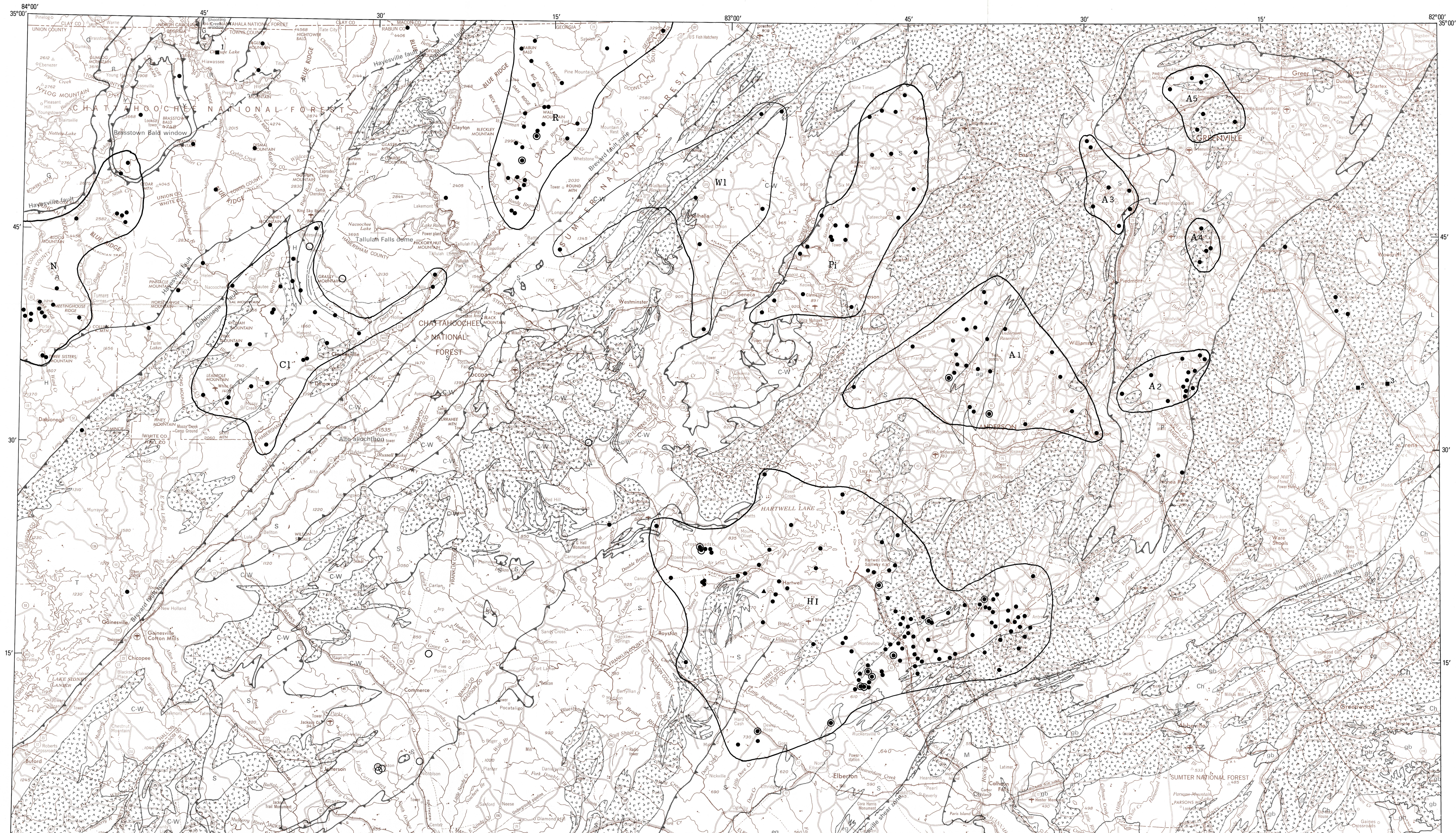
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF–2198–D



Base from U.S. Geological Survey, 1954 (limited revision, 1964)
Transverse Mercator projection

SCALE 1:250 000
DATUM IS MEAN SEA LEVEL

Geology modified from Nelson and others (1987, 1989)

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MAP SHOWING MICA PEGMATITES AND PEGMATITE DISTRICTS IN THE GREENVILLE 1° × 2° QUADRANGLE

EXPLANATION

[Pegmatite localities are plotted from Sloan (1908), Galpin (1915), Sterrett (1923), Furcron and Teague (1943), Teague and Furcron (1948), Georgia Department of Mines, Mining, and Geology (1951), Griffitts (1953), Heinrich and Jahns (1953), Olson and Griffitts (1953), Furcron (1959), Overstreet and Bell (1965a, b), and K.H. Teague (unpub. report in files of the Division of Geology, State Development Board, South Carolina. Many locations are only approximate]

- Generalized boundary of pegmatite district
- Mica pegmatite—Outside known pegmatite district
- Mica pegmatite containing beryl
- Beryl occurrence in pegmatite or quartz vein
- Flake-mica deposit
- Large deposit of vein quartz—1, Bell Mountain, Ga.; 2, Big Knob, S.C.; 3, Little Knob, S.C.

Pegmatite district

N	North Georgia
R	Rabun
Cl	Clarkesville
Wl	Walhalla
Pi	Pickens
HI	Hartwell–Iva
A1, A2, A3, A4, A5	Anderson–Greenville—Consists of five unnamed districts

LIST OF MAP UNITS AND SYMBOLS
[Stacking order of thrust sheets]

Blue Ridge thrust stack

T	Tallulah Falls thrust sheet
R	Richard Russell thrust sheet
Y	Young Harris thrust sheet
H	Helen thrust sheet
G	Great Smoky thrust sheet

Inner Piedmont thrust stack

L	Laurens thrust sheet
P	Paris Mountain thrust sheet
S	Six Mile thrust sheet—Includes the metagabbro at Anderson (Paleozoic?) (ag) and the Elberton Granite (Mississippian) (eg)
C-W	Chauga–Walhalla thrust complex

Southeast of Lowndesville shear zone

Ch	Charlotte thrust sheet—Includes the Concord Plutonic Suite (Silurian and Devonian) (gb) and the granitic rocks at Coronaca (as used by Fullagar and Butler, 1979; Permian) (cg)
M	Mafic–ultramafic thrust sheet

Granite, granodiorite, quartz diorite, and diorite gneiss, undivided (Pennsylvanian to Cambrian)—Shown mostly where rocks cover large areas or where tectonic boundaries are obscured

Contact

Thrust fault—Dashed where inferred; queried where uncertain. Sawteeth on upper plate

Shear zone

Kyanite schist—Queried where uncertain. Shown around Tallulah Falls dome

DISCUSSION

INTRODUCTION

Mineral resources of the Greenville 1° × 2° quadrangle, South Carolina, Georgia, and North Carolina, were assessed between 1984 and 1990 under the Conterminous United States Mineral Assessment Program (CUSMAP) of the U.S. Geological Survey (USGS). The mineral resource assessments were made on the basis of geologic, geochemical, and geophysical investigations and on the distribution of mines, prospects, and mineral occurrences reported in the literature.

This report is an assessment of the minerals associated with mica pegmatites in the Greenville quadrangle. It is based on the geology as mapped by Nelson and others (1989), on field studies conducted from 1952 to 1962 by the USGS for the Defense Minerals Exploration Administration (DMEA) and the concurrent examination of many of the known mica mines and prospects in Georgia, and on the published geologic literature and an unpublished report by K.H. Teague on file with the South Carolina Development Board, Division of Geology, in Columbia, S.C.

GEOLOGIC SETTING

The Greenville 1° × 2° quadrangle extends from the Blue Ridge province in the northwest corner to the Piedmont province in the southeast corner (fig. 1A). In the Valley and Ridge province of the southern Appalachians west of the Greenville quadrangle, it has long been known that westward-transported thrust sheets are the dominant structural elements (Rodgers, 1970, p. 39–59). Recent work has shown, however, that the same structural style also dominates the crystalline rocks east of the Valley and Ridge (Cook and others, 1979; Harris and others, 1981). Previously, the rocks of the Greenville quadrangle were described as parts of the Blue Ridge, Inner Piedmont, Kings Mountain, Charlotte, and the Carolina slate belts (fig. 1B; King, 1955; Overstreet and Bell, 1965a, b; Hatcher, 1972).

The Greenville quadrangle contains metamorphosed crystalline rocks of mostly Late Proterozoic to Paleozoic age in 11 westward-transported thrust sheets (fig. 2), each having a characteristic rock assemblage (Nelson and others, 1989). In ascending stacking order, the Great Smoky, Helen, Young Harris, Richard Russell, and Tallulah Falls thrust sheets form the Blue Ridge thrust stack northwest of the Brevard fault zone. The Inner Piedmont thrust stack, southeast of the Brevard fault zone, contains, in ascending order, the Chauga–Walhalla thrust complex and the Six Mile, Paris Mountain, and Laurens thrust sheets. The Lowndesville shear zone separates the Inner Piedmont thrust stack from the Charlotte thrust sheet and a separate mafic–ultramafic thrust sheet.

Rocks of all the thrust sheets are polydeformed and polymetamorphic (Nelson, 1988, p. 11). Many rocks of the Blue Ridge and Inner Piedmont thrust stacks are at medium to high metamorphic grade in the kyanite or sillimanite zone (fig. 3). The Charlotte and mafic–ultramafic thrust sheets are generally of low to medium grade. Nelson (1988, p. 9–11), in summarizing the timing of regional metamorphism, recognized separate metamorphic events at 470 to 430 million years ago (Ma) for the thrust sheets west of the Dahlonega thrust fault, about 365 Ma for the Tallulah Falls and Six Mile thrust sheets, about 365 or possibly 430 to 410 Ma for the Chauga–Walhalla thrust complex, about 344 Ma for the Paris Mountain and Laurens thrust sheets, and 338 to 312 Ma for the Charlotte and mafic–ultramafic thrust sheets. Granitic masses in most of these thrust sheets appear to be generally pre- or synmetamorphic. Exceptions include the Elberton Granite in the Six Mile thrust sheet, which is dated at 350 to 320 Ma (Ross and Bickford, 1980, p. 52; Whitney and others, 1980, p. 63), and the granite at Coronaca in the Charlotte thrust sheet, which is 278 Ma (Fullagar and Butler, 1979, p. 169).

Rocks of the Blue Ridge Thrust Stack

Great Smoky Thrust Sheet

The Great Smoky thrust sheet in the northwest corner of the Greenville quadrangle consists chiefly of metamorphosed conglomerate, sandstone, and shale of the Great Smoky Group, which is part of the Ocoee Supergroup of Late Proterozoic age (Nelson and others, 1989). These rocks are overlain in a small area of a few acres in the northwest corner of the quadrangle by the Nantahala Slate of Cambrian age. Farther southeast, rocks of the Great Smoky thrust sheet are also exposed below the Hayesville fault in the Brasstown Bald and Shooting Creek windows, which are areas eroded through the Richard Russell and Young Harris thrust sheets (fig. 2). Unlike the other thrust sheets to the southeast, the Great Smoky thrust sheet contains no recognizable igneous or metaigneous rocks in the Greenville quadrangle other than a few small mica-pegmatite bodies of metamorphic origin that are found where the rocks have reached kyanite or sillimanite metamorphic grade.

Helen Thrust Sheet

The Helen thrust sheet contains a variety of metamorphosed interlayered sedimentary and volcanic rocks of Late Proterozoic and (or) early Paleozoic age (Nelson and others, 1989). These rocks include siltstone, sandstone, shale, and chemically deposited sedimentary rocks and mafic to felsic tuffs, flows, and intrusive bodies, which are now micaceous and quartzofeldspathic gneiss and schist, quartzite, iron- and manganese-rich quartz schist, amphibolite, metagabbro, granitic to dioritic gneiss, and metatrondhjemite (Cook and Burnell, 1986). Rocks of the Helen thrust sheet overlie rocks of the Great Smoky thrust sheet along an unnamed fault zone southwest of the Greenville quadrangle (Nelson, 1991). The Dahlonega fault forms the boundary between the Helen thrust sheet and the Tallulah Falls thrust sheet to the southeast.

Young Harris Thrust Sheet

A complex of mafic and ultramafic rocks makes up the relatively thin Young Harris thrust sheet, which lies between the Great Smoky and the Richard Russell thrust sheets and is exposed only in narrow belts around the Brasstown Bald and Shooting Creek windows (fig. 2) in the northwestern part of the quadrangle (Nelson and others, 1989). The complex includes masses of gabbro, troctolite, pyroxenite, talc schist, eclogite, wehrlite, and amphibolite; it may, in part, represent a tectonic melange. The age of these rocks, which may be Late Proterozoic or early Paleozoic, is not well established. All the other thrust sheets above the Great Smoky thrust sheet also contain a variety of rare ultramafic and mafic rocks, commonly as small discontinuous pods but locally as larger mappable units.

Richard Russell Thrust Sheet

Metasandstone, quartzofeldspathic gneiss, metagraywacke, biotite gneiss, mica schist, and lesser amounts of amphibolite, together with granitic gneiss, granodiorite gneiss, and granitic pegmatite make up most of the Richard Russell thrust sheet (Nelson and Gillon, 1985). The metamorphic rocks are mostly Middle Proterozoic in age, but some metagabbro and quartz dioritic to tonalitic gneiss in this thrust sheet may be of early Paleozoic age (Nelson, 1988; Nelson and others, 1989). This thrust sheet overlies parts of the Helen and Great Smoky thrust sheets along the Hayesville thrust fault.

Tallulah Falls Thrust Sheet

The Tallulah Falls thrust sheet contains interlayered and folded metagraywacke, mica schist, amphibolite, aluminous schist, quartzite, biotite gneiss, biotite schist, quartzofeldspathic gneiss, amphibolite, and several types of granitoid rock (Nelson and others, 1989). Most of the rocks are of Late Proterozoic to early Paleozoic age except for two masses of granitic gneiss of Middle Proterozoic age. This thrust sheet is bounded to the southeast by the Brevard fault zone.

Rocks of the Inner Piedmont Thrust Stack

Chauga–Walhalla Thrust Complex

The Chauga–Walhalla thrust complex of Nelson and others (1987), which contains smaller thrust sheets separated by poorly defined thrust faults or tectonic slides, trends northeastward across the quadrangle immediately southeast of the Brevard fault zone. This thrust complex includes rocks assigned by Hatcher (1972) to the Chauga belt and by Griffin (1969) to his Walhalla nappe. Abundant amphibolite, especially in the Walhalla nappe, is interlayered with various types of quartzofeldspathic and micaceous gneiss and schist, metasandstone, metasiltstone, carbonate rocks, quartzite, phyllonitic schist, and pegmatite of Late Proterozoic to early Paleozoic age in the complex.

Six Mile Thrust Sheet

Rock units consisting of various combinations of mica schist, sillimanite schist, manganiferous schist, felsic gneiss, amphibolite, quartzofeldspathic gneiss, megacrystic biotite gneiss, metagraywacke, quartzite schist, and quartzite of Late Proterozoic to early Paleozoic age are widespread in the Six Mile thrust sheet (Nelson and others, 1989). A distinctive quartz-garnet rock (gondite) and various types of mostly Paleozoic plutonic gneiss, pegmatite, and quartz veins also are found in this thrust sheet, which structurally overlies the Chauga–Walhalla thrust complex.

Paris Mountain Thrust Sheet

The Paris Mountain thrust sheet consists chiefly of sillimanite schist, quartzite, and amphibolite of Late Proterozoic to early Paleozoic age, and granitic gneiss of Paleozoic age (Nelson and others, 1989). It has been thrust over the Six Mile thrust sheet.

Laurens Thrust Sheet

The principal rock types of the Laurens thrust sheet are layered biotite gneiss, amphibolite, hornblende gneiss, mica schist, and sillimanite schist, interlayered with lesser amounts of marble and magnetite-bearing quartzite, all of Late Proterozoic to early Paleozoic age (Nelson and others, 1989). Also included are Paleozoic granitic and granodioritic gneiss. The Laurens thrust sheet structurally overlies the Six Mile and Paris Mountain thrust sheets (Art Nelson, USGS, written commun., 1990).

Rocks Southeast of the Lowndesville Shear Zone

Mafic–Ultramafic Thrust Sheet

A melange of probable Late Proterozoic to early Paleozoic age that contains fragmental ultramafic and mafic rocks in a quartzofeldspathic matrix together with several different-sized granitic bodies of Paleozoic age is near the south border of the Greenville quadrangle southeast of the Lowndesville shear zone (Nelson and others, 1989). This melange, which is at least partly equivalent to the Juliette melange of Higgins and others (1989), may represent a separate thrust sheet. To the northeast, these rocks are bordered by the volcanic-arc assemblage of the Charlotte thrust sheet. The boundary between the melange and the volcanic arc has not been observed but is inferred to be a thrust fault.

Charlotte Thrust Sheet

Metamorphosed volcanic and related sedimentary rocks of Late Proterozoic to early Paleozoic age, together with plutonic rocks of Paleozoic age, make up a volcanic-arc assemblage, which may or may not represent a distinct thrust sheet or thrust complex (Nelson and others, 1989). These rocks have been traditionally included in the Kings Mountain belt, Charlotte belt, and Carolina slate belt (fig. 1B; King, 1955; Overstreet and Bell, 1965a, b). The rocks include metatuff, amphibolite, phyllite, quartzite, greenstone, biotite gneiss, biotite schist, quartzofeldspathic gneiss, mica schist, and various types of granitoid gneiss. The Charlotte thrust sheet also has relatively unmetamorphosed mafic igneous complexes of Paleozoic age that range in composition from gabbro to syenite and diorite (Butler and Ragland, 1969). The Charlotte volcanic-arc assemblage and the adjacent melange complex overlie rocks of the Six Mile and Laurens thrust sheets along the Lowndesville shear zone.

GRANITIC PEGMATITES

Granitic pegmatites are light-colored, coarse-grained igneous rocks, which have the composition of granite to granodiorite and are commonly found as dikes or sills in amphibolite-grade or higher grade metamorphic rocks or in large granitic intrusions. Individual mineral grains and crystals range in length from less than 1 in. to more than 40 ft, and a large variation in grain size within a single pegmatite body is common.

The deposits range from small pods and thin seams to large masses tens of feet thick and hundreds of feet long. In general, they are tabular or lenticular bodies and may pinch and swell either along strike or downdip, or both. Where pinch-and-swell structure is pronounced, the pegmatite body may appear to be a series of lenses that follow a narrow zone in the metamorphic rock. Most lenticular bodies are discoidal and have one axis shorter than the other two, but some have one axis much longer and are best described as pipelike.

Granitic pegmatites have been classified by Černý (1982, p. 1–2) and Černý and Meintzer (1988, p. 171) according to depth of formation into (1) miarolitic pegmatites formed at shallow depths of 1 to 2 mi, (2) rare-element pegmatites formed at intermediate depths of 2 to 4 mi, (3) mica or muscovite pegmatites formed at depths of 4 to 7 mi, and (4) abyssal pegmatites formed at depths of more than 7 mi. Miarolitic pegmatites are the pods formed in cavities in the upper parts of epizonal granites intruded into low-rank metamorphic rocks. They contain piezoelectric quartz crystal, optical fluorite, gem-quality beryl, topaz, and other exotic minerals. Rare-element pegmatites contain elements such as Li, Rb, Cs, Be, Ta, Sn, and Nb and are generated by fractional crystallization of granite magma. Mica pegmatites contain minimal, if any, rare-element minerals but may have extensive muscovite and feldspar resources. They may be the direct product of partial melting of metasedimentary and metavolcanic rocks in the crust, a process called anatexis, or be related to anatectic granites. Abyssal pegmatites form in granulite-facies metamorphic rocks and contain no economic concentrations of minerals. They commonly grade into migmatite and have no obvious granitic source. Of these four types, only mica pegmatites are found in any abundance in the Greenville quadrangle.

MICA-PEGMATITE DEPOSITS

Mica or muscovite pegmatite forms as synmetamorphic intrusive rock in medium- to high-grade (Barrovian series) metamorphic belts and is widely distributed in the Blue Ridge and Piedmont provinces of the southern Appalachians. Six out of 26 described pegmatite districts in the southeastern United States (Lesure and Shirley, 1968) are wholly or partly in the Greenville quadrangle (fig. 4). Little geologic study has been done on these deposits since the World War II USGS pegmatite studies (Parker, 1950; Jahns and others, 1952; Griffitts, 1953; Olson and Griffitts, 1953). Earlier studies by Sterrett (1923), Galpin (1915), and Furcron and Teague (1943) gave important details on deposits mined earlier and now no longer accessible.

Deposits of mica pegmatite in the Greenville quadrangle are found in all the thrust sheets in the Blue Ridge and Inner Piedmont thrust stacks (fig. 5). No mica pegmatite has been reported in the Charlotte or mafic–ultramafic thrust sheets. The pegmatite bodies are generally restricted to areas where metamorphic conditions are of kyanite grade or higher, but the distribution throughout these high-grade metamorphic belts is uneven.

Mica pegmatites in the Greenville quadrangle are light-colored, coarsely crystalline igneous rocks composed mostly of quartz, oligoclase, perthite, and muscovite. Accessory minerals include biotite, garnet, and apatite. Tourmaline and beryl are rare and generally limited to just a few crystals in any one deposit. In pegmatites that have been mined, crystals of muscovite, commonly termed "books," generally constitute 2 to 6 percent of the rock mined. Local rich shoots or pockets might have as much as 40 percent muscovite, but large volumes of pegmatite have 2 percent or less.

In many mica pegmatites, the minerals are more or less evenly distributed throughout, but, in others, the minerals are segregated into certain layers or parts of the body called zones (Cameron and others, 1949; Norton, 1983). In general, the zones are successive shells, complete or incomplete, that commonly reflect the shape or structure of the whole pegmatite body. Where best developed, the zones are concentric about an innermost zone or core, followed by one or more intermediate zones, a wall zone, and finally an outermost border zone. These zones are important economically where they can be mined selectively to recover desired minerals by hand-sorting. Muscovite is generally concentrated in the wall zone or along the margin of a quartz core; perthite, important for ceramic uses, is concentrated in the intermediate zones or in the core.

None of the mica-pegmatite bodies in the Greenville quadrangle have been dated. Some similar pegmatites in the Blue Ridge thrust stack of North Carolina range in age from 520 to 260 Ma (Lesure, 1968, p. 9–10). An age of 375 Ma for the Spruce Pine pegmatites was suggested by Hadley and Goldsmith (1963, p. 107), and an age of 400 Ma was suggested by Kish and others (1976). Pegmatites in the Bryson City district may be older, about 440 Ma. Pegmatites in the Blue Ridge thrust stack of the Greenville quadrangle (fig. 2) are probably about the same age as those in the Blue Ridge of North Carolina; pegmatites in the Inner Piedmont thrust stack may be a little younger.

Previous studies that have increased the general knowledge of the occurrence, origin, and economic importance of mica-pegmatite deposits include Cameron and others (1949), Jahns (1955), and Černý (1982). Studies made during World War II that have helped improve techniques of mica prospecting and exploration include Jahns and Lancaster (1950), Jahns and others (1952), and Norton and Page (1956). Today the high cost of hand labor limits the economic potential of most pegmatite deposits in the United States.

MINERAL COMMODITIES RELATED TO MICA PEGMATITE AND GRANITE

Feldspar, mica, and quartz, where the rocks are fresh, and kaolin, mica, and quartz, where the rocks are weathered to saprolite, are the only mineral commodities of economic importance related to mica pegmatite and granite in the Greenville 1° × 2° quadrangle. Other economically important pegmatite minerals, such as beryl, columbite–tantalite, spodumene, and uranium and rare-earth minerals are uncommon, rare, or nonexistent in the type of mica pegmatite commonly found in the Greenville quadrangle.

Feldspar

Producers and consumers know feldspar as a beneficiated mixture composed of feldspar minerals, less than 5 percent to more than 20 percent quartz, and traces of other minerals. Perthite or perthitic microcline (potash spar), albite (soda spar), and oligoclase (soda-lime spar) are the principal types of feldspar mined. Feldspar is used principally in glassmaking as a source of alumina and alkali to enhance workability of molten glass and to provide chemical stability to inhibit devitrification. It is also used in ceramic mixtures as a flux, and minor amounts are used as abrasives in soaps and as fillers in paint, rubber, and plastics. In 1986 nearly 54 percent of the feldspar mined in the United States was used in glass, 46 percent in pottery, and less than 1 percent in other uses (Potter, 1988, p. 367). Most of the feldspar currently used in the United States is obtained from granitic rocks by open-pit mining methods and concentrated by flotation processing. Flake mica and quartz are potential byproducts. North Carolina is the major producing State and has for many years produced one-half or more of the United States feldspar. In recent years, California, Connecticut, Georgia, South Carolina, and South Dakota have been the other important feldspar producers.

Within the Greenville quadrangle, a small amount of feldspar has been produced from at least one pegmatite in Rabun County, Ga. (Furcron and Teague, 1943, p. 151–153), and feldspar has been prospected for in several pegmatite bodies in South Carolina (Sloan, 1908, p. 142–149). The resources of feldspar in pegmatite in the Greenville quadrangle are small (Lesure and others, 1968, p. 280).

The significant feldspar production in Georgia has been from granite and pegmatite in De Kalb, Greene, and Jasper Counties, 20 to 50 mi south of the Greenville quadrangle; production in South Carolina has been from a granite quarry near Pacolet in Spartanburg County, 13 mi east of the quadrangle, where the fines from the quarry are used as mill feed for the flotation recovery of feldspar (Eddy and others, 1972). Neal and others (1973) have found that feldspar concentrates from some granite and granitic gneiss from the Blue Ridge and Inner Piedmont thrust stacks in North Carolina just north of the Greenville quadrangle are suitable for use in glass and ceramic manufacture. Many of the large granite and granitic gneiss bodies in the Inner Piedmont and Blue Ridge thrust stacks in the Greenville quadrangle are similar in age, composition, and geologic setting to those studied by Neal and others (1973) and are, thus, probably potential sources of feldspar. Total resources of feldspar, mostly in granite and granitic gneiss and to a lesser extent in pegmatite, are large in the Greenville quadrangle because of the abundance and large volume of these rocks (see map).

Mica

The principal mica minerals recognized commercially are muscovite (white mica), biotite (black mica), and phlogopite (amber mica). All have a perfect basal cleavage and form crystals (books) that can be split into thin sheets that have various degrees of transparency, toughness, flexibility, and elasticity. Muscovite is the most important commercially in the United States, but some biotite has been mined. Commercial phlogopite comes from Canada and Madagascar.

Two types of mica are sold: sheet and scrap or flake. Sheet mica is mined only from coarse-grained mica pegmatite. The mica must be relatively flat, free from most defects, and large enough to be cut into pieces 1 in.[2] that have a minimum dimension of 0.75 in. on one side. Small sheets of untrimmed mica of poorer quality that can be punched or trimmed into disks 1 in. or larger in diameter are classified as punch mica and are included in the general category of sheet mica. Built-up mica made from very thin sheets (splittings) and reconstituted mica made from delaminated scrap can be substituted for larger sheet mica for some uses (Skow, 1962, p. 23). Scrap mica includes all mica recovered from pegmatite mining and processing that does not meet sheet-mica specifications. Flake mica is fine-grained mica recovered from mining granite, fine-grained pegmatite, or muscovite-rich schist. Scrap and flake mica are ground to a powder before use.

The mica industry has changed rapidly in the last 30 years (Benbow, 1988). Little sheet mica has been produced in the United States since the end of the U.S. Government's mica-buying program in 1962; probably no more than a few hundred pounds has been produced in any one year during the last 10 years (table 1). Production of sheet mica in Georgia and South Carolina has always been much less than that in North Carolina (table 1). Annual consumption of sheet mica in the United States, which has dropped steadily since World War II, has leveled off at about 2.3 million lb since 1982 (Davis, 1988). Sheet-mica resources are discussed below by thrust stack.

Production of scrap and flake mica in the United States has averaged 137,000 tons in recent years (Davis, 1985, 1988). North Carolina produces about 60 percent of the flake mica, and the rest is divided among Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota. In the Greenville quadrangle, because only one mine is currently producing flake mica, there are no production figures available. This mine is in Hart County, Ga., 1 mi south of Hartwell, and Grant (1958) reported that it produces flake mica from granite saprolite. Flake-mica production in South Carolina in recent years has come from sericite schist from Lancaster County, 85 mi east of the Greenville quadrangle.

The Greenville quadrangle contains large resources of flake mica in muscovite-rich mica schist, which is present in all the thrust sheets except the Young Harris and the mafic–ultramafic thrust sheets. Most of these schist units are thin and widely scattered and have not been tested for suitability. Similar schist, however, has been sampled in the Blue Ridge and Inner Piedmont thrust stacks in North Carolina 5 to 50 mi north of the Greenville quadrangle and was found to be a suitable source of flake mica (Lewis and others, 1971).

In general, granite in the Greenville quadrangle contains more biotite than muscovite (Nelson and others, 1989). Locally, where muscovite is abundant and the rock has been weathered to saprolite, flake-mica resources could be large. Areas of granitic gneiss in the Inner Piedmont thrust stack have a moderate potential for deposits of flake mica in saprolite similar to the one being mined near Hartwell, Ga.

Quartz

Nearly pure quartz, an important component in the quartz cores of pegmatites and in granite, is the principal ingredient for most types of glass. Sedimentary deposits of quartz, such as sandstone and alluvial sands, are the main sources for raw material for glass. In 1933, however, crushed quartz from the quartz core of a pegmatite in the Blue Ridge thrust stack of North Carolina was used in formulating the glass for the 200-in. mirror for the telescope at Mount Palomar Observatory, Calif. (Stuckey, 1965, p. 442–443). Until recently in the Spruce Pine district of North Carolina, much of the quartz separated from feldspar and flake mica by flotation was sold for plaster sand, or road sand, or released into nearby streams. Increased concern for the environment has led to the development of an ultrapure quartz byproduct from feldspar and flake-mica mining by feldspar mining companies in the Spruce Pine district of North Carolina. This quartz product contains only about 30 parts per million (ppm) impurities. The raw material requirements of the fiber optic and synthetic quartz crystal industries are for such high-purity quartz, but the fine grain size of the flotation product may present problems in use. Resources of quartz in all the quartz cores of mica pegmatites in the Greenville quadrangle are probably large, but any one deposit could be too small for efficient mining. Resources of quartz in granite in the quadrangle, however, are even greater. The use of granite as a source for pure quartz is shown by the usable quartz products obtained from the fines produced in granite quarry operations near Pacolet, S.C., which is 13 mi east of the Greenville quadrangle (Eddy and others, 1972).

A geologically different type of quartz resource is found in the large mass of vein quartz exposed on Bell Mountain, about 2 mi northeast of Hiawassee, Towns County, Ga., in the Richard Russell thrust sheet (Hurst and Horton, 1964) and in similar masses of vein quartz on Big Knob and Little Knob, 6 to 7 mi northwest of Laurens, Laurens County, S.C., in the Laurens thrust sheet. The Bell Mountain deposit was mined for several years for use as crushed stone, especially in prestressed concrete products, but it can probably be used as a source of high-purity quartz. Hurst and Horton (1964) estimated resources of several million tons of quartz in the deposit. The Big and Little Knob deposits contain minor amounts of impurities (Buie and Robinson, 1958, p. 12) that may limit their use in glass manufacture.

Kaolin

Deeply weathered pegmatite and granite contain residual white clay that is kaolinite, halloysite, metahalloysite, or mixtures of all three. Deposits of this type are mined extensively around Spruce Pine in the North Carolina Blue Ridge thrust stack 63 mi north of the Greenville quadrangle. Similar residual clays developed on granite and pegmatite are found in Georgia and South Carolina (Ries and others, 1922, p. 79–82). These have not been developed (Sloan, 1904; McCallie, 1926, p. 29), in part, because of the larger deposits of sedimentary kaolin in the Coastal Plain of both States. Although these residual clays are a potential resource, they have not been studied in enough detail to make quantitative resource assessments.

Beryl

Beryl is an important source of the metal beryllium, which is used in beryllium copper or other alloys and as beryllium oxide. Both the alloys and the oxide are used in the electronic, automotive, and aerospace industries (Petkof, 1985, p. 75–79). Most of the United States beryllium comes from bertrandite, a beryllium mineral found mostly in hydrothermal deposits in Utah and New Mexico (Griffitts, 1973, p. 90–91). Precious and semiprecious varieties of beryl are known as emerald, aquamarine, heliodor, and morganite.

Furcron (1959) listed beryl localities in Georgia by county. In the Georgia part of the Greenville quadrangle, Banks, Barrow, Franklin, and Stephens Counties contain one locality each, Hart and Rabun Counties two, Jackson County three, and Elbert County five. The location of the Stephens County occurrence is too vague to allow plotting, and some of the other occurrences can only be approximately plotted on the map. Several other beryl occurrences, recorded during the USGS studies made for DMEA exploration projects during the 1950's, have been added to the map. All of these beryl occurrences consist of a few crystals found in pegmatite or crystal fragments in soil related to weathered pegmatite. The only significant beryl production in Georgia was about 2 tons of beryl produced from 1952 to 1957 from the Cochran mine in Cherokee County 20 mi west of the Greenville quadrangle (Furcron, 1959, p. 2).

In South Carolina, Sloan (1908, p. 155–56) mentioned four beryl occurrences in Anderson County, and McCauley (1964, p. 21–22) mentioned three more in Anderson County and one in Greenville County, all in the Greenville quadrangle. These are mineral-collecting localities where a few crystals of beryl have been found in pegmatite or in soil probably derived from pegmatite. There has been no commercial production of beryl in South Carolina, and there is no resource potential for beryl in the mica pegmatites exposed in the Greenville quadrangle. The rocks in the quadrangle have little potential for the occurrence of beryl resources.

MICA PEGMATITE IN THE GREENVILLE QUADRANGLE

Blue Ridge Thrust Stack

West of the Brevard fault zone, mica pegmatite is found mostly in the Richard Russell and Tallulah Falls thrust sheets and sparingly in the Great Smoky, Young Harris, and Helen thrust sheets (fig. 2; map). Most of the deposits, which are found in three areas named the North Georgia, Rabun, and Clarkesville districts (map), have been described by Galpin (1915), Sterrett (1923), Furcron and Teague (1943), or Heinrich and Jahns (1953). Total production is not recorded, but some 47 mines produced about 16,000 lb of sheet mica during World War II (Lesure and Shirley, 1968, p. 323).

The North Georgia district contains more than 60 mines and prospects in Towns, Union, Lumpkin, and Fannin Counties, but at least two-thirds of the deposits, including the more productive ones, are west of the Greenville quadrangle. Although most of the deposits are in the Richard Russell thrust sheet, several are in the Young Harris and Great Smoky thrust sheets within the Brasstown Bald window (map). An area 20 to 25 mi long that contains only a few scattered deposits separates the North Georgia district from the more productive Franklin–Sylva pegmatite district to the northeast in North Carolina (fig. 4).

The pegmatites are generally thin tabular bodies consisting of quartz, plagioclase, perthite, and muscovite; sparse accessory minerals include garnet, biotite, and apatite. Mica is commonly concentrated near the margins of massive quartz cores. The mica tends to be light brown or green and of poor quality. Bending, ruling, cracking, and stains are common. So are crystal imperfections that produce corrugations or reeves and "A" structure where two sets of reeves intersect at an angle of about 60°. Mining was active in the district during 1898–1908 and again shortly after World War I, but there has been little mining or prospecting since that time. Many of the mines are now overgrown and hard to find. The North Georgia district has a moderate potential for additional mica resources; the area between this district and the Franklin–Sylva district to the northeast in North Carolina has a low potential (figs. 4 and 5).

About 29 mines and prospects are in the Rabun district, an area 4 to 10 mi wide and 15 mi long in northeastern Rabun County, Ga., and western Oconee County, S.C., in the Tallulah Falls thrust sheet (map). This district is a southern extension of the better known Cashiers district of North Carolina described by Olson (1952) (fig. 4). The pegmatites are generally deeply weathered and poorly exposed. They contain mostly perthite, plagioclase, quartz, and muscovite. Small amounts of rare accessory minerals include garnet, biotite, tourmaline, beryl, gahnite, and zircon. The mica is green or greenish brown and commonly has flat or wedge-shaped "A" structure. Much of the mica is stained, bent, and ruled. This district also has a moderate potential for additional mica resources (fig. 5).

More than 25 mica deposits are widely scattered in the Clarkesville district in the Tallulah Falls thrust sheet in Habersham and White Counties (Hurst and Crawford, 1964, p. 65; Hurst and Otwell, 1964, p. 64). The deposits are generally weathered and poorly exposed. The mica is mostly green, small, and stained, and much of it has "A" structure. Production is unknown and probably small, but there is a moderate potential for additional mica resources in the Clarkesville district (fig. 5).

A few scattered mica deposits are found in Hall County to the southwest of the Clarkesville district (Galpin, 1915; Heinrich and Jahns, 1953). Very little is known about these deposits, but in general they are small and deeply weathered. The mica is small, fair to poor quality, and scarce. One mine, the Merck or Old Hope, about 1 mi northwest of the city limits of Gainesville, Ga., was worked extensively (Heinrich and Jahns, 1953, p. 387). This area has little potential for mica resources.

Inner Piedmont Thrust Stack

Three pegmatite districts, the Anderson–Greenville, Walhalla–Pickens, and Hartwell–Iva, in the Inner Piedmont thrust stack of the Greenville quadrangle have been described (Lesure and Shirley, 1968, p. 323). Only a few small deposits are outside these districts. The Anderson–Greenville district is here divided into five smaller unnamed areas that more closely reflect the boundary between the Six Mile and Paris Mountain thrust sheets (map). Together, these five areas contain about 50 known pegmatite bodies, of which about half have been prospected. The Walhalla–Pickens district is here divided into the western Walhalla part, which contains 7 widely spaced deposits in the Chauga–Walhalla thrust complex, and the eastern Pickens part, which contains 21 deposits in the Six Mile thrust sheet. The Hartwell–Iva district contains more than 100 deposits in the Six Mile thrust sheet in Elbert, Franklin, and Hart Counties, Ga., and Anderson and Abbeville Counties, S.C. (Furcron and Teague, 1943; Griffitts, 1953).

Pegmatites in all these areas are generally similar; they are chiefly mixtures of plagioclase, quartz, perthite, muscovite, and biotite. Garnet is the principal accessory mineral, but tourmaline and beryl are found sparsely in some of the pegmatites in the Hartwell–Iva and Anderson–Greenville districts. Internal structure is simple. Most deposits have a quartz core and plagioclase–quartz–muscovite wall zone; a few deposits have perthite intermediate zones. The pegmatite bodies are generally small, but Bynum and Griffin (1982, p. 81) reported one pegmatite dike, or possibly a series of elongate lenses, that extends for 4 mi just east of Secession Lake in Abbeville County, S.C. Most trend northeast and cut across the foliation of the enclosing metamorphic country rocks.

The muscovite is chiefly ruby but some deposits contain both ruby and green mica or just green mica. Both wall-zone and core-margin concentrations of mica are present, but much of the mica is of poor quality and small. Clay stain, mineral specks, flat and wedge-shaped "A" structure, and cracks are the principal defects.

Little is known about early production from the three districts. According to records of the Colonial Mica Corp., eight mines in the Walhalla–Pickens district produced about 500 lb of sheet and punch mica during World War II. At the same time, about 430 lb of sheet mica was produced from 11 deposits in the Anderson–Greenville district. Only the Willimon mine in this district, 9 mi southeast of Greenville, S.C., has been mined extensively (Olson and Griffitts, 1953, p. 319–320). In the Hartwell–Iva district, some 76 mines and prospects produced 12,019 lb of sheet and punch mica during World War II (Jahns and others, 1952, p. 85–86). In this district the recently discovered Taylor mine was a good producer from 1958 to 1960 and had a production of about 150 tons of mine-run mica from which 19,500 lb of full-trimmed sheet mica was sold (Lesure, 1962). The Pickens, Anderson–Greenville, and Hartwell–Iva districts have a moderate potential for additional deposits; the Walhalla district probably has only a low potential (fig. 5).

SHEET-MICA RESOURCES

Precise values for demonstrated reserves of sheet mica in the pegmatite districts of the Greenville quadrangle cannot be calculated from the data normally available in mining districts because no development work preceded pegmatite mining, and no mica-bearing rock was blocked out. An appraisal of the currently subeconomic inferred reserves of sheet mica remaining in the ground, based on the premise that the abundance of pegmatite bodies minable at depths of 100 to 200 ft is almost certain to be nearly the same as that at the surface, indicates that at least as much mica remains in the districts as has been mined, or probably the equivalent to 100,000 to 200,000 lb of fully trimmed mica (table 1). Whether this mica will be found within a minable depth of a few hundred feet of the surface and mined depends largely on such economic factors as domestic market and prices, which influence the amount of prospecting. Under normal market conditions, domestic sheet mica cannot compete with foreign imports because of the small size of the deposits and the large amount of hand labor needed to mine and process sheet mica.

The general scarcity of mica pegmatites in areas outside the pegmatite districts suggests that such areas have a lower potential for the occurrence of minable deposits. During the Federal Government's last mica-buying program (1952–62), most of the large, producing sheet-mica mines were ones that had been big producers in the past. Many of these mines were worked out or were left in a condition that will make further mining difficult. The rate of new discoveries was small during both World War II and the 1950's, even though exploration was encouraged by financial assistance from the Federal Government. The Taylor mine in the Hartwell–Iva district was a notable success among the many deposits explored with the aid of DMEA exploration contracts (Lesure, 1962). The deposits exposed at the surface, however, have generally been prospected, and the difficulty and cost of finding and evaluating unexposed deposits are great. Detailed geologic studies of structural control and country-rock alteration and the use of geochemical and geophysical techniques might help locate additional pegmatites that have recoverable sheet mica.

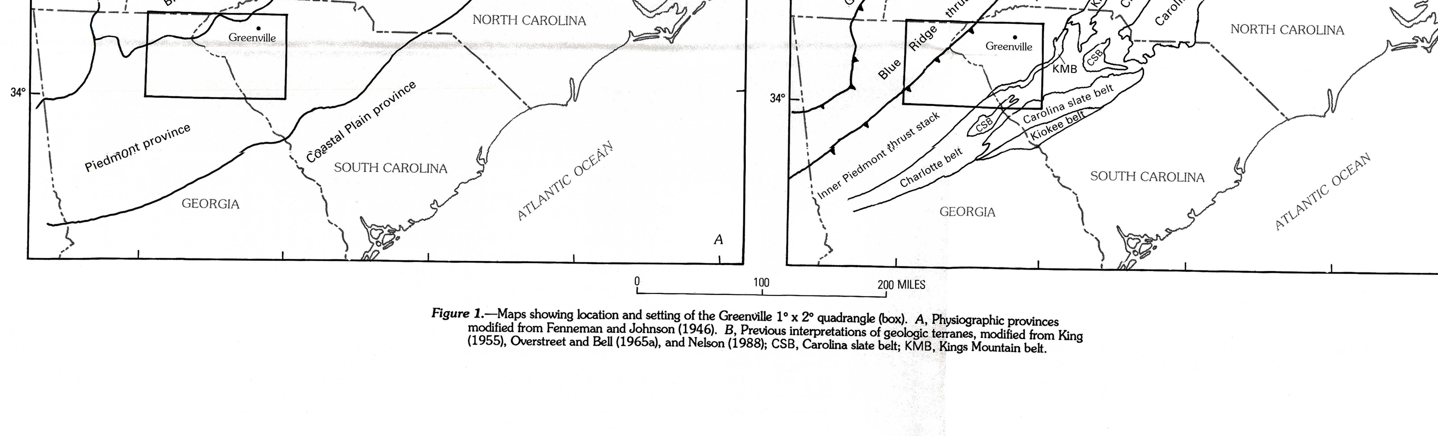
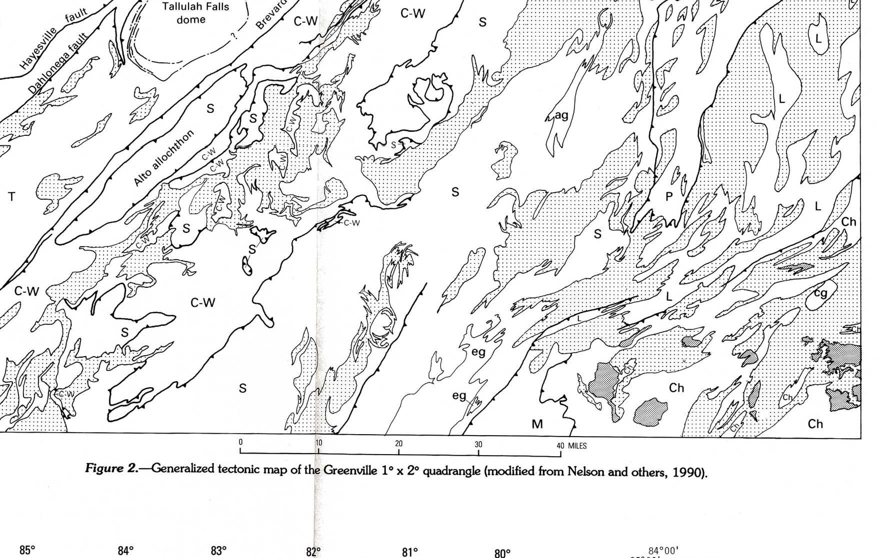


Figure 1.—Maps showing location and setting of the Greenville 1° x 2° quadrangle (box). *A*, Physiographic provinces modified from Fenneman and Johnson (1946). *B*, Previous interpretations of geologic terranes, modified from King (1955), Overstreet and Bell (1965a), and Nelson (1988); CSB, Carolina slate belt; KMB, Kings Mountain belt.



EXPLANATION
(Stacking order of thrust sheets)

Blue Ridge thrust stack

T	Tallulah Falls thrust sheet
R	Richard Russell thrust sheet
Y	Young Harris thrust sheet
H	Helen thrust sheet
G	Great Smoky thrust sheet

Inner Piedmont thrust stack

L	Laurens thrust sheet
P	Paris Mountain thrust sheet
S	Six mile thrust sheet—Includes metagabbro at Anderson (ag) and Elberton Granite (eg)
C-W	Chauga–Walhalla thrust complex

Southeast of Lowndesville shear zone

Ch	Charlotte thrust sheet—Includes granite at Coronaca (cg)
M	Mafic–ultramafic thrust sheet

Granitic rocks—Shown where they obscure faults or where extensive

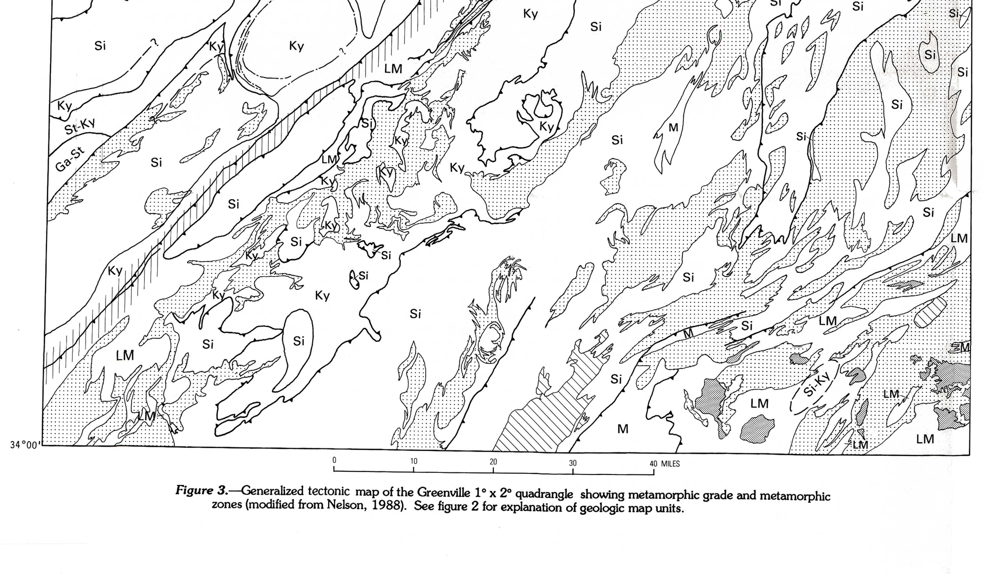
Gabbro and related rocks

Contact

Thrust fault—Dashed where inferred; queried where uncertain. Sawteeth on upper plate

Kyanite schist—Queried where uncertain. Shown around Tallulah Falls dome

Figure 2.—Generalized tectonic map of the Greenville 1° x 2° quadrangle (modified from Nelson and others, 1990).



EXPLANATION

Metamorphic grade

LM	Low to medium
M	Medium

Metamorphic zone—May be shown combined

Ga	Garnet
St	Staurolite
Ky	Kyanite
Si	Sillimanite

Retrograded

Isograd—Dashed where inferred. Letters represent metamorphic zones

Granitic rocks—Shown where they obscure faults or where extensive

Gabbro and related rocks

Contact

Thrust fault—Dashed where inferred; queried where uncertain. Sawteeth on upper plate

Kyanite schist—Queried where uncertain. Shown around Tallulah Falls dome

Figure 3.—Generalized tectonic map of the Greenville 1° x 2° quadrangle showing metamorphic grade and metamorphic zones (modified from Nelson, 1988). See figure 2 for explanation of geologic map units.

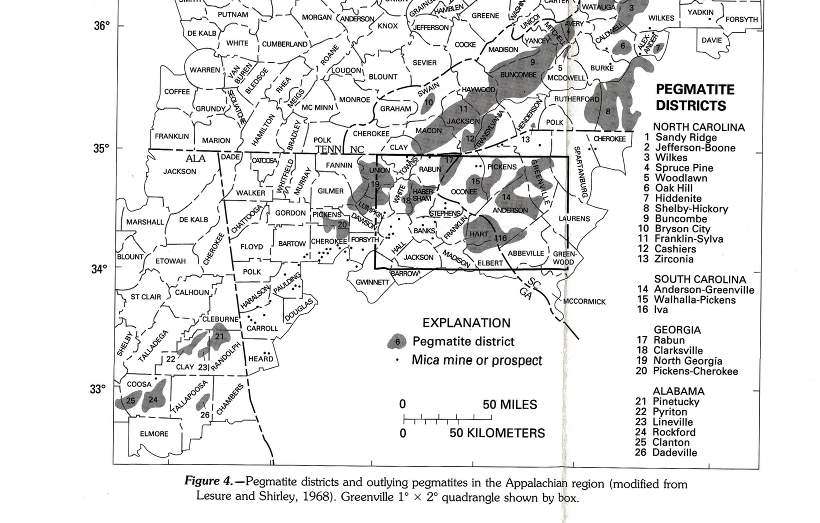
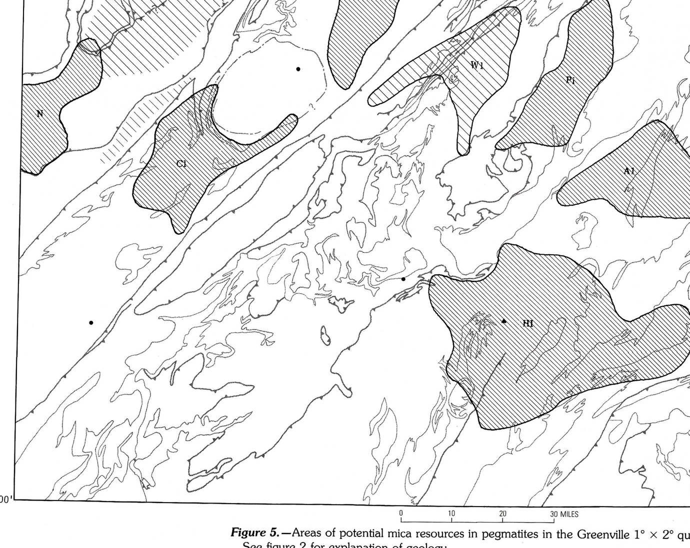


Figure 4.—Pegmatite districts and outlying pegmatites in the Appalachian region (modified from Lesure and Shirley, 1968). Greenville 1° × 2° quadrangle shown by box.



EXPLANATION

- Generalized boundary of pegmatite district
- Mica pegmatite—Outside known pegmatite district
- Flake-mica deposit
- Large deposit of vein quartz—1, Bell Mountain, Ga.; 2, Big Knob, S.C.; 3, Little Knob, S.C.

Pegmatite district

N	North Georgia
R	Rabun
Cl	Clarkesville
Wl	Walhalla
Pi	Pickens
HI	Hartwell–Iva
A1, A2, A3, A4, A5	Anderson–Greenville—Consists of five unnamed districts

Potential for additional mica-pegmatite resources

- Moderate
- Low

Figure 5.—Areas of potential mica resources in pegmatites in the Greenville 1° × 2° quadrangle. See figure 2 for explanation of geology.

Table 1.—Sheet-mica production in Georgia, North Carolina, and South Carolina compared to United States production and imports

[Data in thousands of pounds; —, data not published]

Years	Georgia	North Carolina	South Carolina	United States Production	United States Imports
1931–40	—	5,297	—	9,578	41,620
1941–50	16	8,397	2	14,555	168,947
1951–60	108	5,519	10	6,969	108,398
1961–70	—	—	—	1,996	87,938
1971–80	—	—	—	93	52,970
1981–87	—	—	—	1	24,173

MINERAL RESOURCE ASSESSMENT OF PEGMATITE MINERALS IN THE GREENVILLE 1° × 2° QUADRANGLE, SOUTH CAROLINA, GEORGIA, AND NORTH CAROLINA

By
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1993

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