  Bear left to go west on Cleburne Co 10
92.6 0.7  Stratigraphic intercalation of meta-pelites within meta-basalt
94.9 2.3  Junction unmarked county road and Turkey Heaven Mountain road (gravel).

**LOCALITY A - BORROW PIT**
Proceed up Turkey Heaven Mountain road

95.2 0.3  Logging road to north, park, walk up road about 100 yards

**LOCALITY B - LOGGING TRAIL PITS**
Proceed from Stop B northeastward on Turkey Heaven Mountain road

95.5 0.3  Logging road to south, continue on main road
98.4 2.9  Logging road to east, continue on main road
98.5 0.1  Logging road to west, park along main road, walk west on logging road about 200 yards

**LOCALITY C - VEIN SITE AND PITS**

Stop 4.  Kyanite - Turkey Heaven Mountain, Cleburne County, Alabama

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Geological Survey of Alabama
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Tuscaloosa, Alabama 35486

The kyanite occurrences on Turkey Heaven Mountain were first described in 1873 in the field notes of E.A. Smith, State Geologist of Alabama. In 1939, Bowles described several kyanite prospects and openings along the mountain. Espenshade and Potter (1960) cataloged the Turkey Heaven Mountain deposits with other occurrences of kyanite in Alabama. Neathery (1965, 1967) studied the mineralogy and paragenesis of the Turkey Heaven Mountain deposits. Reynolds and Neathery (1982) reported on the economic potential of the Cleburne County deposits.

The kyanite appears to occur more frequently in the muscovite schist units of the Poe Bridge Mountain Metamorphic Suite than in the more graphitic units of the Poe Bridge Mountain or the Wedowee Metamorphic Suite which caps the mountain, although thick kyanite-bearing quartz veins occur in the graphite schist. The mineral assemblages characteristic of the Turkey Heaven Mountain deposits
includes kyanite, muscovite, rutile, ilmenite, quartz, pyrolusite, graphite, and minor amounts of potassium feldspar and albite. Kyanite in these deposits is often altered to paragonite mica. Degree of paragonite retrogression varies from traces to total replacement. This affects the quality of potentially mineable kyanite; the more paragonite, the less desirable the deposit.

Neathery (1967) suggested that the kyanite at Turkey Heaven Mountain may have been formed in place under conditions of stress metasomatism or may have been deposited from hydrothermal solution. The graphite units have been interpreted to have acted as a heat sink or CO₂-rich buffer during the formation of the kyanite coincident with regional prograde metamorphism (Neathery, 1967). Kyanite occurs associated with both late-stage quartz-muscovite-rutile-ilmenite feldspar veins similar to the Turkey Heaven Mountain deposits and as disseminated porphyroblasts in the aluminous schist of the Poe Bridge Mountain Metamorphic Suite. The total area underlain by rocks containing disseminated kyanite is large; however, the volume-percent of kyanite averages 0.5 but may increase to 2.0 locally. Saprolite samples from selected localities across the area, when washed, yield residual kyanite concentrations ranging up to 3 percent by volume (Reynolds and Neathery, 1982).

The areal extent of the kyanite district is generally well defined, but the extent of individual deposits is not known. Reserves cannot be estimated from present data. Although no economically mineable deposits of disseminated kyanite have been discovered, there is a possibility that small pockets of kyanite-rich rock occur in restricted areas of southern Cleburne County. Of more economic potential are the vein-type and porphyroblastic occurrences.

Four types of kyanite occurrences have been noted at and around Turkey Heaven Mountain:

1. As large crystals along foliation and fracture planes in the aluminous schist.
2. As large porphyroblasts of interlocking tabular crystals embedded along foliation planes.
3. In massive boulders several feet in diameter that are typically composed of interlocking tabular crystals with quartz and occasional rutile.
4. In kyanite-bearing quartz veins.

LOCALITY A) Road Junction-Borrow Pit - Approximately 10 years ago this area was stripped for fill material. When the ground was cleared, large kyanite crystals and small kyanite clusters were commonly visible in the saprolite. A recent visit to the site revealed abundant small, 1 inch or less, kyanite crystal fragments scattered in the soil. Most of the kyanite is gray to blue gray.

Figure 10: Location map to kyanite sites on Turkey Heaven Mountain, Cleburne County, Alabama (Rightower and Ross Mountain 7 1/2 minute topographic quadrangles.)
LOCALITY B) Logging Trail-Pits - Two prospect pits occur adjacent to the logging trail and both have kyanite. The smaller, shallow prospect pit is adjacent to the trail. The largest pit is about 10 yards east of the road. Boulders or domnicks of paragonite-altered kyanite were found at this locality in the mid-1960's. Several boulders can still be found but much of the kyanite has been removed. Prospect in the dump area.

LOCALITY C) Vein Site - This is the most famous area on Turkey Heaven Mountain for kyanite. This area was one of the original discovery sites in the 1800's. Located here are several small pits or trenches and two larger pits. Exposed in the largest pit are the remains of the kyanite-bearing quartz vein. As you can see, local rock hounds and mineral collectors have been busy. Good kyanite crystals can be recovered from the vein and also, specimens can be found in the dumps. Most of the kyanite at this locality is dark to light blue. Much of it shows paragonite alteration. It was from this location that Neathery (1965, 1967) recovered large pseudomorphs of paragonite after kyanite, some of which are currently on display at the museum of the Canadian Geological Survey in Ottawa, Ontario, Canada.

103.6 5.1 Return to Cleburne County Road 10 and turn west toward Micaville
108.4 4.8 Turn right to go north on U.S. 431
112.0 3.6 Hollis Crossroads - Turn left to go south on Ala 9 toward Lineville
130.3 18.3 Turn right to go north on Ala 49
135.3 5.0 Just beyond mile marker 65 turn left on to unnamed paved road
135.8 0.5 Turn right at stop sign across from Oak Grove Church
138.2 2.4 Turn left at stop sign
138.6 0.4 Turn right at Concord Church
139.5 0.9 Turn left and cross railroad tracks
139.6 0.1 PYRITON - pull off on to dirt road on the right - continue driving south toward Highland

Stop 5. National Pyrite and Copper Co. Mine, Pyriton District
S. H. Stow
Oak Ridge Laboratories
P. O. Box X
Oak Ridge, Tennessee 37830

Stop on Highway 77, cross the railroad tracks and walk down the small road in front of the first house on the right. Cross the creek and examine the outcrops at the base of the hill. The Hillabee Greenstone is less than 200 m thick here. This interval is dominantly laminated mafic phyllite and contains massive sulfides some 20 to 40 m above the top of the basin transition zone. The Hillabee outcrops in the bluffs on the south side of Mill Creek. These bluffs are capped by the Hollins Line fault.

The Pyriton sulfide deposits represent volcanogenic massive sulfides in the Hillabee Greenstone. Mining of these deposits occurred from the 1850's until 1919. This stop is at the old National Pyrite and Copper Co. mine. The Carpenter mine is located 2.3 km west along strike; other mines and prospect pits occur for at least 9 km westward.

At this mine in situ ore is poorly preserved. Good exposures of the mineralized zone can be found, however, along Mill Creek near the Carpenter mine west of the National Pyrite and Copper Co. mine. The gossan is well exposed at the mine entrance. The mineralized zone at this stop ranges from 0.3 to 7.1 meters thick. Historic accounts record 50- to 300-pound lumps of solid sulfides which were removed from the underground workings.

Good samples of massive sulfides can be found on the mine dumps. Most ore is banded with individual laminae of sulfides varying up to 6 cm thick. Sulfide laminae are interlayered with relatively barren mafic phyllite. Sulfide-rich layers occur in sharp contact with the barren phyllite. In addition, sulfides occur as disseminated euhedra of pyrite in mafic phyllite, in which they may constitute 40 percent of the rock. All gradations exist between the banded and disseminated ore. Pyrite is the most abundant sulfide and comprises generally at least 95 percent of the sulfides in the ore. Chalcopyrite, and rarely covellite, can be seen in hand specimens. Sphalerite and galena, which can be observed microscopically, are not recognizable in hand specimens. Cupferous oxidation products, such as malachite, are also found.

Caution should be used on the unstable mine dumps. Open shafts occur in the woods at the top of hill. Stay away from these areas.

140.3 0.7 Enter Highland and turn right on to Clay Co. 31 toward Ashland
147.6 7.3 Enter Ashland and bear right around court house through two traffic lights
147.7 0.1 Straight through third light to go south on Ala 9 toward Millerville

156.1 8.4 Enter Millerville and turn right to go west on Ala 148 toward Sylacauga

165.1 9.0 Nice vista - Greg might add comments here - photo stop if time allows

176.4 11.3 Enter Sylacauga and turn left at traffic light on Main St.

176.7 0.3 Turn right at stop sign on to Ft. Williams St.

178.4 1.7 Turn right at traffic light to go north on U.S. 280

179.7 1.3 Towne Inn on left

End of Day 1

Pyriton District

Figure 11. Location map to the National Pyrite and Copper Co. Mine, Pyriton District (Lineville West 7 1/2 minute quadrangle).
Day 2

0.0 0.0 Starting out from Towne Inn, go south on U.S. 280.
2.9 2.9 Exit from U.S. 280 to go south on U.S. 231 toward Rockford.
22.2 19.3 Enter Rockford and turn right to go west on Ala 22 - possible car park location.
23.7 1.5 Turn left on to dirt road just before mile marker 96.
23.8 0.1 Bear right at fork in road toward landfill.
24.1 0.3 Bear right at fork in road (last good point for bus to turn around).
24.5 0.4 Two Bit Tin Mine - 0.1 mile north of dirt road walking out ridge that meets the road 100 yards before gate to landfill - turn around and drive back toward Ala 22.

Stop 1. Two Bit Tin Prospect, Coosa County, Alabama

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The Two Bit Prospect (prospect #28 of Hunter, 1944) is within the NE 1/4 of Section 22, T.22N., R.18E., approximately 4 km west from Rockford via Alabama Highway 22. The property was explored by shallow trenches, diamond drilling and underground bulk sampling during the World War II era (Reed, 1960). Some relatively high-grade material encountered during this work was processed through the tin mill that was operated on an experimental basis a few kilometers west of Rockford during this same period. The mineralogy of the prospect was described by Cook (1974). The prospect area was evaluated in detail during exploration that resulted in the discovery of the McAllister Sn-Ta deposit approximately one kilometer to the northeast and is presently one of a series of tin occurrences being examined by graduate students at the University of Alabama.

The Two Bit Prospect consists of a small ellipsoidal plug-like body of pegmatite and several associated pegmatite dikes. In outcrop, the plug-like mass is generally elongate in a northerly direction and is hosted by locally graphitic Wedowee Group metasediments. The pegmatite tie only a short distance west of the Rockford Granite-Wedowee contact. Relatively aluminous zones within the host Wedowee metasediments contain sericitized andalusite porphyroblasts near the Rockford Granite contact in the Two Bit area.

The Two Bit plug-like pegmatite is not zoned in the classical sense, but exhibits irregular, generally parallel, north-trending compositional bands highlighted by locally abundant albite aplite. Other zones are more typical quartz-k-feldspar-mica pegmatite while still others zones are characterized by smoky quartz-white mica, giant potash feldspar crystals, or equigranular quartz-mica rock. The exploration shaft near the south end of the plug encountered rather typical, locally cassiterite-rich, quartz-feldspar-white mica pegmatite as suggested by dump material immediately west of the plug outcrop. Prospect trenches southeast and northwest of the plug-like pegmatite cut narrow unzoned (though cassiterite-bearing) pegmatites typical of the Rockford Granite roof zone complex.

The mineralogy of the Two Bit pegmatite "plug" is complex and has been the focus of field trips by various amateur and professional groups, primarily due to the presence of a rather wide array of secondary phosphate minerals. These phosphates have apparently resulted from a series of complex reactions involving the decomposition of primary triplite and apatite by acid waters generated by the weathering of small amounts of iron sulfide minerals in both the pegmatite and immediately adjacent schist. The suite of secondary phosphates includes rockbridgeite-fromelite, hetersote-purpurite, phosphosiderite, laueite, strunzite, beraunite, stewartite, and carbonate apatite. The presence of pocket-like concentrations of secondary phosphates is usually marked by the abundance of purple phosphosiderite crusts. Aunutite is locally conspicuous as minute plates that are brilliant-green fluorescent under short-wave ultraviolet light. Small tabular columbite crystals are locally common in granular albite aplite. Small anhedral masses of blue-green manganapatite and subhedral pink spessartine garnet are locally conspicuous in the fresh albite aplite of the main pegmatite plug.

Although this location is one of the best documented and most interesting of the Coosa County tin occurrences, megascopically identifiable cassiterite is surprisingly rare in the presently exposed part of the plug-like pegmatite mass. Cassiterite-rich dump samples suggest that the mineral occurs as coarsely crystalline, coffee-brown crystals up to 3 cm in length intergrown with equigranular quartz-mica aggregates. Crystal surfaces are generally wavy and are commonly coated with a thin film of fine-grained white mica. Some crystals are shattered with internal fractures filled with similar mica.

Additional interesting mineral occurrences are in the immediate Two Bit Prospect and vicinity. Beryl crystals up to 0.5 meter in length, some containing gem quality green areas, have been found in the southwest side of the present Coosa County landfill approximately 1.0 km southwest of the Two Bit Prospect. Colorless and white cesium beryl and black anhedral tantalite, tantalowedgeite, and tapiolite occur in soil over filled trenches at the McAllister Sn-Ta prospect immediately adjacent to Alabama Highway 22, approximately 600 meters northeast of the Two Bit Prospect. Gold can be panned from the creek flowing under Alabama Highway 22 approximately 400 meters north-northeast of the Two Bit Prospect.
Two Bit Tin Prospect

Figure 12. Location map to the Two Bit Tin Prospect, Coosa County, Alabama (Flag Mountain and Rockford 7 1/2 minute quadrangles).

24.9 0.4 Continue toward Ala 22, bearing left where dirt road joins from the right forming a fork
25.2 0.3 Bear left at stop sign
25.3 0.1 Turn left to go west on Ala 22
25.5 0.2 Beryl locality on hillside to the left
25.6 0.1 Tourmaline locality before driveway on right
32.0 6.4 Continue west on Ala 22 through flashing yellow light
39.0 7.0 Cross Coosa River and enter Chilton County
39.2 0.2 Mitchell Dam Amphibolite Stop - park on right - turn around to go east on Ala 22

Stop 2. Mitchell Dam Amphibolite - Alabama Tin Belt

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The Mitchell Dam Amphibolite is among the best exposures of medium to high metamorphic grade mafic rocks in the southern Appalachians. The amphibolite host is the Higgins Ferry Group (Neathery, 1975) of the Ashland Supergroup (Tull, 1978). The Ashland Supergroup contains a very thick (3-5 kilometers), diverse sequence of graphitic, garnetiferous and/or manganiferous schists, quartzites, and concordant amphibolite units, of which the Mitchell Dam is structurally the upper-most unit. The age of the Higgins Ferry Group is probably late Precambrian.

The Mitchell Dam Amphibolite at this stop is a sequence of medium to coarse-grained thinly banded and foliated orthoamphibolite. The amphibolite is composed predominantly of green to black hornblende and plagioclase (An10 to An50) in almost equal proportions, with relict augite common in the cores of hornblende crystals. Most of the plagioclase occurs as thin discontinuous bands 1 to 12 mm thick. Accessory phases include epidote, actinolite, chlorite, garnet, paragonite, quartz, and sphene. Epidote occurs principally as an alteration product of a plagioclase consuming reaction associated with a retrograde metamorphic event. Because of a consistent concordant relationship with the host metasediments, the Mitchell Dam Amphibolite has been interpreted to be metamorphosed basalt flows which erupted during late Precambrian rifting and became intercalated with sediment. These rocks were later affected by Devonian metamorphism to produce the present relationships.
Calc-silicate pods of diopside, grossular garnet, plagioclase, epidote, and sphene occur as isolated fold noses within the amphibolite. These are especially well-exposed in a quarry near the west bank of the Coosa River. These calc-silicate pods probably are the metamorphosed equivalents of a marl protolith. The calc-silicate layers were affected by an intense folding which isoclinal repeated the layers and transposed the compositional horizons producing the thickened fold hinges and attenuated fold limbs.

Located on the east bank of the Coosa River along Alabama Highway 22 is an excellent exposure of amphibolite that contains a rather spectacular low angle fault. The fault can be identified as a sinuous zone of cataclastic material above drag folds in the footwall. Proximal to the upper end of the roadcut, the amphibolite has been retrograded to an actinolite-rich rock. The actinolite occurs as slender prismatic yellow-green to pale blue-green crystals and comprises up to 80 percent of the rock.

39.7 0.5 Amphibolite/Brittle Deformation Stop - exposed in road cuts on both sides of Ala 22
46.3 6.6 Turn right at flashing yellow light to go south on Coosa Co 29
47.9 1.6 Turn left to go east on Coosa Co 14
48.4 0.5 Continue on Coosa Co 14 through 4-way intersection at Richville
52.4 4.0 Mica Mine Stop - pull off on to shoulder of road, mine located 20 yards south of road - continue east on Coosa Co 14

Stop 3. Mica Mine

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This stop exhibits the remnants of an abandoned mica mine; the rock that was mined at this locality is one of the Rockford-type pegmatite bodies. These pegmatites were mined primarily for muscovite and kaolinite which can still be easily found at this locality. The pegmatites, which are Devonian in age, were intruded into metasedimentary rocks of the late Precambrian Wedowee Group and are late-stage fractionation products of the Rockford Granite. The muscovite found at this stop commonly occurs in large "books" approximately 3 cm in diameter and several cm in thickness. The kaolinite can easily be recognized because of its bright white color and is ubiquitous throughout the mine area. Occurrences of beryl and tourmaline have been recognized in and around the mine, the tourmaline

Figure 13. Location map to the Mitchell Dam Amphibolite (Mitchell Dam 7 1/2 minute quadrangle).
often weathering to a very dark saprolite which contrasts well with the kaolinite-rich weathered pegmatite. Beryl crystals are relatively rare but may be found as blue-green euhedral crystals up to 10 cm in length. These crystals are highly resistant to weathering effects and when found usually prove to be excellent specimens.

54.5 2.1 Turn left to go north on U.S. 231 toward Rockford
59.8 5.3 Enter Rockford and continue north on U.S. 231
79.1 19.3 Approaching Sylacauga, go north on U.S. 280
82.0 2.9 Towne Inn on left

End of Day 2

Figure 14. Location map to the Mica Mine (Richville and Rockford 7 1/2 minute quadrangles).
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