Mica Deposits of the Southeastern Piedmont

Part 1. General Features

GEOLOGICAL SURVEY PROFESSIONAL PAPER 248-A

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By RICHARD H. JAHNS, WALLACE R. GRIFFITTS, *and* E. WM. HEINRICH

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Distribution and structure of pegmatite bodies in the area, their mineralogical characteristics, and the economic possibilities of the mica and other pegmatite minerals

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PART 1. GENERAL FEATURES

By Richard H. Jahns, Wallace R. Griffitts, and E. Wm. Heinrich

ABSTRACT

The increased demand for mica, beryl, columbite-tantalite, and other pegmatite minerals during World War II brought about a widespread revival of pegmatite prospecting and mining. Because of the need for a careful appraisal of domestic pegmatite resources, geologists of the U. S. Geological Survey examined 568 deposits in the southeastern Piedmont between 1939 and 1946. Special attention was given to the distribution of commercially desirable pegmatites within the region and the individual districts and also to the distribution of specific minerals in the districts and within the pegmatite bodies. A study also was made of the physical characteristics of mica and other pegmatite minerals. Recommendations for mine development were made, and production and cost data were analyzed and correlated, where possible, with geologic features.

Within given areas the pegmatites of the southeastern Piedmont are uniform in structure and composition. For that reason it was possible to predict the type and position of valuable minerals within deposits and to use these predictions as guides to exploration and mining.

Most mica-bearing pegmatites of the southeastern Piedmont are in foliated micaceous and hornblendic schists and gneisses. Most of the micaceous rocks were formed by the metamorphism of impure sandstones, shales, and silicic volcanic rocks. The hornblendic rocks probably are metamorphosed intrusive and volcanic rocks of mafic composition. Quartzite, conglomerate, phyllite, and marble are less common rocks. All are of moderate to high-rank metamorphism, and many contain abundant granitic or pegmatitic material as impregnations or distinct intrusive masses.

Igneous rocks are abundant in belts that are parallel to those of the metamorphic rocks. Granitic rocks, perhaps related to the pegmatites, are common in and near most of the pegmatite districts. Diorite, gabbro, periodotite, pyroxenite, and other mafic rocks are widespread in small stocks, sills, and pods. Most are younger than the metamorphic rocks but older than the pegmatite. Diabase dikes, presumably of Triassic age, occur in all districts.

The granitic rocks, probably of late Paleozoic age, occur in bodies a few feet to tens of miles long. Satellitic sills and dikes are common in several districts, and hybrid rocks and metamorphosed envelopes occur alongside some granite stocks. Most of the larger granite masses are in the central and eastern parts of the Piedmont and are separated from those of the Blue Ridge by belts of schist and gneiss in which there is little granite. Most of the rocks, rich in sodic plagioclase, range in composition from quartz monzonite to quartz diorite but are called granite in this report. Most are medium-grained and nonporphyritic; some are layered or foliated.

The regional trend of the schistosity and foliation is northeast. The regional dip in the northern part of the Piedmont is dominantly northwest, but elsewhere it is southeast. Thrust faults trend parallel to the foliation of the metamorphic rocks and may have a very large displacement. Younger faults bound areas in which are basins of Triassic age.

Most of the rocks in the Piedmont are weathered to a depth of at least 10 ft. The structure of the rocks is generally well preserved in the saprolite, the residual product of weathering of the rocks. Plagioclase is more readily weathered than potash feldspar in the granites and pegmatites. Quartz and muscovite are the most resistant minerals.

More than 1,600 mica deposits have been mined in the southeastern Piedmont. At least 595 yielded clear sheet mica of high quality during World War II. The main areas of mining are the Amelia district in Virginia, the Ridgeway-Sandy Ridge district in North Carolina and Virginia, the Shelby-Hickory district in North Carolina, the Hartwell district in South Carolina and Georgia, the Thomaston-Barnesville district in Georgia, and three areas in east-central Alabama. Most of the pegmatites are near a gently curving line between Fredericksburg, Va., and central Alabama. The deposits are most widely scattered in Alabama and Georgia.

In some districts the pegmatites are clustered around granite bodies. Elsewhere they occur along contacts between rock formations. Most closely spaced lenses occur along single zones in the country rock or en echelon in single belts. Pegmatite bodies may be tabular, pod-shaped, or irregular. Their average trend is northeast, and most dip and plunge steeply. Pegmatite bodies range from less than an inch to more than 130 ft. in thickness; most that have been mined are at least 3 ft. thick. Some have been mined for 250 ft. or more down the dip.

Within a given district or part of a district the pegmatites are alike in the way they occur. Many occupy fractures; others are parallel to the foliation planes in the country rock. The shape of the conformable deposits reflects the structure of the country rock. Suggestions of parallelism between the axes of pegmatite bodies and fold axes in the country rocks are known. Most pegmatite contacts are sharp, whether straight, curving, or irregular. The commonest types of wall-rock alteration are recrystallization of the minerals, conversion of hornblende to biotite, and impregnation with quartz, feldspar, mica, or tourmaline.

The units in pegmatite bodies have been divided into three groups: (1) zones; (2) fracture fillings; (3) replacement bodies. In some areas, most of the pegmatite is in bodies that are not zoned; however, in the southeastern Piedmont those bodies that contain minable concentrations of minerals are zoned. The zones have been classified as border zones, wall zones, intermediate zones, and cores. A few deposits contain three intermediate zones, but most have only one. The wall-to-core sequence of rock types in the pegmatites is uniform in many deposits and involves a progressive increase in grain size and content of potash feldspar and a decrease in content of plagioclase feldspar. Valuable minerals characteristically occur in certain zones and with certain types of pegmatite and

may be further concentrated in shoots. More than 150 minerals have been reported from the pegmatites, but 6 of these constitute 99 percent of most deposits. The minerals were formed in a sequence that is similar in all districts, although overlaps in time of formation are not rare.

Muscovite occurs in well-formed crystals as well as in irregular books. The books vary in ease of splitting, hardness, color, and amount of fracturing. "A" and herringbone mica are common locally and may yield flat sheets. Thick pieces of Piedmont mica are most commonly brown or reddish brown; a little is green. Color zoning is not rare, although the color of mica from one zone or shoot is usually very uniform. Mineral stains of various kinds are common in the mica of some Piedmont areas but are unimportant in most deposits. Clay stains are widespread and affect the mica of most thoroughly weathered pegmatites.

In determining the color and electrical properties of mica from over 200 deposits, no correlation was found between the color and power factor of well-prepared mica, and even most stained mica was found to have a low power factor. Mechanical defects are much more important than electrical properties in the grading of most mica.

Flat mica that yields an average of 5 percent sheet mica occurs in unzoned deposits and the wall zones of zoned deposits. This has been the most important source of sheet. Books of "A" mica, larger than the flat books, are most common in intermediate zones and rarely yield more than 3 percent sheet mica. The wall zones average about 7 percent recoverable book mica; the intermediate zones about 5 percent. The quality of sheet mica varies between deposits, between districts, and with different preparation. Probably less than one-fifth of all the mica obtained from the Piedmont deposits during World War II was of no. 1 quality.

Feldspar is mined mainly in the Virginia part of the Piedmont, where it occurs in cores and intermediate zones of large pegmatite bodies. Other deposits are known elsewhere in the Piedmont. Kaolin was mined on a small scale in Virginia, but the smallness of most pegmatite bodies has discouraged kaolin mining in most of the Piedmont.

Beryl occurs sparingly in many pegmatites north of Alabama, but the total production and reserves are small. Other beryllium minerals are scarce. Spodumene is abundant in pegmatites from the tin-spodumene belt, from which it can be obtained by milling the pegmatite, but it has not been reported from other areas. Cassiterite and gem materials have been obtained in small amounts, but of these only the amazon stone of the Amelia district and the emerald of the Shelby-Hickory district have been profitably mined. Niobium and tantalum minerals occur in moderate amounts in a few pegmatites but are generally very rare. Monazite, though obtained in fine specimens in Virginia, occurs in commercial amounts only in placer deposits in the Carolinas. Other pegmatite minerals are uncommon and of value only as mineral specimens.

Mica mining has been carried on intermittently since the fourteenth century. The output has varied with economic conditions and has reached peaks during the two world wars. Nearly 600 Piedmont deposits yielded 360,758 lb of salable mica in the period 1942–45. Most Piedmont mica deposits are soft enough to be worked by pick and shovel; a few have been worked by means of large open-cuts or by moderately extensive underground workings. Machines were simple and few in number except during World War II.

Wartime experience has shown that the reopening of mines is made difficult by the presence of old workings of unknown extent and that a knowledge of the geology supplemented by data from diamond-drill cores can be used to good advantage in exploring and mining pegmatites. Several new deposits were found, and probably many more exist. The Piedmont as a whole has not been as thoroughly prospected for feldspar as for mica. Many of the known mica deposits may be potential sources of high-grade potash feldspar.

INTRODUCTION

BACKGROUND OF THE INVESTIGATION

Many pegmatites in the Piedmont province of the Southeastern States have been prospected and mined during the period 1865–1946. The output has comprised large quantities of feldspar, kaolin, mica, quartz, and spodumene, as well as small quantities of beryl and other beryllium minerals, biotite, cassiterite, niobium-tantalum minerals, garnet, monazite and other rare-earth minerals, titanium minerals, industrial topaz, uranium minerals, zircon, and sphene. Included are small quantities of gem minerals and mineral specimens. The pegmatite mining is sporadic, and as a large proportion of the minerals listed is recovered as byproducts, the output during a given period depends mainly upon market conditions for mica and feldspar.

The demand for pegmatite minerals during World War II brought about a widespread revival of prospecting and mining. Many new uses for these minerals and for products obtained from them had been introduced during the previous two decades, and these and other uses were greatly expanded by military requirements. The need for a careful appraisal of domestic resources of pegmatite minerals was emphasized by the attendant rapid increases in demand and a heavy dependence on foreign sources of supply. As early as 1939 a program of pegmatite investigations was begun in the Southeastern States and in South Dakota by the Geological Survey, and by 1942 it had been expanded to Nation-wide scope.

The well-known report of Sterrett (1923) formed an excellent background for the recent studies, which were aimed at mapping and studying many deposits in detail. Attention was directed toward (1) the distribution of commercially desirable pegmatites with respect to broad areal and structural geologic features, (2) the distribution of pegmatite minerals within districts or areas and within individual pegmatite bodies, (3) the economic potentialities of the pegmatite-mineral deposits, and (4) a thorough study of the physical characteristics of the minerals, particularly muscovite. Recommendations for mine development were made from time to time, and attempts also were made to analyze production and cost data and to correlate them with geologic features wherever possible. The study demonstrated that the occurrence of mica and other desirable pegmatite constituents is systematic and that a knowledge of the structure of the deposits can be successfully used in overcoming problems that arise in prospecting and mining the pegmatites.

Within given districts or areas, the pegmatites of the southeastern Piedmont are remarkably uniform in their structural and mineralogical features, and many appear to have had a common origin. Similar observations have been made by Survey members who have recently studied pegmatites in other parts of the United States and in South America. All this work has shown that the traditionally "erratic and unpredictable" nature of most pegmatites is generally imaginary and that the deposits obey certain broad rules and within a given area can be analyzed and classified in much the same manner as many metalliferous deposits. Such classifications are basically empirical, and interpretations based upon them have been repeatedly confirmed by recent mining. Theoretical explanations for most of the features have been devised.

FIELD AND OFFICE WORK

The studies of the mica areas in the southeastern Piedmont were made intermittently between 1941 and 1946. A total of 568 pegmatites were studied in detail, and more than 140 of these were mapped. Emphasis was placed upon subdivision of the pegmatites into units of differing mineralogy and texture and upon the recognition and interpretation of structural features in both pegmatites and country rock. The mica investigations extended over most of the general pegmatite belt, but little attention was given to the tin-spodumene pegmatites of the Carolinas, which were studied by T. L. Kesler and others between 1938 and 1942, or to the tin-bearing pegmatites of Alabama, which were studied by W. C. Stoll in 1943.

The first of the investigations upon which this report is based involved brief examinations of several South Carolina deposits by J. C. Olson in 1941. During the following year T. L. Kesler made a preliminary study of deposits in the Thomaston-Barnesville district of Georgia, and L. R. Page examined several tantalum-beryllium deposits in Amelia County, Va. Work was greatly expanded in 1943, chiefly under the direction of J. C. Olson, and field parties were active in Virginia, North Carolina, Georgia, and Alabama. During 1944 and 1945 an expanded program of investigations was set up under the general supervision of R. H. Jahns and the immediate direction of W. R. Griffitts, E. Wm. Heinrich, and Jahns. Studies of all major areas were completed by September 1945, and only a few operating mines were visited thereafter. The men who took part in the investigations included V. C. Fryklund, Jr. (1943), W. R. Griffitts (1944–45), E. Wm. Heinrich (1944–45), R. H. Jahns (1944–46), T. L. Kesler (1942), M. R. Klepper (1943–44), D. M. Larrabee (1943–44), R. W. Lemke (1943–45), Roswell Miller III (1944), J. J. Norton (1943), J. C. Olson (1941–45), J. J. Page (1943), J. M. Parker III (1943–44), L. C. Pray (1944), and W. C. Stoll (1943). W. B. Allen, W. B. Baldwin, Edward Ellingwood III, W. P. Irwin, R. L. Smith, and J. H. Stillwell served as field assistants during various stages of the program.

The work in North Carolina was done in cooperation with the State Department of Conservation and Development, and the work elsewhere was coordinated with state-sponsored investigations whenever possible. The Colonial Mica Corp., an agent for the Metals Reserve Company and sole purchaser of domestic strategic-grade mica during much of World War II, was informed of results of the Survey studies and in turn supplied much information concerning the economic aspects of the mica industry. Many deposits were visited and several large mines were revisited from time to time at the request or upon the recommendation of Colonial Mica Corp. engineers. The U. S. Bureau of Mines explored several deposits in Virginia, North Carolina, Georgia, and Alabama by means of trenches, pits, and diamond-drill holes. The cores were logged and the hole locations were mapped by Survey geologists, and in some instances the exploration was planned and interpreted by members of both organizations, acting in close cooperation.

Samples of muscovite were collected from the workings or dumps of most mines and prospects as the work progressed. Many of these were subjected to a series of physical and electrical tests in Asheville, N. C., during the summer of 1945. These tests were made under the joint auspices of the U. S. Geological Survey, the State of North Carolina, the State College of North Carolina, and the Tennessee Valley Authority by F. W. Lancaster, of the State College of North Carolina, and by R. H. Jahns. Laboratory studies of feldspars and other pegmatite minerals were made in various Geological Survey offices. Systematic mineralogical studies of samples from the Morefield deposit, Amelia County, Va., were made in the Washington laboratories of the Geological Survey by J. J. Glass, who also contributed mineralogic data on specimens from many other deposits. The colors of the sheet mica from more than 1,600 deposits were determined by Frances H. Jahns in Ashville and Spruce Pine, as well as in the laboratories of the California Institute of Technology at Pasadena. Production and quality data supplied by the Colonial Mica Corp. were compiled and analyzed in Ashville by Frances H. Jahns, Ida M. Morgan, J. E. Husted, W. R. Griffitts, and Roswell Miller III and in Pasadena by R. H. Jahns.

During much of the time emphasis was placed upon field studies, and little time could be taken for the writing of general geologic reports or for the study of the mass of accumulating data. By the end of 1944 many of the men who participated in the earlier work were transferred to other assignments or had entered military service. Consequently it became the lot of a few remaining men to integrate the results of the widespread investigations and to reexamine the earlier work in the light of newly acquired information and new or modified interpretations. Thus many mine descriptions represent the joint efforts of two or more men. Those who were primarily responsible for mapping the mines are named on the maps. The data upon which the report is based were accumulated by many men, but the responsibility for most of the interpretations and generalizations must be assumed by W. R. Griffitts, E. Wm. Heinrich, R. H. Jahns, and R. W. Lemke, who prepared the general and summary sections of the report.

ACKNOWLEDGMENTS

Effective coordination of the investigations with activities of the Colonial Mica Corp. was made possible through the efforts of W. J. Alexander, Southern District Manager, E. J. Lintner and L. A. Norman, Jr., administrative assistants, and field engineers and buyers stationed in all parts of the pegmatite belt. The cooperation in the field of Mr. Norman and of Kenneth Carr, E. B. Ward, and D. J. Smith was particularly helpful in planning and executing many phases of the project. Dr. Jasper L. Stuckey, State Geologist of North Carolina, was unfailingly interested in the investigations and expedited the publication of several preliminary reports on mica deposits in the southeastern United States. He was the chief organizer of the program of detailed mica testing. H. S. Rankin and C. E. Hunter, of the Regional Products Research Division, Tennessee Valley Authority, also were very active in the mica-testing work, and Mr. Hunter gave generously of his time in accompanying Survey men on several field examinations.

W. A. Beck, L. A. Dahners, Jr., Robert Hickman, F. K. McIntosh, and H. D. Pallister, of the U. S. Bureau of Mines, were in charge of drilling and trenching programs in the Southeastern States, and their friendly cooperation is gratefully acknowledged. Suggestions and information supplied by Dr. Arthur Bevan, State Geologist of Virginia; Captain Garland Peyton, State Geologist, and Dr. A. S. Furcron, Assistant State Geologist, of Georgia; and Dr. E. A. Smith, State Geologist of Alabama, also are much appreciated. Without exception property owners and mine operators cooperated wholeheartedly throughout the investigations, and many generously permitted publication of production and mining-cost data. D. B. Sterrett, who worked several mines in Virginia during the wartime period, furnished much useful information on Virginia and North Carolina deposits. It is a pleasure to acknowledge the personal kindness of Mr. Sterrett, as well as H. L. Kennedy, of Black Mountain, F. B. Hendricks, of Shelby, and H. A. Knight, of High Point, N. C.

W. T. Schaller and C. S. Ross, of the Geological Survey, made helpful suggestions and criticisms during several discussions of mica occurrence and pegmatite genesis, and the broad interpretations and conclusions for many problems were improved by exchanges of information with E. N. Cameron, J. B. Hanley, A. H. McNair, and L. R. Page, who were in charge of pegmatite investigations in other parts of the United States.

W. J. Alexander and Bradley Johnson, of the Colonial Mica Corp., examined and criticized parts of the manuscript, particularly those dealing with the properties of mica. Most of the photographs of mica were made by Lou Reeder, of the Photographic Laboratories, California Institute of Technology.

GEOGRAPHY OF THE AREA

LOCATION AND ACCESS

The Piedmont province is the southeasternmost subdivision of the Appalachian Highlands, one of the eight major physiographic divisions of the United States. It is a well-defined longitudinal belt that trends approximately parallel to the edge of the continent and lies 70 to 200 miles from the coast line in the Southeastern States. The southern part of the Piedmont belt extends southwestward from the Potomac River through central Virginia and North Carolina, western South Carolina, and central and northeastern Georgia, tapering out in east-central Alabama. It is about 600 miles long and nearly 100 miles in average width, with a maximum width of about 140 miles in parts of North Carolina and Virginia. The Coastal Plain bounds the Piedmont province on the east and southeast, and the Blue Ridge province bounds it on the northwest (fig. 1).

The southeastern Piedmont includes many of the large towns and cities of the Southeastern States. Along or near its southeastern border, known as the fall line, are such cities as Washington, D. C.; Richmond, Va.; Columbia, S. C.; and Augusta, Macon, and Columbus, Ga. A main line of the Southern Railway traverses the belt from one end to the other, and both main and branch lines of the Chesapeake & Ohio, Norfolk & Western, Virginian, Seaboard, Central of Georgia, Southern, Atlanta & West Point, and several other railroads extend across the belt or serve small areas within it. There is also a widespread network of excellent state and Federal highways, and secondary roads provide access to most parts of the region. Travel between the Piedmont and the mountainous Blue Ridge province, however, is restricted to a few favorable routes.

TOPOGRAPHY

The Piedmont part of the Appalachian region is essentially a low-level plateau that is somewhat dissected by streams. Nearly all the province in the Southeastern States is in the so-called Piedmont Upland, a rolling country underlain by deformed crystalline rocks. The altitudes of this upland surface range from less than

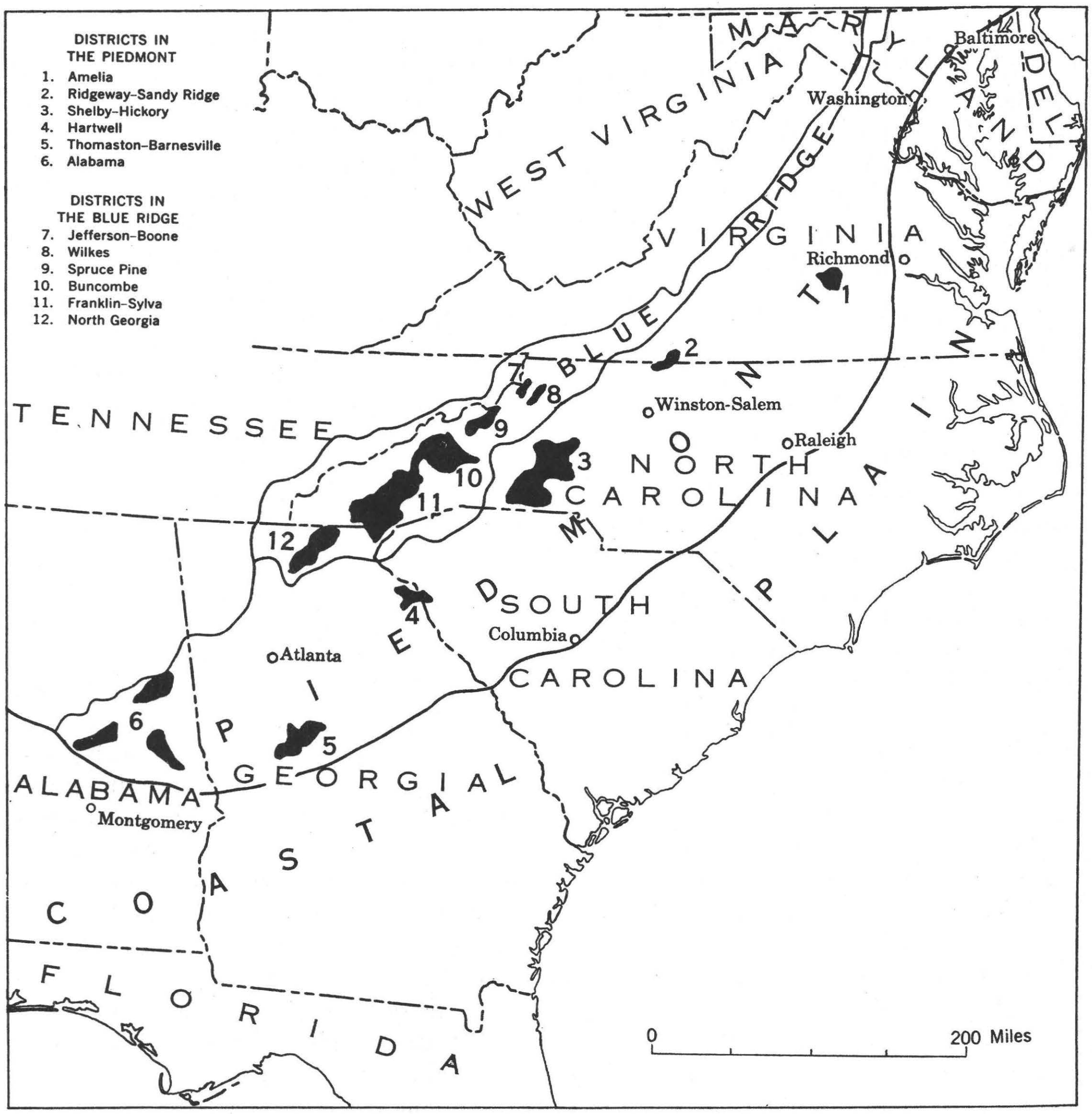

FIGURE 1.—Index map of the southeastern United States, showing the location of the main pegmatite districts in the Piedmont and the Blue Ridge.

200 ft along part of the southeastern border to as much as 1,800 ft in the northern part of Georgia. The entire province slopes gradually southeastward from the mountains to the Coastal Plain, with a general gradient of 10 to 20 ft per mile. It is characterized by nearly flat to gently rolling slopes with a general relief of 40 ft or less. Moderate or steep slopes are developed only on the sides of stream valleys or local ridges and hills that project above the general plateau surface. The maximum relief in some areas amounts to several hundred feet and is greatest along the northwestern border of the province, where deep valleys and some prominent hills form rough country along the Blue Ridge front. Variations in relief are due in part to relative degrees of stream dissection and in part to differences in the resistance of the underlying rocks to erosion.

The northwestern border of the Piedmont in the Southeastern States is at the foot of the Blue Ridge and is not everywhere clearly defined. The inner part of the plateau lies at altitudes of 700 ft in northern Virginia; 900 to 1,500 ft in central Virginia and northern North Carolina; and 1,800 ft in northern Georgia, where it is known as the Dahlonega Plateau. The southeastern edge of the plateau, where the hard rocks are overlapped by the soft sediments of the Coastal Plain, is less than 300 ft above sea level in most places. It is marked by a slight break in slope and by rapids or falls in many of the streams that cross it.

Many hills and ridges rise above the general Piedmont surface, both singly and in groups. They are held up by hard or otherwise resistant rock and form prominent landmarks. Some are of mountain proportions. Examples of these monadnocks include Mount Airy, the South Mountains, Flat Swamp Mountain, and Kings Mountain in North Carolina and Stone Mountain and Crane Mountain in Georgia.

DRAINAGE

The principal rivers of the Virginia and Carolina Piedmont flow in a general southeasterly direction. They include the Potomac, Rappahannock, James, and Roanoke in Virginia; the Cape Fear, Yadkin, and Catawba in North Carolina; and the Broad, Saluda, and Savannah in South Carolina. The Oconee, Ocmulgee, and Flint in Georgia also flow southward and southeastward, but the Chattahoochee and Tallapoosa, farther west, drain westward and southwestward, following the structure of the underlying rocks for long distances. The larger rivers in Virginia rise far to the west of the Piedmont, whereas the headwaters of those farther south and southwest are in the Piedmont itself or on the adjacent slopes of the Blue Ridge.

Most of the main streams flow in broad valleys flanked by moderate slopes much dissected by tributaries. The valleys are narrower and V-shaped near the Blue Ridge front, especially in the southwestern half of the Piedmont belt. The gradients of streams in most of the Piedmont are gentle but steepen distinctly near the boundary with the Coastal Plain. The rapids and falls along and near this boundary are the basis for the well-known term "fall line."

CLIMATE AND VEGETATION

The climate of the southeastern Piedmont is warm and temperate. The mean annual temperature ranges from 60 to 65 F in various parts of the belt, with mean winter temperatures of 40 to 50 F and mean summer temperatures of 75 to 80 F. The summers are long, and the growing season is characteristically extended. The winters are sometimes sharp or severe, especially in parts of the province near or along the Blue Ridge front. The climate is humid, with an annual precipitation of 42 to 54 in. distributed throughout the year. The precipitation increases southwestward in the belt and in general is highest in areas adjacent to the Blue Ridge. The humidity of the atmosphere averages 72 to 75 percent.

Most of the Piedmont soils are residual and have been developed from the weathering of igneous and metamorphic rocks. They are known as "red clay" soils, owing to their red to brownish-gray color, and are not particularly fertile. Moreover, much of the topsoil in the southeastern Piedmont has been eroded. The only other soils of importance are deposits of alluvium along major river courses.

The part of the Piedmont not under cultivation supports a heavy growth of grasses, brush, and trees. Hardwoods are the most abundant tree types, and hickory, maple, and oak are widespread. Pine is common on slopes adjacent to the Coastal Plain, and other evergreen types occur in the highest parts of the province. Abundant logs, posts, and lumber for mine buildings, underground timbering, and other uses associated with mining activities are readily available in most areas. Most Piedmont mines require much timbering in soft weathered rock that is below ground water, but both weathered and fresh hard rocks require little timber where continually dry.

GEOLOGY OF THE AREA

ROCK FORMATIONS

METAMORPHIC ROCKS

Nearly all the mica-bearing pegmatites of the southeastern Piedmont occur in highly foliated metamorphic rocks (pl. 1), which form sinuous but rather regular belts that trend northeast. Individual belts range in width from less than a mile to 30 miles or more. They are parallel to the elongation of the Piedmont province in Virginia and the Carolinas but disappear beneath the younger Coastal Plain sediments of Georgia and Alabama (Stose and Ljungstedt, 1932).

The chief rock types are micaceous schists and gneisses, which are included in the Wissahickon schist of Virginia, the Carolina gneiss of Virginia and the Carolinas, and the Ashland mica schist of Alabama. Interlayered with these rocks are hornblendic schists and gneisses that have been called Roan gneiss in the Carolinas and Georgia and metagabbro in parts of Virginia. Both these and associated metamorphic rocks are commonly considered to be of pre-Cambrian age, although an increasing volume of evidence suggests a Paleozoic age for some.

The micaceous rocks comprise immense thicknesses of quartzose mica schists and gneisses; sericite phyllite; and impure quartzite. Most of the rocks are markedly feldspathic. Oligoclase occurs as disseminated grains throughout large thicknesses of schist and gneiss and also forms coarse metacrysts in some layers. Potash feldspar is present locally. All are well foliated and in general vary greatly in mineral distribution and coarseness. The muscovite and biotite, for example, range from tiny flakes to plates and foils 2 in. or more across.

Most of the metamorphic rocks were developed from impure sandstones and sandy shales, but some may represent metamorphosed silicic volcanic rocks. All the schists and gneisses that are hosts to pegmatite are of moderate- to high-rank metamorphism, and sillimanite occurs in many parts of the terrane, especially in the Carolinas and Georgia. Garnetiferous layers are widespread and abundant, and staurolite also is common in some areas. Graphite-and kyanite-bearing rocks are recorded from all the states. Accessory minerals in the pegmatite districts include apatite, epidote, garnet, graphite, hornblende, ilmenite, kyanite, magnetite, orthoclase, pyrite and other sulfides, sillimanite, sphene, staurolite, tourmaline, and zircon. Rutile is present locally, and corundum is known in parts of the North Carolina and Georgia Piedmont.

Pods and stringers of granite and pegmatite are common, and many of the metamorphic rocks contain abundant disseminated igneous material. Individual metacrysts of oligoclase, albite, and microcline range in diameter from less than $\frac{1}{8}$ to 4 in. or more. Augen gneiss, in which "eyes" or rounded metacrysts of feldspar are abundant, are common in all districts. The effects of granitization have been reported from many areas, but the extent of such effects is unknown. In parts of the Georgia Piedmont quartz-mica schist can be traced into massive or faintly foliated granite. Intermediate phases in the transition include "knotty" schist with abundant augen or metacrysts of feldspar, schist with or without metacrysts but rich in disseminated feldspar, and massive to faintly foliated biotite gneiss. However, these relations have not been studied in enough detail to permit any definite conclusions as to the origin of the rocks.

Hornblendic rocks that have been variously designated as Roan gneiss, metagabbro, schistose diorite, and greenstone occur in nearly all areas, chiefly as thin layers in micaceous rocks. Larger masses of hornblende gneiss or metagabbro are very abundant in parts of North Carolina and Virginia, where they generally contain many inclusions of micaceous metamorphic rocks. The most widespread hornblendic rock types are plagioclase-amphibole schists and gneisses, with varying amounts of epidote, chlorite, and minor quartz. Some of the rocks are massive, but most are well foliated.

Accessory minerals in these rocks include apatite, biotite, garnet, ilmenite, magnetite, pyrite and other sulfides, rutile, sphene, and tourmaline. Hornblende is scattered through the rocks and also occurs as nearly monomineralic layers and as feltlike aggregates of needles parallel to the foliation of the rocks. Most of the amphibole-bearing rocks probably are metamorphosed intrusives, volcanics, and sediments rich in volcanic material of intermediate to basic composition. Many are younger than the mica-rich schists and gneisses, in which they commonly occur as dikes, sills, and stocks.

Other rock types in the metamorphic terrane include quartzite, quartz conglomerate, phyllite, and marble. Most of these lie outside the boundaries of the pegmatite areas, although lenses of dolomitic marble occur in such areas in central Virginia and North Carolina.

IGNEOUS ROCKS

Igneous rocks are widespread and abundant in the southeastern Piedmont in belts that are, in a general way, parallel to the flanking belts of metamorphic rocks (pl. 1). Granitic intrusives are common in and near most of the pegmatite districts, and a few are plainly related to the pegmatites. Diorite, gabbro, peridotite, pyroxenite, and other mafic types also are widespread, although individual masses rarely are as large as those of the more silicic intrusives. Metamorphosed volcanic rocks, comprising greenstones and more silicic types, occur in a very broad belt west of Raleigh, N. C., and east of the main mica districts in the State. Smaller belts are present elsewhere in the region, and silicic volcanic rocks occur alone in some areas. Many metamorphosed volcanic types are interlayered with the typical Carolina and Roan Gneisses but are not distinguished from those rocks on most geologic maps.

Massive to schistose gabbro is exposed over much of the Virginia Piedmont and parts of North Carolina, where it consists of medium- to coarse-grained labradorite, dark-colored hornblende, and minor olivine, with accessory apatite, augite, biotite, magnetite, and sphene. Much is rich in chlorite and epidote. Hornblende occurs as even grains, some of which form distinct layers that range in thickness from a knife edge to a quarter of an inch or more. Clusters and sprays of needles as much as 2 in. long also are present locally. The foliation of the rocks is due to the arrangement of individual hornblende and elongate feldspar crystals, and the structure commonly is accentuated by oriented platy aggregates of crystals and by hornblende- or feldspar-rich layers.

The gabbroic rocks occur as sills, pods, large plugs, and stocks. Many are parallel to the country-rock structure, but most contacts are discordant in detail. Some dikes are very thick, and a few are said to be as much as a quarter of a mile wide. Inclusions of country rock are locally abundant. Most of the mafic igneous rocks are younger than the metamorphic rocks, but they are older than the pegmatites.

Peridotite and pyroxenite occur in Virginia and North Carolina as small bodies that are oval to nearly circular in plan. They consist of olivine, pyroxene, and calcic plagioclase, with accessory magnetite, chromite, and spinel. Much of the olivine shows progressive alteration to pyroxene and to hornblende. Some of these rocks have been altered to serpentine or masses rich in talc, chlorite, and carbonate minerals. In parts of northern Upson County, Ga., a peculiar garnet-pyroxene rock appears to form pluglike masses a mile or more in outcrop diameter. Markedly schistose diorite occurs in Yadkin County and in other parts of the North Carolina Piedmont. Much of it is only slightly more silicic than the gabbro already described, but in general its principal feldspar is andesine, rather than labradorite, and it contains a higher proportion of light-colored minerals. Quartz is present in it locally.

Greenstone masses are widespread and form large parts of the terrain in the North Carolina Piedmont, generally east of the largest pegmatite districts. Most appear to be much-altered flows of intermediate to basic composition, but a few transect the structure of the enclosing rock and hence are of intrusive origin. They consist mainly of plagioclase, chlorite, epidote, hornblende, and carbonate minerals, with only traces of the original minerals and textures. Most belts of these rocks are virtually barren of pegmatites.

Diabase dikes, presumably of Triassic age, occur in all the pegmatite districts but appear to be most abundant in parts of Virginia and Georgia. They probably are related to larger intrusive masses exposed in downfaulted blocks of Triassic rocks in North Carolina, Virginia, and other states to the north. Most are a few inches to 12 ft thick and transect the structure of all other rocks. They are nearly vertical and in most areas strike northwest to north. The rock is typically greenish black to black where fresh, but it weathers to a yellowish or reddish brown. It consists of labradorite and augite, with minor olivine quartz, orthoclase, apatite, biotite, chlorite, hornblende, magnetite, and pyrite. The textures are typically diabasic. One dike that cuts the Short Tom Smith pegmatite in Rockingham County, N. C., is coarse-grained and gabbroic in appearance, but diabasic structure is well developed near its margins.

Granitic intrusive rocks, probably of late Paleozoic age, occur in many areas (pl. 1), chiefly as tabular bodies, pods, stocks, and other semiconcordant masses that range in length from a few feet to tens of miles. Around most of the large masses are swarms of apophyses and satellitic sills and dikes, and in several districts the large masses themselves are composite, consisting of branching, interfingering sills and pods that are separated by lenses and projections of metamorphic rocks. In general the larger masses and belts of granitic rocks are in the central and eastern parts of the Piedmont and are separated from the Blue Ridge province by areas of schist and gneiss and little granite. The larger masses generally are not accompanied by large numbers of pegmatite bodies.

The smaller granite masses in other igneous rocks and in the metamorphic rocks are distinct sills, lenses, and dikes, many of which pinch and swell markedly along strike and down dip. Hybrid rocks also are common and consist of schist or gneiss with abundant granitic material, either as impregnations or as lit-par-lit stringers. These have been variously termed injection gneiss, migmatite, hybrid or mixed gneiss, and granitized gneiss.

The granitic rocks are rich in sodic plagioclase and range in composition from quartz monzonite to quartz diorite. Many are very light colored. The most silicic types occur in Virginia and North Carolina, the least silicic in Virginia and Alabama. Although true granites are very rare, so few of the individual masses have been studied in detail that they are described in this report under the general term "granite." Most of these are white to medium gray and consist of oligoclase, potash feldspar, quartz, muscovite, and biotite, with accessory garnet, apatite, magnetite, sphene, and zircon. Ilmenite, rutile, and carbonates occur locally, and sericite, epidote, and clinozoisite are typical alteration minerals. Monazite has been found by J. B. Mertie, Jr., to be a widespread accessory constituent of certain granites, and he has used the content of monazite and other heavy minerals to distinguish between otherwise similar granites.

A few of the granites are porphyritic, with phenocrysts of plagioclase and potash feldspar as much as three-quarters of an inch in diameter. Some of the others are predominantly fine- to medium-grained and nonporphyritic but have porphyritic facies. Some are homogeneous aggregates of quartz, feldspar, and other minerals, with a typical "salt and pepper" appearance, but others are distinctly layered or foliated. In some areas foliated and nonfoliated rocks occur side by side but evidently represent different structural histories.

Planar structures in the granites are due to uniform orientation of individual mica flakes, to alined layers rich in mica flakes, to streaks of granular garnet or quartz, and locally to wisps of country rock. The structures generally are parallel to the walls of the granite masses, although in some small, badly contorted masses they are parallel to the country-rock foliation, regardless of the orientation of the contacts between the intrusive granite and the wall rock. Under the microscope many of the granitic rocks appear to be markedly granulated, with local recrystallization of muscovite and biotite. Some of this late mica is oriented in directions other than that of the principal foliation in the rock.

Pegmatite stringers, lenses, and pods are abundant in the granite of many areas. In general they either are conformable with the foliation or follow distinct crosscutting fractures. Irregular crystals of feldspar are scattered through the granites near many pegmatite contacts.

The granites contain abundant inclusions of metamorphic rocks, many of which show partial digestion or pronounced metamorphic effects. Chief among these effects is the conversion of hornblende to biotite. In addition, potash feldspar, quartz, and monazite are developed in some schists, and the biotite, garnet, graphite, and sillimanite in others are recrystallized and much coarsened. Large metacrysts of feldspar are present in the foliated rocks adjacent to many granite contacts. Exomorphic action in the basic igneous rocks includes development of mica in the gabbros and actinolite in the peridotites.

Pegmatites are rare in most thick masses of metavolcanic rocks, but they are abundant in all other rock types except those of post-Paleozoic age. Like the granitic rocks, they are rich in plagioclase and range in composition from quartz monzonite to quartz diorite. They occur as sills, dikes, pods, plugs, series of lenses, and more irregular bodies, and they range from thin stringers to large masses several hundred feet long and 50 ft. or more wide.

The age of the granites and pegmatites has not been accurately established. The relations between granite emplacement and deformation suggest that the Pinckneyville granite was emplaced during the last stages of the Appalachian revolution and is therefore of late Carboniferous age. Other granites in the Piedmont appear to have the same relations, but they have not been thoroughly studied. Several age determinations have been made on radioactive minerals from the Blue Ridge, but none are available for Piedmont minerals. The minerals from the Blue Ridge have been assigned ages, ranging from pre-Cambrian to Carboniferous, that agree only poorly or disagree flatly both with the geologically determined ages and with one another. The assignment of definite ages to the igneous rocks must be postponed until more regional geologic studies have been completed.

STRUCTURE

The crystalline rocks of the southeastern Piedmont have been extensively folded and faulted, and many of them have been highly metamorphosed as well. The intensity of deformation is distinctly greater than in the Blue Ridge province to the northwest. The regional trend of bedding, schistosity, and foliation is northeast, but more northerly or easterly strikes are present within small areas. The regional dip is dominantly northwest in Virginia and the northern part of North Carolina, but elsewhere it is southeast. In general the metamorphic rocks have been compressed into tight folds. Although the trends of many belts of metamorphic rocks suggest a simple regional structure, their distribution and attitude are very intricate in detail. Most have been affected by more than one period of deformation, so that in many places their structure is extremely complex.

The broad folds, like individual belts of metamorphic rocks, most commonly trend northeast. Many plunge gently southwest, especially those in the Carolina Piedmont. Igneous rocks occur along the flanks of some folds as sills and elongate concordant stocks and along the axes of others as domical masses. Many of the largest granite bodies are elongate domes, whose emplacement was controlled by or has caused the anticlinal structure of the flanking foliated rocks. The axis of the Virgilina syncline bisects a very broad belt of metamorphosed volcanic rocks of Paleozoic (?) age that extends from Lunenburg County, Va., south-southwestward and southwestward to Lancaster County, S. C. A smaller belt of similar rocks, which are compressed into two elongate major folds, marks the eastearn boundary of the Piedmont in northern North Carolina.

Small-scale folds, ranging in amplitude from a few inches to a hundred feet or more, are exposed in many areas. Most trend northeast and plunge gently southwest. On a still smaller scale, some phyllites are a series of sharp, closely spaced flexures along whose axial planes the rock is easily split. This secondary or "slip" cleavage transects the foliation or schistosity of the host rock at distinct, and commonly high, angles. Many joints form regular sets, the distribution and spacing of which appear to be functions of the competency of the host rocks as well as the regional setting. The joints are prominent, for example, in schist with few partings or poorly developed foliation, but they commonly die out in adjacent well-foliated or fissile schist. Some joints appear to be closely related to Paleozoic deformation, whereas others are quite clearly related to Mesozoic faulting. The distinction between joints of different ages has rarely been made in the field, with the result that the over-all patterns are quite confused.

The foliation of metamorphic rocks is much crumpled and contorted along contacts with some masses of granite and pegmatite. Most of the larger-scale folds and nearly all the faults may be older than the bulk of the silicic intrusive rocks. However, the small number of faults distinctly later than the pegmatites indicates that the faulting during Mesozoic time caused the tilting of long blocks, the interiors of which were not intimately deformed.

Three general types of foliation in the granitic rocks can be distinguished on the basis of their probable origin. The most common of these is flow, or primary foliation, which ordinarily consists of orientated mica flakes and uniformly elongated feldspar crystals. This structure was developed by flowage during emplacement of the granites and is most easily recognized in those that were injected along well-defined fractures. There is no consistent parallelism between the foliation of the intrusive rocks and that of the wall rocks, but the foliation is parallel to the contacts between the emplaced granite and wall rock in most places. A second type of foliation, developed by deformation after emplacement, generally is parallel to the country-rock structure and thus is parallel to the contacts between the emplaced granite and the wall rock only in sills or conformable parts of large bodies. It is a structure superimposed upon the granite after its emplacement, and ordinarily it occurs in rather small rock masses that have been severely contorted and granulated like that shown in figure 2.

The third type of foliation, which is inherited from the country rock, is most common in granite masses that contain many wispy inclusions of schist and are bounded by very irregular intricate and gradational contacts. Such foliation may be merely a continuation of that in the adjacent schist. It is well developed, for example, in a quartz-oligoclase-muscovite-garnet granite in the southern Georgia Piedmont. This granite can be traced into mica schist, and some of it may have formed from the schist by replacement. The relations of the three general types of foliation are summarized in figure 3.

Large-scale faulting has further complicated the structure of the Piedmont rocks. Major thrust faults, parallel in trend to the regional trend of the associated metamorphic rocks, extend for strike distances of 50 miles or more in Georgia and North Carolina. Displacement along some of them may be very large. Both these and other, less positively identifiable structural breaks in some places separate rocks of high-rank from rocks of lower-rank metamorphism. Smaller thrusts are recorded from many areas and, like the major faults, appear to be the result of compression.

A much later period of deformation is represented by high-angle normal faults that mark one or more sides of several large elongate areas of Triassic sedimentary and igneous rocks. These may be downfaulted remnants of a once-great blanket of nearly unmetamorphosed rocks. The normal faulting was accompanied and possibly preceded by fracturing and fissuring in the surrounding crystalline rocks, and many of the openings were filled by diabase dikes that trend north to west. Many pegmatites are cut by faults of small displacement, and several are offset along them for distances of 10 ft or more. The quartz and feldspar along such faults generally are fractured, brecciated, or granulated, and the book mica is ruled, warped, or otherwise deformed.

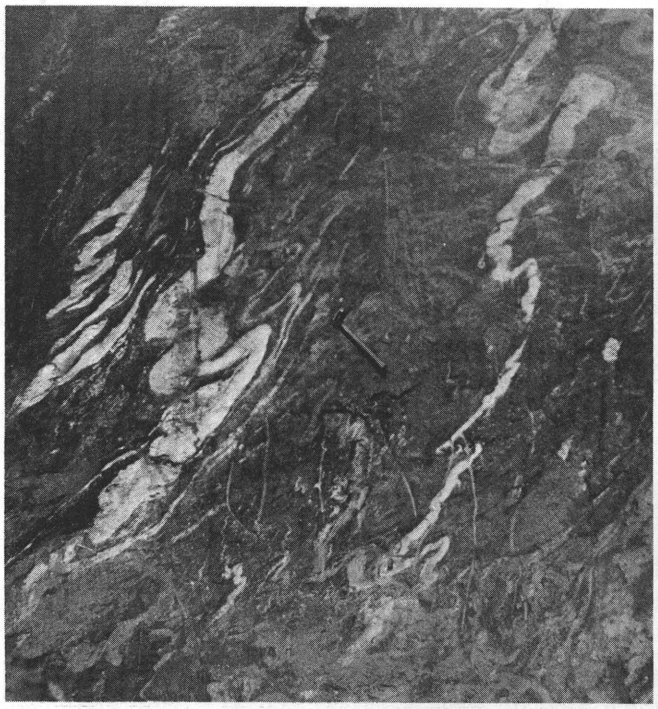

FIGURE 2.—Contorted sills and discordant stringers of medium-grained granite and fine-grained pegmatite (white) in fine- to medium-grained granite (dark gray), main open-cut of the Short Tom Smith mine, Rockingham County, N. C. The host granite also contains an earlier set of contorted granite sills (light gray).

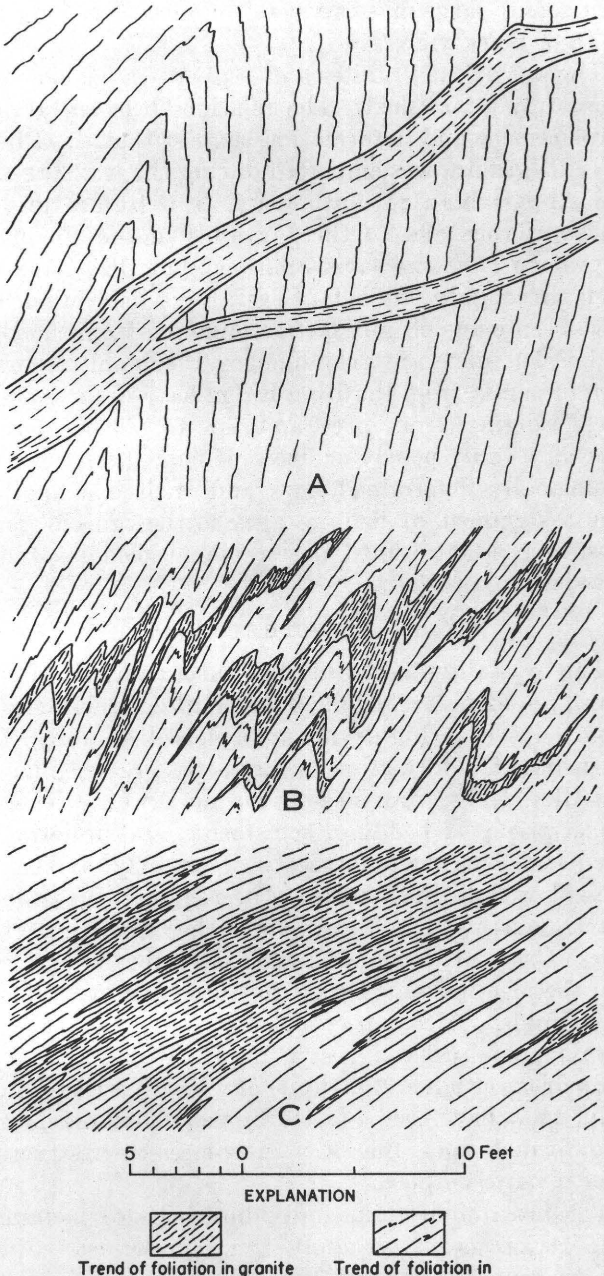

FIGURE 3.—Typical relations between foliation in small granite masses and the structure of the adjacent country rock. *A*, Branching dike with flow foliation essentially parallel with the walls. *B*, Contorted sills with secondary foliation parallel to axial planes of folds. *C*, Masses of replacement origin, with planar structure inherited from replaced rock.

WEATHERING

Nearly all the rocks in the Piedmont province are thoroughly weathered to depths of 10 ft or more, and exposures of fresh rock are present only in scattered road cuts, stream beds, quarries, and other excavations and on favorable hill slopes. Most of the mica mines are entirely in weathered rock, and in several areas altered material extends as far as 160 ft beneath the surface. The structure of the rocks generally is well preserved despite the alteration and assists in the identification of the original material. Slivers, flakes, and larger, less regular masses of rock relatively resistant to chemical attack are even more useful in this connection. The transition from thoroughly weathered to hard rock is, in most places, rather abrupt.

Schists and gneisses ordinarily yield sandy clay soils. These are light gray and contain abundant flakes of mica wherever they are developed from the uncommon quartz-muscovite and feldspathic quartz-muscovite rocks, but they are tan, reddish, or reddish brown wherever biotite or hornblende was an abundant original constituent. Kyanite-, garnet-, and sillimanite-bearing rocks characteristically yield soil with abundant crystals and crystal aggregates of these more resistant minerals. Irregular residual boulders of kyanite and sillimanite are locally abundant.

Many of the mafic igneous rocks are resistant and form bold outcrops or large residual boulders. Others weather to yellowish- or reddish-brown clay soil. The diabase is altered along joint planes, with progressive inward weathering of the joint blocks, and many dikes can be recognized by surface accumulations of rounded boulders several inches to 4 ft in diameter. Most of the granitic and pegmatitic igneous rocks are kaolinized to considerable depths. Plagioclase is characteristically kaolinized much more thoroughly and to greater depths than microcline, and the microcline can be identified with certainty in the outcrops of many pegmatites. Some crystals of coarse perthite are markedly cellular in appearance, owing to weathering of the albite plates and subsequent washing out of the kaolin thus formed. On a larger scale, the regular pattern of quartz spindles in some masses of kaolin bears testimony to their occurrence in graphic granite prior to thorough weathering of the feldspar. Where the rocks are light-colored, light-colored soils are developed; where they contain abundant biotite or hornblende the soils are correspondingly more brownish. Some of the granites are only slightly weathered at the surface and crop out as rounded bosses, mushroomlike forms, and smooth or gently rounded floors.

Owing to deep weathering, most pegmatite bodies are not well exposed at the surface. Many of them, however, yield recognizable residual concentrations of mica and quartz, and many mica mines were opened because such accumulations were discovered during the plowing of fields or exploration of wooded areas. The weathered pegmatite is easy to mine, as it generally can be handled by pick-and-shovel methods. On the other hand, it is extremely difficult to maintain mine workings in such material if it is water-saturated. Moreover, weathering may cause the development of clay, iron, and manganese stains in the book mica.

DISTRIBUTION OF THE PEGMATITES

The pegmatites of the Southeastern States occur in two well-defined belts, the Blue Ridge belt on the northwest and the longer and broader Piedmont belt on the southeast (fig. 1 and pl. 1). The principal mica-producing areas of the Piedmont belt are the Amelia district in Virginia, the Ridgeway-Sandy Ridge district in Virginia and North Carolina, the Shelby-Hickory district in North Carolina, the Hartwell district in Georgia and South Carolina, the Thomaston-Barnesville district, in Georgia, and three parts of east-central Alabama. Many deposits are scattered through the areas between and around individual districts, though generally within the belts, and others are in outlying areas. Mica has been obtained, for example, from pegmatites near the northern corner of Virginia and as far east in North Carolina as Raleigh (pl. 1). Most of the deposits, however, are concentrated along a gently curving line that extends southwestward from points near the fall line in Virginia to the western part of the North Carolina Piedmont and thence south-southwestward into Georgia. The pegmatites are more widely scattered in Alabama and western Georgia.

Nearly 5,000 mica deposits have been mined or prospected in the entire area of the southeastern United States. More than 1,600 of these are in the Piedmont province. Table 1 is a summation by districts and areas of the number of Piedmont mines and prospects that yielded clear sheet mica of high quality during the period of World War II, the number of mines and prospects studied in detail by the Geological Survey during the period 1939–46, and the estimated minimum number of deposits worked since 1880. The deposits studied by the Geological Survey include all those that yielded substantial quantities of sheet mica during World War II. The Shelby-Hickory district leads the others in total production, number of mines and prospects, and areal extent. There is no consistent relation, however, between the mineral output from a given district and its areal extent. The production of sheet mica from the small Ridgeway-Sandy Ridge district, for example, has been greater than that from all the deposits in Alabama.

TABLE 1.—*Summary data on the number of mica mines and prospects in the Piedmont region of the southeastern States*

Locality	Mines and prospects yielding clear sheet mica of strategic quality during World War II	Mines and prospects studied by U. S. Geological Survey 1939–46	Estimated minimum number of mines and prospects worked since 1880
Amelia district	13	83	120
Ridgeway-Sandy Ridge district	34	30	80
Outlying deposits in Virginia	24	29	200
Shelby-Hickory district	250	168	350
Outlying deposits in North Carolina	37	6	100
Outlying deposits in South Carolina	27	13	60
Hartwell district	76	33	150
Thomaston-Barnesville district	59	69	150
Outlying deposits in Georgia	34	11	170
Alabama deposits	41	126	250
Total	595	568	1,630

Nearly all the pegmatites occur in highly foliated metamorphic rocks, especially mica and hornblende schists and gneisses. A few are enclosed by quartzite, chlorite schist, granite, or other rocks, and some lie along contacts between two rock types. In several districts the pegmatites are distributed around or alongside large masses of silicic intrusive rock with which they may be genetically related. Thus most of the mica-bearing pegmatites in Alabama occur along the northwest side of the main body of Pinckneyville granite, and a few lie southeast of it or below the upward projection of its keel. In the western Virginia Piedmont, stained-mica deposits occur near the batholith of the Leatherwood granite and clear-mica deposits lie farther away and to the south.

GENERAL CHARACTERISTICS OF THE PEGMATITES

Most of the pegmatite bodies are tabular or lenticular; others are cigar-shaped, trough-shaped, markedly pinching and swelling, or so complicated by branches, bulges, or more irregular offshoots that they cannot be conveniently classified (fig. 4). Sills and concordant lenses are the dominant forms in Alabama, in the western part of the Hartwell district, and in the central and eastern parts of the Ridgeway-Sandy Ridge district, but elsewhere most of the pegmatite bodies are markedly discordant (table 2), many of them parallel to the country-rock foliation in strike but transecting it in dip. The dominant trend in nearly all areas is northeast, with a range from west-northwest through north to due east. Nearly all the pegmatites have moderately steep to very steep dips, and in most districts they commonly plunge steeply as well. Gentle plunges prevail, however, in the Otter River-Moneta area of Virginia, in the Hartwell district of Georgia, and in the Alabama areas.

Individual pegmatite bodies range from stringers and pods less than an inch in maximum thickness to tabular masses several hundred feet long and more than 130 ft thick. Most of those that have been profitably mined are at least 3 ft thick, and many are 6 to 12 ft thick. Dikes 150 to nearly 1,000 ft in strike length occur in some areas, but in others few are more than 80 ft long. Many closely spaced lenses may occur en echelon within specific belts of foliated country rock or even occur at specific horizons in such rocks (fig. 4), but this type of occurrence is exceptional in the Piedmont, in marked contrast to its common occurrence in the Blue Ridge. A series of such pods and lenses more than 1,000 ft long has been worked in the Brown mine, Upson County, Ga. Some pegmatite bodies have been explored or mined for distances of 250 ft or more down their dip, whereas the bottoms of others have been found at depths of 50 ft or less. The keels of many pegmatite lenses have been reached in mines of the Amelia, Ridgeway-Sandy Ridge, Shelby-Hickory, and Hartwell districts, and several deposits in other districts also are known to terminate at fairly shallow depths. In general, the downward terminations are abrupt rather than gradual thinnings with depth.

The broad structural features of pegmatite bodies are rather uniform within individual districts or parts of districts; hence the shape of one that is poorly exposed often can be predicted with some assurance by analogy with others whose structure is better known. Exposures are so incomplete in many areas, however, that the basic data necessary for such prediction are not obtainable. Suggestions of parallel or normal relations between the axes of pegmatite bodies and the axes of linear elements, small folds, and even large-scale structures in the adjacent country rock are recorded from several districts, especially in areas characterized by conformable deposits. Similar relationships have been found in pegmatite areas of South Dakota (Page, 1945), New Mexico (Jahns, 1946), and the Blue Ridge (Olson, 1944). However, no such

TABLE 2.—*General characteristics of pegmatites in the principal districts of the southeastern Piedmont*

Locality	General form of pegmatite bodies	Dominant trend or trends	General dip	General plunge	Dominant type of country rock
Amelia district, Va.:					
Jefferson-Amelia area	Discordant lenses and pods.	East	Steep	Steep or vertical	Quartz-mica schist and gneiss.
Morefield-Denaro area	Elongate dikes	North-northeast to east.	do	Steep	Do.
Ridgeway-Sandy Ridge district, Va.-N. C.	Sills and concordant lenses; some discordant tongues.	Northeast to east	Low to moderate north and northwest.	Gentle north or south	Quartz-mica schist; some granitic gneiss and granite.
Virginia:					
Otter River-Moneta area	Large sills and slightly discordant dikes.	Northeast to east-northeast.	Moderate to steep northwest to north-northwest.	Gentle northeast and southwest.	Quartz-mica schist and hornblende gneiss.
Shelby-Hickory district, N. C.:					
Western and southwestern part.	Discordant lenses	North to northeast	Steep	Very gentle to steep	Quartz-mica schist and gneiss; hornblende gneiss; granite.
Rest of district	Dikes and discordant lenses.	East	do	Steep	Do.
Hartwell district, Ga	Dikes, sills, and concordant lenses.	Northeast	Moderate to steep south east.	Flat to moderately steep north.	Quartz-mica gneiss and schist.
Thomaston-Barnesville district, Ga.	Sills and strike dikes	North to east-northeast.	Moderate southeast to vertical.	Southwest	Quartz-mica gneiss and schist; some hornblende gneiss.
Alabama	Sills and concordant lenses	Northeast	Moderate to steep southeast.	Gentle to moderate south.	Quartz-mica schist and gneiss.

parallelism has been demonstrated in most of the Piedmont districts characterized by disconformable deposits.

Many discordant pegmatites evidently were emplaced along elements of widespread sets of fractures. For example, in the northern part of the Amelia district and the central part of the Shelby district, the characteristic forms are steeply dipping lenses that trend east, or nearly normal to the trend of the pegmatite belt and the northwestward dipping country-rock foliation. Few of the dikes are more than 250 ft long, and many pinch out at depths of less than 125 ft. Many are closely spaced in well-defined groups and are arranged en echelon in plan and probably in section as well. In the southeastern part of the Amelia district most of the pegmatites also are sharply discordant but trend east-northeast and are characteristically long and continuous. Several are 1,000 ft or more long, and at least one is known to persist to a depth of nearly 150 ft. None have thinned greatly at the greatest depths to which they have been explored.

RELATIONS OF PEGMATITES TO WALL ROCKS

The shapes of many concordant pegmatite bodies closely reflect the structure of the adjacent country rock. Thus many crescentic, boomerang-shaped, fishhook-shaped, or otherwise curved bodies occur at marked bends in the foliation of the enclosing schists and gneisses (fig. 3). On a much smaller scale, however, bends and rolls in the wall-rock structure commonly reflect bulges and constrictions in the pegmatites. Most of the discordant pegmatites appear to follow fractures, and in general there is no consistent relation between their attitude and that of the enclosing rocks. On the other hand, they may change thickness or shape where they pass from one type of wall rock into another. In some places this seems due to differences in degree or type of fracturing in the various wall rocks during or prior to emplacement of the pegmatite dikes.

Many pegmatite bodies are discoidal lenses and stringers that are conformable with the foliation of granitic wall rocks. Some in the Ridgeway-Sandy Ridge district occur along well-defined planar structural breaks in the granite but cut across the foliation at distinct angles. In contrast, the pegmatite bodies of the northeastern North Carolina Piedmont are sills in foliated granite and dikes in adjacent mica and hornblende schists and gneisses. Pegmatite-granite contacts at two mines studied are extremely complex,

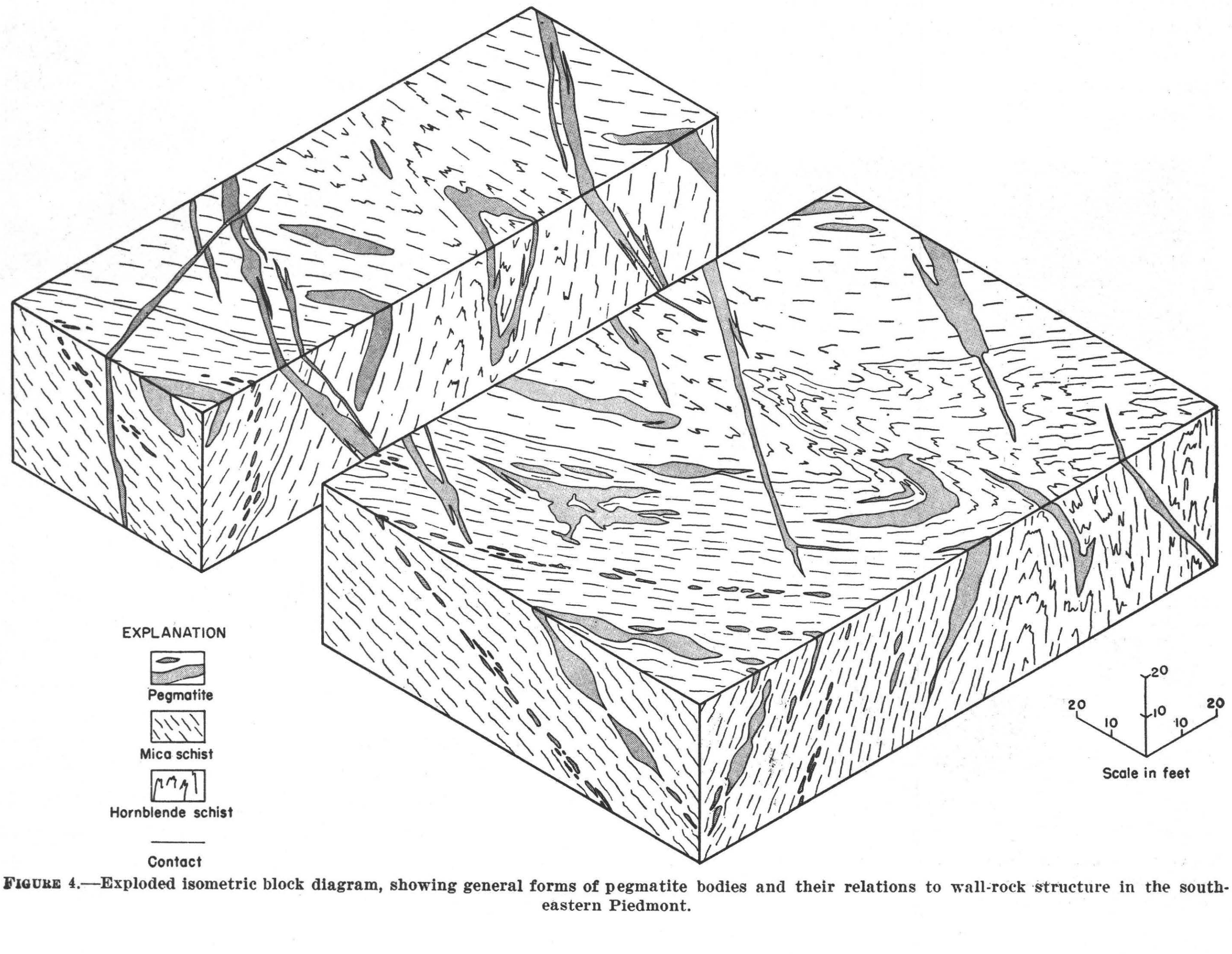

FIGURE 4.—Exploded isometric block diagram, showing general forms of pegmatite bodies and their relations to wall-rock structure in the southeastern Piedmont.

FIGURE 5.—Irregular contacts between pegmatite and granite, main open-cut of the E. R. Self mine, Gaston County, N. C.

with many branches, embayments, and even ramifying veinlike masses. An excellent example was exposed in the main open-cut of the E. R. Self mine, where the wall-rock granite is host to many irregular pegmatite tongues and a few disconnected pods (fig. 5). Appreciable quantities of wall rock at such localities may have been digested by the pegmatite solutions.

The shapes of the deposits that occur in schists and gneisses are controlled by fractures, by country-rock foliation, by country-rock lithology, or by combinations of features. Many dikes have sill-like apophyses, and

FIGURE 6.—Sinuous discordant apophysis above a bulge in the hanging wall (portal of main incline), Knight mine, Rockingham County, N. C., in November 1944.

branches from most sills are at least in part discordant. Some tabular masses of pegmatite are regular in shape or branch in a very simple manner, but others are extremely complex. All gradations between these two extremes are known, and several occur within individual pegmatites in some districts. For example, the Knight pegmatite in Rockingham County, N. C., is an elongate sill or tongue that splits into two thinner sills along its western edge. Elsewhere it includes lenses of country-rock schist that are parallel to its walls. Near the main portal of the mine, however, a sharply discordant, sinuous dike extends upward from the hanging wall (fig. 6). It appears to have been emplaced along diagonal fractures.

Most contacts between pegmatite and wall rock are sharp (fig. 7). Some of these are straight or only gently curving, whereas others are uneven, either on a

FIGURE 7.—Sharp hanging-wall contact in the main east crosscut of the Knight mine, Rockingham County, N. C. Note the fine-grained border zone and coarse mica books (dark gray to black) in the wall zone.

large scale or in detail. Still others vary along strike or down dip. In the Hawkins mine, Stokes County, N. C., the hanging wall of the mica-bearing pegmatite sill is very even where exposed in the upper part of the main incline. It is overlain successively by 1½ to 2 ft of feldspathic schist and a 1- to 5-ft sill of distinctly layered and foliated, medium-grained granite (fig. 8), which fingers out down dip into zones of injection gneiss. In the lower part of the incline the hanging wall of the pegmatite cuts across the overlying feldspathic gneiss and plainly crosses the granite and its associated injection gneiss (fig. 9).

The wall rock is warped or contorted along the margins of some pegmatite dikes (fig. 10), and such disturbance can be ascribed to emplacement of the pegmatite in many localities. In others, however, it appears to have resulted from movement along a fault older than the pegmatite. This is especially clear where the wall rock is warped in opposite directions on opposite sides of the pegmatite or its general attitude differs greatly on opposite sides, particularly where the rock on one side of the pegmatite is distinctly different from that on the other side (fig. 10).

The most common types of wall-rock alteration adjacent to the pegmatites are the recrystallization of feldspar and muscovite in the mica gneisses and some of the granites, the conversion of hornblende to biotite, and the general introduction of feldspar, micas, and quartz. Many schists and gneisses are impregnated with much fine-grained feldspar, and both metamorphic and intrusive rocks commonly contain metacrysts of microcline or plagioclase that range in diameter from 1/4 to 10 in. or more. At some localities these are surrounded by foils of muscovite or biotite. Other effects brought

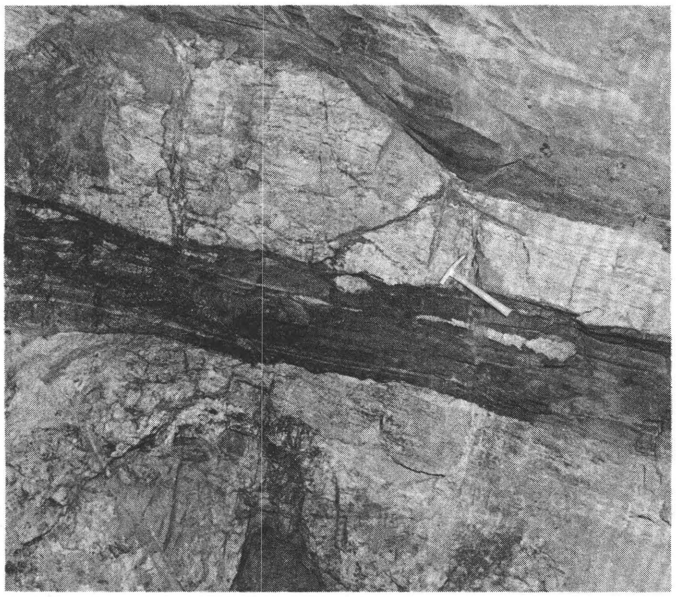

FIGURE 8.—Foliated and layered sill of granite (upper light layer) underlain by schist (dark layer), Hawkins mine, Stokes County, N. C. The schist is underlain first by layered granite, then by mica-bearing pegmatite.

about by pegmatite injection in some places include the introduction of black tourmaline, the alteration of sillimanite and kyanite, the coarse recrystallization of graphite, and the development of tremolite and other silicate minerals in carbonate rocks. Some schists and granites are unusually rich in garnet along pegmatite contacts, but it is rarely clear whether this mineral was introduced from the pegmatite magma or was formed by reconstitution of original constituents of the wall rock.

INTERNAL STRUCTURE OF THE PEGMATITES

Many pegmatites are simple aggregates of quartz, feldspar, and accessory minerals that cannot be readily divided into units of contrasting composition or texture. These unzoned deposits contain the major part of pegmatitic material in some areas but in general have re-

FIGURE 9.—The same granite sill shown in figure 8 (Hawkins mine, Stokes County, N. C.) cut by mica-bearing pegmatite (below and to the left).

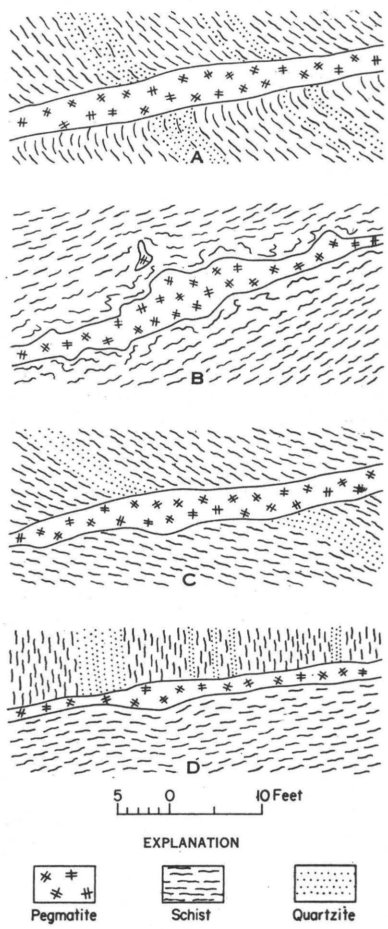

FIGURE 10.—Idealized plans showing wall-rock disturbance along pegmatite contacts. *A*, Unidirectional drag, attributable to emplacement of the pegmatite body. *B*, Contortion localized along pegmatite contacts and presumably caused by the pegmatite body during emplacement. *C*, Pegmatite body emplaced along a fault, with the drag predating the pegmatite in age. *D*, Pegmatite body emplaced along a fault.

ceived much less attention than those that are more complex in lithology and internal structure. This latter group includes nearly all pegmatites that contain rare minerals, as well as most of those in the Piedmont that contain minable concentrations of feldspar, mica, beryl, and other minerals. A general systematic arrangement of lithologic units in such pegmatites has long been recognized, and "bands," "barrels," "columns," "layers," "lenses," "pipes," "pods," "ribs," "shoots," "streaks,' "veins," and "zones" are terms commonly used by miners and referred to in geologic literature.

PREVIOUS STUDY

An essentially regular and orderly structure in pegmatites was early recognized by Hunt (1871), who commented upon the distinct layering of many "granitic veinstones" in Maine. Four years later Blake (1885) described the Etta pegmatite, Keystone, S. Dak., as a concentrically zoned mass with four identifiable units. This pattern is clearly shown in an accompanying sketch map made by G. E. Bailey. The internal structure of the same pegmatite was later described in greater detail by Schwartz (1925). Zonal structures in Norwegian pegmatites were recognized and described by Brögger (1890), and he discussed their probable origin in terms of magmatic and hydrothermal processes. Layering and quartz "bands" in pegmatites were subsequently described and discussed by Crosby and Fuller (1897), Spurr (1898, p. 231), and Julien (1901, p. 508). Irregularities of mineral distribution in some pegmatites impressed several early investigators, but others recognized them essentially as irregularities of detail. During the period 1900–1945 it was repeatedly noted that many pegmatites show pronounced mineral segregation and that cavities and concentrations of unusual and economically desirable minerals tend to occur at specific positions within a given deposit.

In describing some pegmatite masses associated with the Duluth gabbro in Minnesota, Grout (1918, especially p. 188) used the terms "border zone," "median zone," and "central zone" and pointed out variations in the composition of these units. Increasing attention was paid to variations of composition in pegmatites by subsequent investigators, but this was focused more upon detailed mineralogy and questions of genesis than upon structure. It has remained for still more recent investigators to place proportionate emphasis upon detailed mapping and structural interpretation of individual parts of pegmatite bodies and to demonstrate the economic value of such studies in prospecting and in the planning of exploration, development, and mining. See, for example, the work of Smith and Page (1941), Olson (1942), Bannerman (1943), Page, Hanley, and Heinrich (1943), Cameron, Larrabee, McNair, and Stewart (1944), Jahns and Wright (1944), Olson, Parker, and Page (1944), de Almeida, Johnston, Leonardos, and Scorza (1944), Olson (1944), Cameron, Larrabee, McNair, Page, Shainin, and Stewart (1945), Johnston (1945), and Jahns (1946). It has been shown by careful studies in many areas that concentrations of economically desirable pegmatite minerals commonly occur in rock units quite distinct from adjacent barren units; hence recent work has fully confirmed the suggestions of many earlier investigators.

CLASSIFICATION AND TERMINOLOGY

The nature, significance, recognition, and nomenclature of structural and petrologic units in pegmatites involve many problems, some of which cannot yet be answered. The answers to others, however, are outlined in this report. They represent the combined efforts of many men, working in most of the pegmatite mining districts in the United States. Although the methods of study differed little from those long used in detailed investigations of metalliferous deposits, the resulting conclusions were obtained only after many discussions and conferences with other members of the Geological Survey. Thus they are syntheses of many points of view and represent a joint effort in every sense.

Detailed studies plainly indicate the need for a stable but flexible classification and terminology of pegmatite units, so that descriptions can be as clear as possible and discussions of structure, genesis, and other problems thereby facilitated. Such units are distinguished on the basis of differences in mineralogy or texture, or both, and three fundamental types have been recognized (Cameron, Jahns, McNair, and Page, 1949), as follows:

1. *Fracture fillings* are bodies, generally tabular, that fill fractures in previously consolidated pegmatite.

2. *Replacement bodies* are units formed primarily by replacement of preexisting pegmatite, with or without obvious structural control.

3. *Zones* are successive shells, complete or incomplete, that commonly reflect the shape or structure of the pegmatite body. Where ideally developed they are concentric about an innermost zone or core.

Although based upon detailed examination and mapping of hundreds of pegmatites, this threefold classification should be regarded, not as wholly fixed, but as a framework that can be expanded or altered as more basic data become available.

Pegmatite units range widely in size, shape, and texture. The smallest are tiny fracture-filling veinlets and the thin outermost zones of many pegmatite bodies. The largest are masses several hundred feet long and as much as 50 ft in minimum dimension. Many units in the Piedmont deposits are sharply bounded and easily distinguished from adjacent units, especially where they differ markedly in composition or texture. Contacts between others are gradational, and in some very coarse grained pegmatites they are difficult to locate within narrow limits. Even where adjacent units are mineralogically similar, however, most boundaries can be mapped conveniently on scales of 20 or 25 ft to 1 in. (fig. 11). Independent assignments of such boundaries by more than one geologist generally agree within narrow limits, provided the same mineralogic or textural basis of distinction is employed.

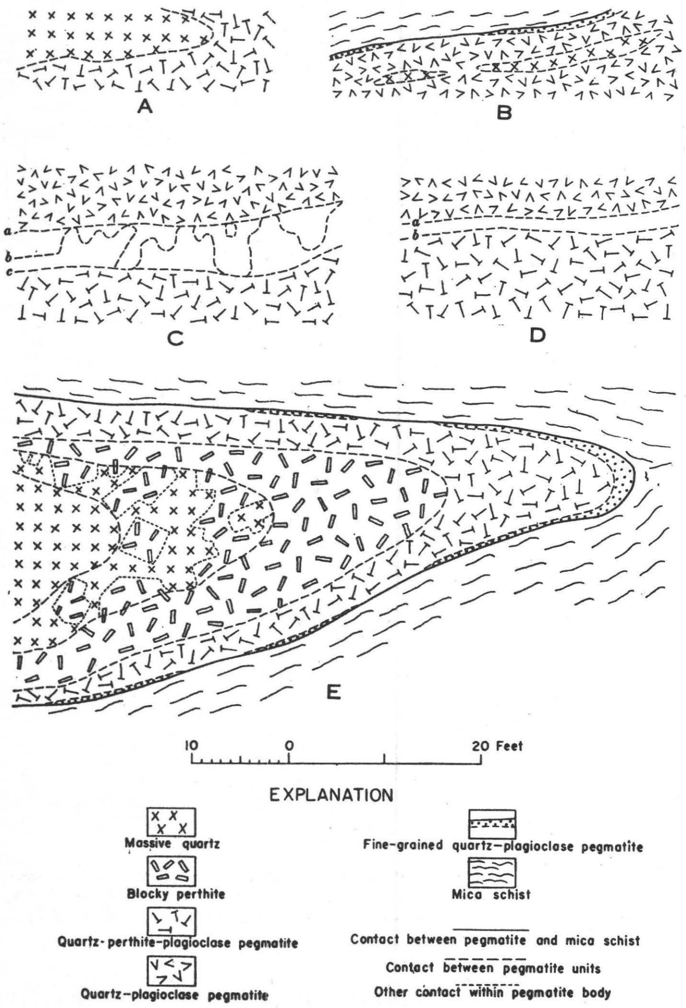

Figure 11.—Variations in boundaries between pegmatite units. *A*, Sharp contact between quartz and granitoid pegmatite. *B*, Sharp contacts between quartz and granitoid pegmatite and between granitoid pegmatite and much finer grained pegmatite. *C*, Upper limit of perthite (line *b*) establishes the contact between two granitoid zones in mapping on a very large scale; for less-detailed mapping the contact might be fixed at any position between lines *a* and *c*. *D*, Lines *a* and *b* represent the upper and lower limits of contact positions between two granitoid zones of finer grain. *E*, Pegmatite body with inner units of massive quartz and very coarse grained perthite. If the mapping is on a very large scale, the zone boundaries may differ considerably in position from such mineralogic boundaries as the margins of individual giant crystals of perthite.

The following size classification is used for pegmatite textures by the Geological Survey:

	General grain size, in inches
Fine	Less than 1.
Medium	1 to 4.
Coarse	4 to 12.
Very coarse	Greater than 12.

It is clear that contacts between pegmatite units become more difficult to map as the grain size of the units increases, especially where the textures are prevailingly granitoid—that is, rather even grained, with anhedral to subhedral grains. In a few pegmatites that have extremely coarse textures, it is easier to show individual mineral masses than to distinguish the boundaries of the unit in which they occur (fig. 11). Despite the practical need for showing the individual mineral masses on detailed maps—especially if these masses are 15 ft or more in diameter— it is commonly important to show the distribution of the entire pegmatite unit as well. It is the unit, rather than its components, however large they may be, that reflects the structure of adjacent units and of the pegmatite body as a whole; the distribution of each component seems best analyzed in terms of the pegmatite unit.

TYPES OF PEGMATITE UNITS

ZONES

Pegmatite zones, if fully formed, would be successive shells concentric about an innermost zone or core (fig. 12). In most pegmatite bodies, however, one or more of the zones are incomplete or discontinuous, and there are all gradations between complete zones and those that are developed only along one side or at one end of a pegmatite body. Whether the zones appear as ideal shells or as pods, straight or curved lenses, chains of lenses, or more irregular masses, they consistently reflect the form and structure of the enclosing pegmatite body (fig. 6).

The following classification of zones has been proposed by Cameron, Jahns, McNair, and Page (1949, p. 20):

1. Border zone (the outermost zone).
2. Wall zone.
3. Intermediate zone.
4. Core (the innermost zone).

The wall zone lies between the border zone and core of any pegmatite that consists of three zones, and it lies next inside the border zone of any pegmatite with more than three zones. Any zone between the core and wall zone is an intermediate zone. It follows that wall and intermediate zones cannot be present in pegmatites that contain only two zones and that intermediate zones cannot occur in pegmatites with fewer than four zones (fig. 12). There is no theoretical limit to the possible number of intermediate zones, but few pegmatites contain more than three such units, and few of the Piedmont deposits contain more than two.

It is rarely safe to make dogmatic assertions regarding the number and detailed distribution of zones in a pegmatite body solely on the basis of outcrops or near-surface exposures. Zones are three-dimensional features; hence three-dimensional data are necessary for a complete understanding of zonal structures, even in

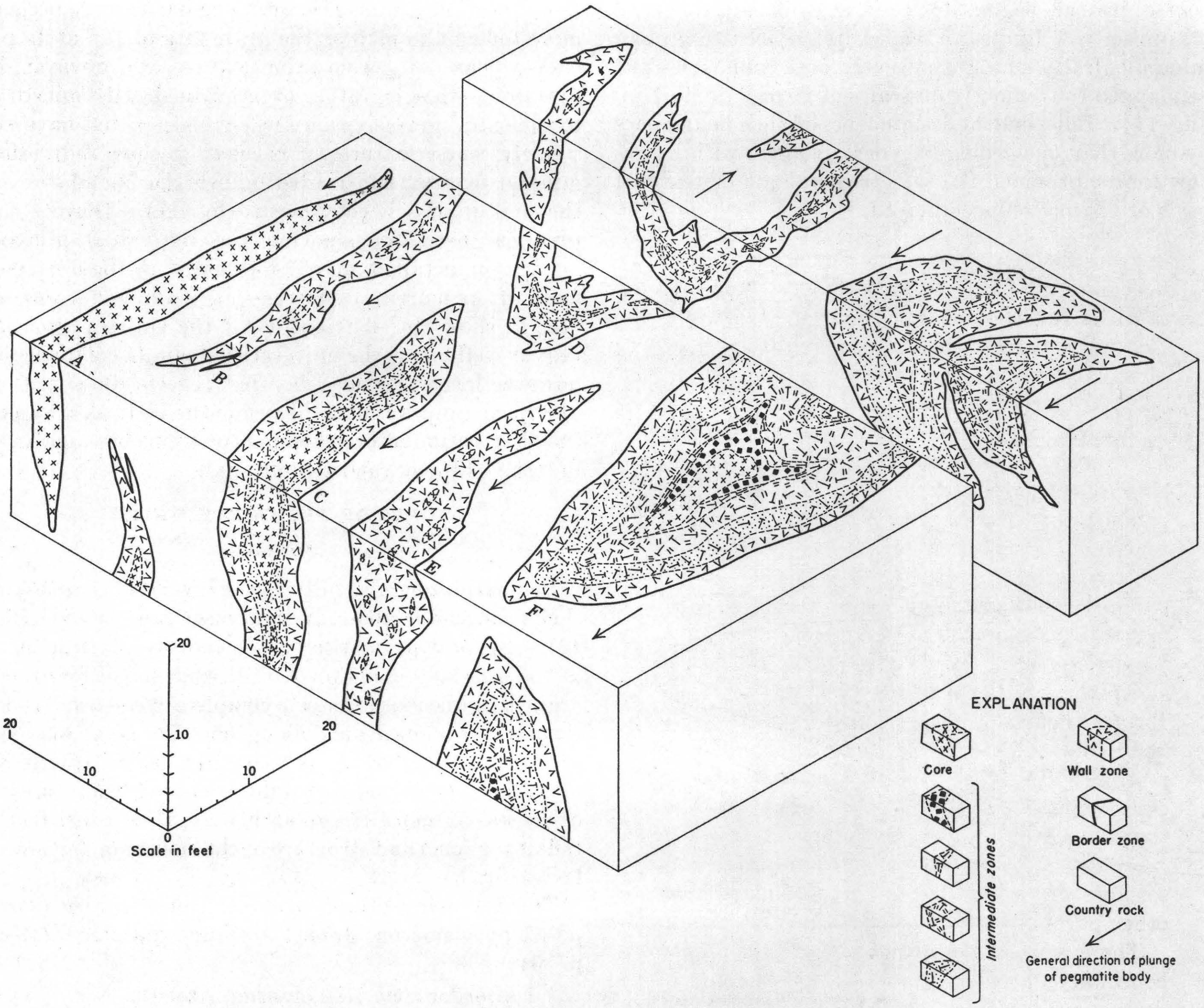

FIGURE 12.—Exploded isometric block diagram, showing the characteristic distribution of completely and partly formed zones in pegmatite bodies. *A*, Typical simple bizonal pegmatite. *B*, Simple pegmatite with lenticular core. *C*, Simple pegmatite with continuous intermediate zone. *D*, Troughlike pegmatite with lenticular core and intermediate zone. *E*, Simple pegmatite with pod-shaped core segments. *F*, Large forked polyzonal pegmatite.

pegmatites of simple shape. Some zones can easily escape detection, especially those that are not complete shells around the deposit. Such a zone may not be exposed, or it may not even be present at the level or levels of available exposures, as pointed out by several investigators. For example, see Cameron, Larrabee, McNair, Page, Shainin, and Stewart (1945, pp. 373, 391–393), Jahns (1946), and Cameron, Jahns, McNair, and Page (1949, pp. 21–24, 106–107). After careful study of the better-exposed deposits in a district it is often possible to predict, with reasonable accuracy, the structure of poorly exposed deposits or the structure of deposits that barely reach the surface. As few zones are complete shells, the possible presence of zone segments in unexplored parts of a pegmatite body may be of considerable economic importance. The usual structure of pegmatites in a given district must naturally be kept in mind when evaluating a poorly exposed body in it.

Pegmatite zones, as previously defined (Cameron, Jahns, McNair, and Page, 1949, pp. 14–19), are units that were not developed in fractures within, or by replacement of, preexisting pegmatite. Many such units, however, undoubtedly were formed in fractures within, or possibly by replacement of, country rock. The outermost zones of many pegmatites probably were de veloped in part by replacement of wall rock. Not all zones can be distinguished from pegmatite replacement bodies with assurance, even though the genesis and significance of the two types of units are fundamentally different. Some fracture fillings and replacement bodies, especially those whose position and attitude are controlled by zonal structure, are concentric about the pegmatite core; hence it should be recognized that the designation of some units as zones is necessarily tentative, pending a more satisfactory determination of their origin.

BORDER ZONES

The border, or outermost, zones are fine-grained selvages that commonly range in thickness from small fractions of an inch to 2 or 3 in. In some pegmatites, the border zones are much thicker, more irregular, and less sharply bounded. Nearly all those in the southeastern Piedmont are ¼- to 2-in. selvages or rinds and hence are too thin to be shown separately on any but the most detailed maps. They are characteristically rich in quartz and are sugary or granitoid in texture. Most consist of quartz and oligoclase, with or without muscovite or biotite. An arrangement of mica flakes or quartz plates and spindles normal to the contacts between pegmatite and wall rock is the commonest structure in border zones of Piedmont deposits.

Some border zones are sharply defined, but others fade into the adjacent wall zones. A great many contacts between border and wall zones are difficult to assign because thorough kaolinization and iron staining of the plagioclase in both units have partly or completely obscured significant textural differences. Some sharply bounded pegmatite selvages may have been formed through rapid initial cooling of the pegmatite body and therefore might be interpreted as chilled margins. In contrast, the composition of other border zones reflects digestion of wall rock and thus differs markedly from the composition of the remainder of the pegmatite. Excellent examples are the biotite-rich selvages of pegmatites in the Amelia district and in other parts of the Virginia-North Carolina Piedmont.

There appears to be little correlation between the continuity of border zones and the sharpness of their development. Some of the most clear-cut and conspicuous selvages are markedly discontinuous, whereas others form complete envelopes around the inner zones of pegmatite bodies. In general, however, border zones are more continuous than is apparent from casual inspection, although they are difficult to distinguish from adjacent parts of wall zones in many places.

Some of the broadest and most continuous—though very irregular—border zones occur in pegmatites around which the country rock is impregnated with much pegmatitic material. This altered wall rock in places grades into the border zone, which generally contains abundant mica flakes oriented parallel with the wall-rock foliation or normal to the pegmatite contact. Many platy concentrations of such flakes can be traced into wisps and thin, tabular masses of partly digested schist, and the entire planar structure of the zone may be inherited from that of replaced wall rock. This type of border zone is rare in Piedmont deposits north of Alabama. Other border zones, layered or distinctly foliated parallel to the pegmatite contacts, are sharply bounded from the wall rock. Such units commonly contain thin layers rich in quartz, mica flakes, or small garnet grains. Some of these may have been developed by flowage during pegmatite emplacement, others by injection along fractures in the border zones, and still others by diffusion and replacement.

WALL ZONES

Wall zones, which are next inside border zones, are typically coarser and much thicker than the border zones. The designation "wall zone" is based on a terminology firmly established in the domestic pegmatite-mining industry, and the actual occurrence of such units as the second zone within the margins of pegmatite bodies is thus ignored. The economic significance and thickness of border zones is so slight that in the industry they have been grouped with the adjacent wall zones or have been overlooked entirely. Wall zones ordinarily are the outermost mappable units in pegmatites, so that the designation is not wholly inappropriate.

Most wall zones are well defined, and in general they are the most continuous units in pegmatites. They range in thickness from a knife edge to 35 ft or more, with averages of 3 to 8 ft in most Piedmont districts. Their most abundant and widespread constituent is plagioclase, mainly oligoclase and calcic albite. Quartz and muscovite also are abundant; biotite is common in many pegmatites and perthite in a few. Accessory minerals include garnet, apatite, and beryl. Rarely the quartz appears as irregular spindles and rods in coarse-grained feldspar to form graphic granite. Most commonly it occurs with micas as nodules or irregular granular masses interstitial to feldspar grains. Nearly all wall zones are granitoid in texture and are fine- to coarse-grained. Porphyritic textures are known in other regions but are rare in the Piedmont.

In most pegmatites the wall zones are sharply bounded from adjacent cores and intermediate zones that consist almost wholly of only one or two minerals. Where zoning is not so distinct, medium- to coarse-grained wall-zone pegmatite commonly grades inward into rock of more potassic composition and markedly coarser texture. Wall zones constitute the bulk of many pegmatites, and they generally extend almost from wall to wall near the ends of both tabular and podlike bodies. They also fill most of the thicker parts of pegmatites that contain thin or discontinuous cores (fig. 12).

The wall zones of most Piedmont pegmatites, even those that are irregular and contain several zones, form complete or nearly complete envelopes around all the inner units. Some of these envelopes are strikingly uniform, and some pinch and swell markedly. Other wall zones are much less complete and occur only as sheets, lenses, or groups of lenses along the footwalls or hanging walls of pegmatite bodies or as hoodlike or saddlelike masses around the ends of the inner units (fig. 12). The thickness, composition, and texture of wall zones commonly vary systematically within the pegmatite bodies, particularly with respect to rolls, bulges, and other irregularities in the contacts between pegmatite and wall rock or the crust or keel of the pegmatite body. Especially great variations occur near inclusions and elongate septa of country rock.

Platy or crudely layered structures are present in some wall zones. Many steeply dipping pegmatites in the southern part of the tin-spodumene belt of the Carolinas contain wall zones with spodumene laths oriented nearly normal to the contacts between pegmatite and country rock. As they are traced toward the centers of several thick dikes, these laths are seen to be bent, possibly by drag from moving material. The central parts of such dikes consist of spodumene, feldspar, and quartz in alternating layers of contrasting coarseness and composition. Both the layers and many individual spodumene laths are essentially parallel with the dike walls. Detailed examination of these pegmatites indicates repeated shearing of a crystal-liquid mixture after formation of the wall zones.

INTERMEDIATE ZONES

Intermediate zones are the least regular and most highly discontinuous of all pegmatite zones. They occur between the wall zones and cores, and where more than one is present in a single pegmatite body they are distinguished by letter, number, or such terms as "outer," "middle," and "inner." Intermediate zones adjacent to cores have been designated as "core-margin" zones in many New England pegmatites (Cameron, Larrabee, McNair, Page, Shainin, and Stewart, 1945, pp. 380–385), but the purely descriptive term "core margin" need not be restricted to zones. It is also very helpful as applied to mica concentrations, replacement bodies, and other lithologic and structural units and is used in this broad sense throughout this report.

Many Piedmont pegmatites contain no intermediate zones, but others contain as many as three. Most of these units are lenticular, and many are so incompletely developed that the internal structures of the pegmatite bodies are markedly asymmetric. Pods, curved lenses, and hoodlike and troughlike forms are common. Slight variations in the shape and attitude of the pegmatite bodies affect the completeness and distribution of intermediate zones more than any other units. In short thick pegmatite pods, for example, such zones commonly are nearly as complete as wall zones, but in thinner pods the intermediate zones are much less continuous. In some long dikes they are restricted to parts where the cores are thin or entirely absent; in others they are restricted to parts where the cores are thick (fig. 13). Most incompletely formed intermediate zones ocur at one or both ends of cores or core segments. They are thickest in such places and characteristically taper out along the flanks of the innermost units. Thin lenses of similar rock may be strung out beyond the tapering ends of many of these hoods.

The composition of the intermediate zones ranges widely. Perthite is the most common mineral and occurs in coarse to very coarse agregates. It forms thick masses in the central parts of some pegmatite bodies

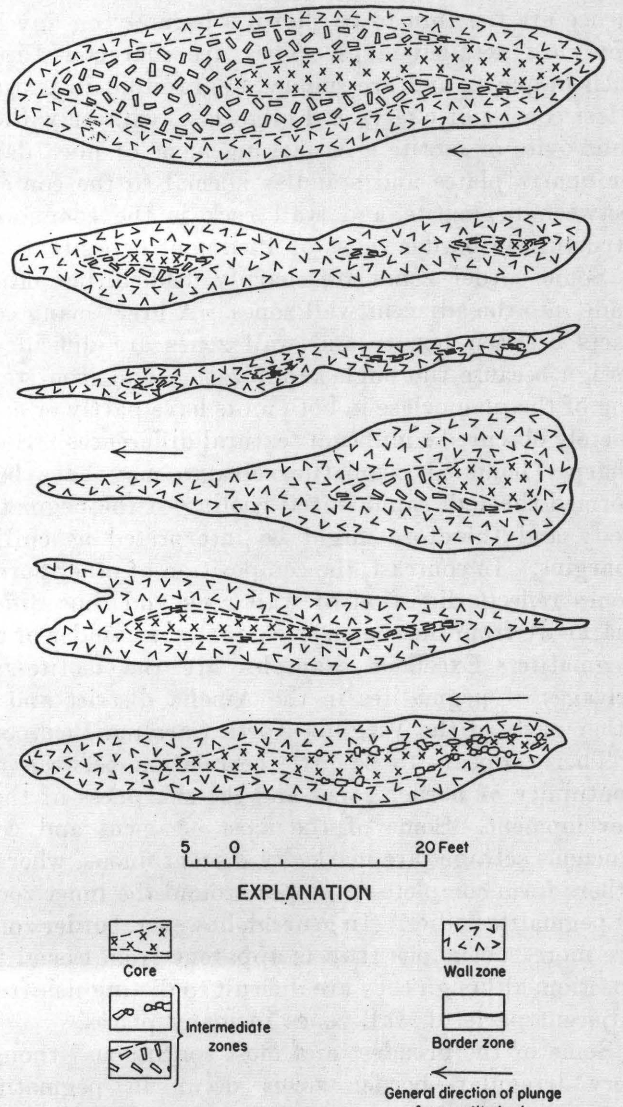

FIGURE 13.—Typical forms of intermediate zones and cores in pegmatite bodies.

beyond the ends of quartz cores where the admixture of other minerals may be great. Large individual crystals stud the margins of some cores and constitute an extreme development of discontinuous intermediate zones (fig. 13). Many thin intermediate zones are rich in coarse "A" books of muscovite. These ordinarily occur against the sides of cores. Quartz, plagioclase, and graphic granite are other common intermediate-zone constituents, and some intermediate zones are granitoid aggregates of perthite, plagioclase, and quartz, with or without muscovite or biotite.

CORES

Cores generally occur at or near the centers of pegmatite bodies, either as elongate pods or as series of disconnected segments (fig. 12). Many are very irregular. Single cores range from long thin "spines" or "ribs" to cigar-shaped and thickly ellipsoidal masses. Ordinarily they are more symmetrically disposed with respect to the sides of elongate pegmatite bodies than with respect to their ends, and they are relatively near the keels or crests of most plunging bodies (fig. 13). In general the core is only a small part of the containing pegmatite body, but in a few pegmatites the cores constitute the great bulk of the zone material. Thus three pegmatite bodies on the Banister and Garner properties in the Hartwell district and several in North Carolina and Virginia consist of massive quartz cores with very thin, discontinuous feldspathic wall zones. In other deposits, like the Mill Race in the Shelby-Hickory district, the cores swell downward and the outer units taper correspondingly. In places the cores occupy the full width of the pegmatite. Cores also constitute the bulk of many pegmatite bodies in which only two zones are developed.

Many cores are discontinuous, particularly in those pegmatites that are very elongate or irregular in shape. Individual segments generally occur in or near the central parts of bulges and are similar to these bulges in shape and attitude. Core segments also are commonly developed at the junctions of thin, elongate pegmatite bodies and their principal branches.

Most cores consist of massive quartz or of massive quartz with scattered large crystals of perthite or plagioclase. Others are composed of coarse, blocky feldspar, with very little quartz. The cores of pegmatites in which only two or three zones are developed generally are medium- to coarse-grained aggregates of quartz and perthite; quartz and plagioclase; or quartz, perthite, and plagioclase, all with or without mica. Graphic granite and quartz-muscovite pegmatite also occur in cores in such pegmatites. These and the granitoid aggregates mentioned are in marked contrast to the monomineralic or bimineralic cores that are so common in pegmatites with three or more zones. Many large pegmatite bodies in which zonal structure is not well developed contain irregular, quartz-rich lenses that are coarser than the surrounding rock. These can be interpreted as small core segments.

FRACTURE FILLINGS

Fracture fillings are formed by the simple filling of fractures in pegmatite. Some are strictly open-space fillings, but all gradations exist between them and fracture-controlled replacement bodies. They are characteristically veinlike and range from thin stringers to tabular masses more than a foot thick and tens of feet long. Some are consistently oriented with respect to zone boundaries and appear to have been developed in contraction cracks formed, perhaps, during cooling of the host pegmatite. Others follow diagonal fractures not systematically related to zonal structure, and still others form irregular stockworks. Many fracture fillings transect boundaries between zones, but others lie entirely within single zones.

Veinlets and other fracture-filling masses occur in nearly all pegmatite districts in the southeastern Piedmont, but they constitute an almost negligible proportion of the total pegmatite material. Only in parts of the Amelia district and in some large pegmatites of the Otter River-Moneta area, Va., are they developed on anything but a minor scale. The most widespread fracture fillings are veins of milky, clear, and smoky quartz, which are especially abundant in intermediate zones and cores. In several pegmatites mined for feldspar in Bedford County, Va., fracture-filling veins of quartz with scattered small crystals of perthite can be traced into core segments of massive quartz, with which they appear to have been formed contemporaneously. Elsewhere, however, they are younger than all zones in the host pegmatite. Lenses and tabular masses of quartz may be fracture fillings in some pegmatites, notably the Hole in Stokes County, N. C., and several in the Shelby-Hickory and Hartwell districts, but their relations to the flanking units are not clear.

Coarse crystals and crystal aggregates of feldspar, especially the perthite of inner zones, are commonly veined by quartz, fine-grained albite, or aggregates of these two minerals. These are abundant, for example, in the Hawkins and Knight pegmatites of the Ridgeway-Sandy Ridge district, N. C., in the Adams pegmatite of the Thomaston-Barnesville district, Ga., and in several pegmatites of the Hartwell district, Ga. Fracture surfaces in many deposits are coated with thin films and layers of yellow to yellowish-green muscovite scales, and aggregates of such minerals and albite fill other fractures. The latter are especially abundant in the Collum "quartz blow-out" pegmatite, Tallapoosa County, Ala. Carbonate and sulfide minerals fill fissures in several pegmatites of the Shelby-Hickory district, N. C., and a garnet-rich layer that contains chlorite, pyrite, and other sulfide minerals is prominent in the A. F. Hoyle pegmatite, Cleveland County. Epidote veinlets have been noted in pegmatite and aplite in Baldwin County, Ga.

Zeolites form white to gray or yellowish-gray coatings on many fracture surfaces, especially in areas near Triassic dikes, and are so nondescript in appearance that they probably have been overlooked at many localities. Steeply dipping layers of tourmaline crystals transect plagioclase-rich pegmatite in the Banister mine, Hart County, Ga., and may have been developed in part at the expense of the host rock. Extreme examples of fracture fillings are thin blades of biotite, some of which are as much as 6 in. wide and 5 ft long. Many transect boundaries between crystals of feldspar, or feldspar and quartz, and others plainly lie athwart the structure of host graphic granite. These blades are not to be confused with those that have been formed contemporaneously with the enclosing pegmatite.

REPLACEMENT BODIES

Replacement bodies are units formed at the expense of preexisting pegmatite, either by solutions derived from other parts of the same pegmatite body or by solutions introduced from external sources. Excluded from this category are pegmatite units formed by replacement of country rock, as well as nearly all mappable units formed prior to complete consolidation of the parts of the pegmatite body affected by replacement (Cameron, Jahns, McNair, and Page, 1949, pp. 84–85). The corrosion, veining, and partial replacement of mineral grains through reaction during consolidation of a pegmatite zone are thus contrasted with the later replacement that occurs during the closing stages or after the formation of the zone. Replacement units are abundant and large in the Herbb No. 2 pegmatite, Powhatan County, and in the Rutherford and Morefield pegmatites, Amelia County, Va., and in many respects are like those described from the Petaca district of northern New Mexico (Jahns, 1946, pp. 48–51). Elsewhere in the Southeastern States, however, such units are rare and are very minor parts of the pegmatites in which they occur. Some replacement bodies are shoots superimposed on the zonal structure of the host pegmatite, but they differ greatly in genesis from the shoots that were developed as parts of zones. Thus the "replacement shoots" are basically different from "zonal shoots" and were formed at a much later stage.

Some replacement units were formed along fractures, others along contacts between pegmatite and wall rock or boundaries between zones. The structural control for still others has been obliterated or is otherwise not clear. Fracture-controlled units range from networks of thin, irregular veinlets, like the stockworks of sugary albite in the coarse, blocky perthite of the Rutherford and Morefield pegmatites, to thick, tabular masses like the coarse cleavelandite "dikes" in parts of the Morefield pegmatite. Large, lobate "cauliflower" masses composed of radiating blades of cleavelandite appear to have been developed along contacts between massive quartz core segments and perthite-rich intermediate zones in the Big Bess pegmatite, Gaston County, N. C. (fig. 19). They project into the quartz and evidently were formed mainly at its expense, although they might have formed before crystallization of the quartz. Large masses consisting of plagioclase and coarse, radiating books of wedge-A muscovite occur in central pegmatite units at the Pat Ayers No. 4 prospect in Randolph County, Ala.

Specific zones, parts of zones, or even specific minerals within the zones of some pegmatites are partly or completely replaced by albite and other minerals. Nearly perfect pseudomorphs of the wall zone appear to have been developed in parts of the Herbb No. 2 and Rutherford pegmatites. These units are aggregates of cleavelandite with minor quartz and accessory tantalum-columbium minerals, but the original wall-zone material probably was a medium- to course-grained granitoid pegmatite with sodic oligoclase as its principal constituent. In contrast to these is the attack on the wall zone of the Champion pegmatite, Amelia County, Va., composed mainly of calcic albite, quartz, and muscovite. The feldspar is extensively corroded, and vugs controlled by cleavage and compositional zones of crystals are locally very abundant, but no large quantities of later-stage minerals appear to have been introduced. Instead the cavities are thinly coated with fine-grained muscovite, some thin tablets of albite, needles of beryl and tourmaline, sulfide minerals, and carbonate minerals, and most of the open space in them is preserved. Similar vugs have been developed on a much smaller scale in several pegmatites of the Shelby-Hickory district, N. C., where they are lined with crystals or filled with anhedral masses of sulfide and carbonate minerals.

A tabular body of plagioclase-quartz pegmatite with abundant coarse book muscovite transects a boundary between zones in the Ben Martin mine of the Hartwell district and probably is of replacement origin. Such bodies appear to be rare. However, the mica in some varieties of "burr rock" may well have been formed by replacement of the host rock. Burr rock is a greisenlike material composed of massive quartz and abundant foils, plates, and equant books of muscovite that range in diameter from less than 1/16 to 5 in. Most are 1/4 to 3/8 in. across. The books contain many irregular inclusions of quartz and occur in crudely platy concentrations, as if controlled by fractures. The positions of these presumed fractures are marked by layers of gradulated and recrystallized quartz, and the mica appears to have been introduced after granulation, probably during recrystallization. Other varieties of burr rock, however, show no evidence of replacement of quartz by mica.

STRUCTURAL CHARACTERISTICS OF PEGMATITE BODIES

SIMPLE PEGMATITES

UNZONED PEGMATITES

A few pegmatites in the southeastern Piedmont appear in the field to be essentially homogeneous or "massive." This lack of zoning may in some places be more apparent than real, owing to incomplete surface exposures or to the presence of other zones in parts of the pegmatite beneath the surface. Moreover, many pegmatites have thin and inconspicous border selvages that are similar in composition but finer-grained than the rock farther from the walls. Slight differences in mineral proportion, plagioclase composition, and color of muscovite, for example, are systematic in their distribution within several pegmatites so studied, and it remains for further and much more extensive laboratory work to demonstrate how much systematic variation in composition occurs in unzoned pegmatites.

Most unzoned Piedmont pegmatites are small stringers, lenses, pods, and tabular masses. They are abundant in many districts, and the total bulk of pegmatite material involved is very large. The most widespread rock type is a fine- to medium-grained granitoid aggregate of plagioclase, quartz, and muscovite, with or without potash feldspar (fig. 20). Biotite is present locally, and typical accessory minerals are apatite, garnet, and magnetite. Beryl, monazite, tourmaline, zircon, and several other species are less common.

Another, very different rock type that forms many unzoned pegmatites is burr rock. In some burr rock the mica is scattered uniformly through the quartz without consistent orientation, but in other varities it is concentrated in poorly defined layers. These layers generally are parallel to the walls of the pegmatite body, but some are oblique or even normal to the walls. Consistent orientation of individual mica books is not common, so that well-developed foliation is rare, even in strongly layered varieties of the rock. The quartz is granular in some burr rock, particularly in the distinctly layered types.

Several other kinds of unzoned pegmatite are known, but these are not quantitatively important. Some consist almost wholly of quartz, with scattered crystals and small irregular aggregates of feldspar, and are scarcely more than quartz "veins." Muscovite is present locally, and a few large books occur in some of these pegmatites. Other quartz-rich bodies contain scattered thin but long plates of biotite, many of which appear to have been developed along fractures. A few pegmatite masses are sugary and aplitic in texture and could not be termed pegmatite except for the occurrence of scattered coarse crystals of plagioclase, perthite, or mica.

ZONED PEGMATITES

GENERAL STRUCTURE AND COMPOSITION

Pegmatites with two zones.—Pegmatites that consist of only two zones are generally simple in composition and structure, and they have many features in common with unzoned pegmatites. Granitoid aggregates of plagioclase, quartz, and muscovite, with finer-grained border selvages of similar composition, form the most abundant type of bizonal pegmatites in the southeastern Piedmont. Many of these pegmatites contain perthite and biotite, and the most common accessory minerals are apatite, beryl, garnet, and tourmaline. So far as general lithology and structure are concerned, these pegmatites are little different from the granitoid types of unzoned pegmatites (fig. 20). Unlike them, however, many of the bizonal masses are very large, reaching lengths of several hundred feet and widths of 30 ft or more.

The cores of nearly all pegmatites in the southeastern Piedmont with only two zones are simple granitoid aggregates, but the outer units of some are distinctly different in composition. Some consist of quartz with minor muscovite, and others are typical fine-grained burr rock. Still others are very rich in mica, with plates, foils, and books that commonly are oriented normal to the contact or nearly so. Many of these appear to have been developed by reaction between pegmatite solutions and the wall rock. Where coarse book mica occurs in bizonal pegmatites, the books generally are sparsely scattered, with little suggestion of shoots, "pipes," or other concentrations.

Pegmatites with more than two zones.—Pegmatites that contain three or more zones are the chief sources of mica, feldspar, and other economically desirable minerals in the southeastern United States. Most consist of thin quartz-mica, quartz-plagioclase, or quartz-plagioclase-mica border zones; wall zones of dominantly granitoid texture; and cores of massive quartz or massive quartz with scattered large crystals of plagioclase or potash feldspar.

Intermediate zones, where present, generally are monomineralic or bimineralic. The common lithologic types include coarse, blocky perthite or plagioclase, coarse-grained perthite-quartz-muscovite or perthite-quartz-biotite pegmatite, coarse-grained graphic granite-biotite pegmatite, and massive quartz with large crystals of perthite or plagioclase. Some intermediate zones, especially the outer intermediate zones of pegmatites with five or more zones, consist of coarse-grained, granitoid quartz-plagioclase-perthite pegmatite, with or without muscovite and with or without biotite. "A" muscovite is most common in intermediate zones, whereas flat books occur in most wall zones. In general, wall zones are combinations of plagioclase, quartz, muscovite, and perthite, with or without biotite. They are richer in plagioclase and leaner in potash feldspar than intermediate zones and ordinarily contain lower proportions of quartz than border zones.

IRREGULARITIES IN ZONAL STRUCTURE

Nonconcentric development of zones.—The zonal structure of most pegmatites in the southeastern Piedmont departs considerably from the ideal concentric layering shown in figure 12, as previously pointed out. Incompletely developed units, especially intermediate

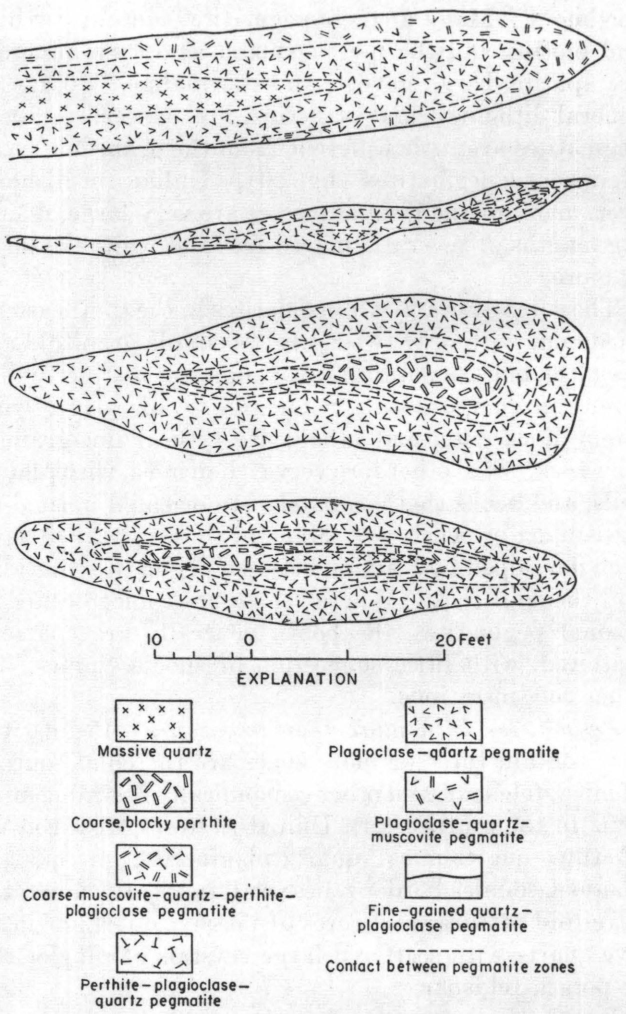

FIGURE 14.—Idealized plans, showing several types of asymmetric zone development in pegmatites.

zones, most commonly affect the symmetry of the internal structure (figs. 12 and 13). Asymmetry is extreme wherever a given zone is developed only at one end or only along the hanging wall or footwall of a pegmatite body (fig. 14). Such relations are especially common in thin, elongate sills and dikes, especially in the western part of the Ridgeway-Sandy Ridge district, N. C. They generally involve intermediate zones, wall zones, or both. The most confusing relations, especially in pegmatites not completely exposed, are along those parts of quartz-core margins that lie beyond the tapering ends of short, thick, hoodlike intermediate zones of coarse, blocky perthite. Although these incompletely developed intermediate zones are next outside the cores, the cores are flanked along most of their margins by middle or outer intermediate zones, or even by wall zones. Thus some so-called core-margin mica concentrations can be traced around the outer margins of discontinuous intermediate zones that are present only at the ends of cores (fig. 14); others continue along the core margin.

Most common among the other nonconcentric zonal structures are irregular pods and lenses, in general relatively coarse grained and rich in quartz, that occur in otherwise homogeneous granitoid pegmatite. These can be interpreted as poorly developed core segments wherever they occur in the central parts of pegmatite bodies, but where they are scattered from wall to wall their significance is not so clear. Most of those that have been studied in detail appear to have been formed from pegmatite solutions that were trapped in isolated pockets within already consolidated pegmatite. The sequence of zones outward from each lens or pod is uniform within a given pegmatite body (fig. 15) and follows the normal pattern for the district. Thus, despite their positions, these scattered features also can be interpreted as core segments, and the enclosing pegmatite bodies can be viewed as a complex of zones developed about scattered centers, rather than about a single center or centrally located series of centers.

A platy segregation of minerals is characteristic of many pegmatites, especially those in parts of the Shelby-Hickory, Hartwell, and Alabama districts. The steeply dipping G. B. McSwain dike, Cleveland County, N. C., consists almost wholly of plagioclase, perthite, muscovite, and quartz, but most of the potash feldspar occurs in nearly horizontal layers, less than a foot thick, that are separated by perthite-poor plagioclase-quartz pegmatite. Similar variations occur within individual zones in other pegmatites, but the cause for these peculiar structures is not known. The Hole pegmatite, Stokes County, N. C., contains several parallel tabular masses of quartz that are separated by feldspathic layers. These quartz masses, which locally are as much as 6 ft thick, might be segments of a core, or some may

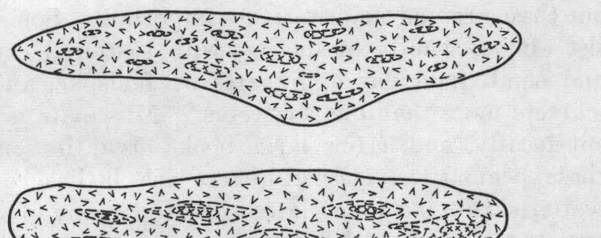

FIGURE 15.—Typical zonal relations in pegmatites with quartz-rich podlike masses.

have been injected along fractures in previously consolidated pegmatite. The quartz core of the Ruby King pegmatite, farther east in the same county, locally splits into two well-defined layers, one of which lies above the other.

One of the most common internal structures in Alabama pegmatites is a parallel arrangement of numerous platy quartz masses 1 to 12 in. thick and 1 to 6 ft long. These generally are parallel to the walls of the enclosing pegmatite bodies. Most are closely spaced and are separated by layers of feldspathic pegmatite with subordinate granular quartz and muscovite. In some deposits each quartz plate is surrounded successively by mica books and by feldspathic pegmatite and hence is like a typical core segment (fig. 16). The structure as a whole may well represent a discontinuous or rudimentary zoning, possibly in part with respect to septa and inclusions of wall rock, and some of the pegmatites show gradations from multiple quartz plates into single central quartz masses. Such gradations extend typically from northeast to southwest along the strike of the gently southwestward-plunging pegmatites, or from keel to crest.

Some pegmatite masses have a coarse and crude lit-par-lit structure, with alternating layers of pegmatite and thinner layers or wisps of wall rock. Most of the wall-rock layers are inclusions, and the others are elongate septa. Pegmatite zones are commonly developed with reference to these country-rock masses rather than only with reference to the main pegmatite walls. In pegmatites at the Banister and Garner mines of the Hartwell district, for example, small lenticular masses of quartz are oriented parallel to contacts between pegmatite and country rock and appear to have been formed in parts of the deposits between the largest and most widely spaced inclusions (fig. 17). In deposits where wall-rock masses are relatively large and far apart, segments of this type of quartz core are correspondingly large and locally are as much as 20 ft long. Where the inclusions are small or abundant, however, the segments are small or absent.

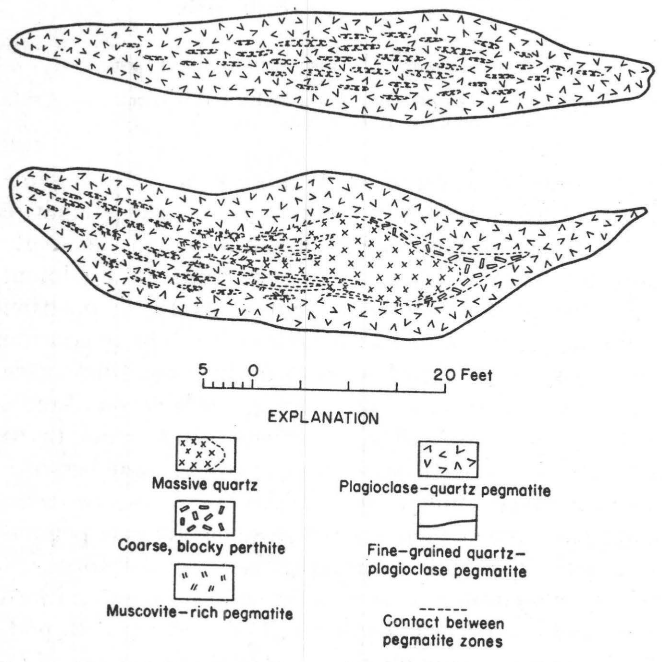

FIGURE 16.—Relations of platy masses of quartz in typical Alabama pegmatites.

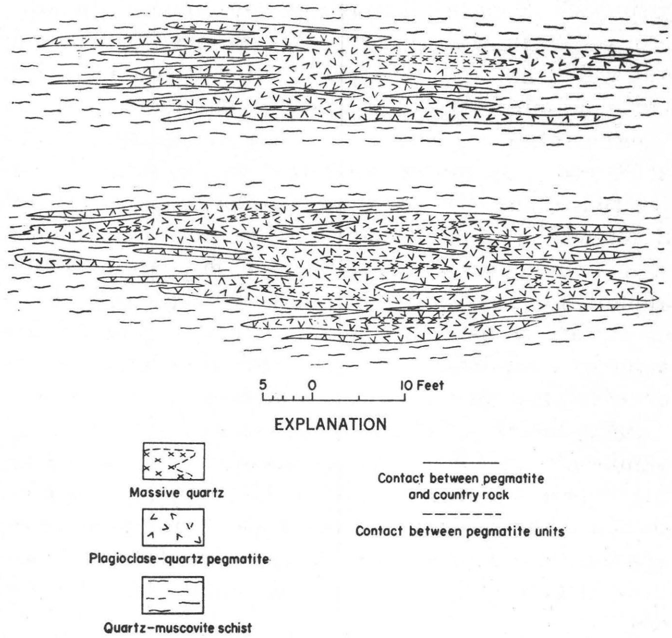

FIGURE 17.—Distribution of platy quartz masses in pegmatites with many septa and inclusions of wall rock.

The pegmatites of several districts are layered in a manner suggesting strong flowage during emplacement and consolidation, and several appear to have been fractured and sheared during or immediately after consolidation, with subsequent introduction of additional pegmatitic material. Thin plates of quartz, lenses of fine- to medium-grained plagioclase, and individual books of muscovite in the Hawkins pegmatite, Stokes County, N. C., are concordant with the walls of the pegmatite sill and appear to have been oriented by flowage within it. Such movements also are evidenced by bent mica books and bent or broken blocks of feldspar. Some late movements were accompanied by the introduction of quartz and local plagioclase. Similar structures are characteristic of several large spodumene-bearing pegmatites in the tin-spodumene belt of the Carolinas.

Shoots. The relative proportions of different minerals within individual zones are by no means constant. In the zones of most pegmatites the order of abundance of the major constituents is uniform, but variations in the proportions of muscovite, biotite, and such accessory minerals as beryl, garnet, and tourmaline commonly are very large. Concentrations of mica are especially prominent in some zones, where they are known as "shoots," "barrels," "columns," "leads," "pockets," or "streaks." Some are barely distinguishable from adjacent parts of the zones, but others are exceptionally rich and well defined. Similar shoots of beryl and other less common minerals are recorded from most districts. Concentrations of certain minerals in specific parts of zones generally can be recognized on the basis of composition alone, but these are emphasized by textural differences in many places. Thus commercial mica shoots commonly are marked, not only by unusually abundant books, but also by relatively large ones. Some shoots are rather uniform in texture, but others are layered or exhibit unsystematic variations in grain size or orientation of constituent minerals.

Some shoots are lenses or elongate pods or even are blanketlike in form, and they commonly occur along the inner or outer margins of the host zones. All gradations are known between these features and true zones, and the distinction between the two—based mainly upon their structural relations—is necessarily an arbitrary one.

All shoots are at least indirectly related to the over-all shape and structure of the enclosing pegmatite bodies. More specifically, they are closely related to and perhaps controlled in distribution and shape by bends, rolls, or other irregularities in contacts between pegmatite units or between pegmatite and wall rock. Some occur only in pegmatite bulges, and others are confined to constrictions. Still others are along the crests or keels of zones (especially cores) or of entire pegmatite bodies, above or beneath warps in pegmatite contacts, at junctions of pegmatite branches, and beyond tapering ends of nearby zones.

Nearly every type of irregularity seems to be a possible control for localization of a shoot of mica or any other mineral within a pegmatite zone, abut it is by no means true that every irregularity in a pegmatite contact is accompanied by a shoot. In many districts there is a striking accordance in direction and degree of plunge between the axes of mica shoots and the axes of minor folds and other irregularities in nearby contacts between pegmatite and wall rock. In some districts the plunge is parallel also to the axes of drag folds and other linear elements in the adjacent country rock.

The distribution of mica and other commercial minerals is not uniform in the zones of the pegmatites of the southeastern Piedmont. This feature is of great economic significance, as few muscovite-bearing zones, for example, can be profitably mined in their entirety. The positions of many of the mica shoots are shown by the distribution of mine workings, and the relatively barren pegmatite adjacent to shoots generally is exposed in the walls and backs of these workings.

Zones are shown on the pegmatite maps of this report wherever possible. Shoots of mica and other minerals are indicated on some maps, but in many instances it it is not practicable to show such features, because their distribution in the pegmatite is not accurately known. Available information concerning them, however, is included in all mine descriptions. It is important to recognize that a zone shown on the map as plagioclase-quartz-muscovite pegmatite, for example, might well contain rich concentrations of book mica in some places, but little of it elsewhere. It is well, therefore, to obtain and interpret all available data concerning the distribution and other characteristics of the mica concentrations in advance of any attempts at exploration or mining.

Telescoping of zones.—Two or more zones that are clearly defined in parts of some pegmatite bodies appear elsewhere to merge along their dip and strike into single units of composition similar to the bulk composition of the corresponding zones. The positions of such

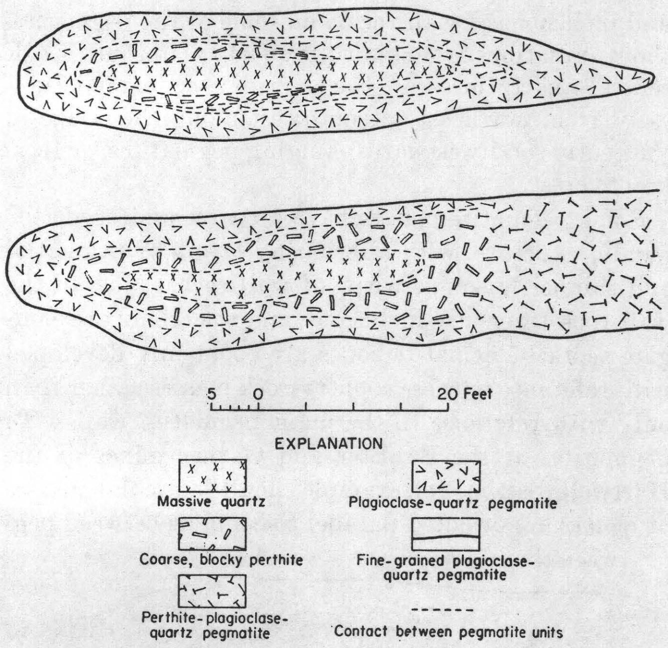

FIGURE 18.—Telescoping of zones in pegmatite (below), contrasted with overlapping of intermediate zones (above).

single units with respect to flanking zones are the same as those occupied jointly in other parts of the pegmatite by the zone pairs or zone groups into which the single unit can be traced; or, more commonly in Piedmont pegmatites, the single units occupy mainly the position of the innermost zone of the zone pair. The gradation from pairs or groups of zones into corresponding single units has been termed "telescoping" (Cameron, Jahns, McNair, and Page, 1949, pp. 43–44) and is not to be confused with simple tapering out of one zone between two or more continuous units (fig. 18). It is most common in podlike pegmatites and in some elongate pegmatites with local bulges or irregular protuberances.

Most telescoping involves intermediate zones and wall zones and is especially common in pegmatites with podlike cores or core segments of massive quartz (fig. 18). Contacts between zones are typically sharp along the

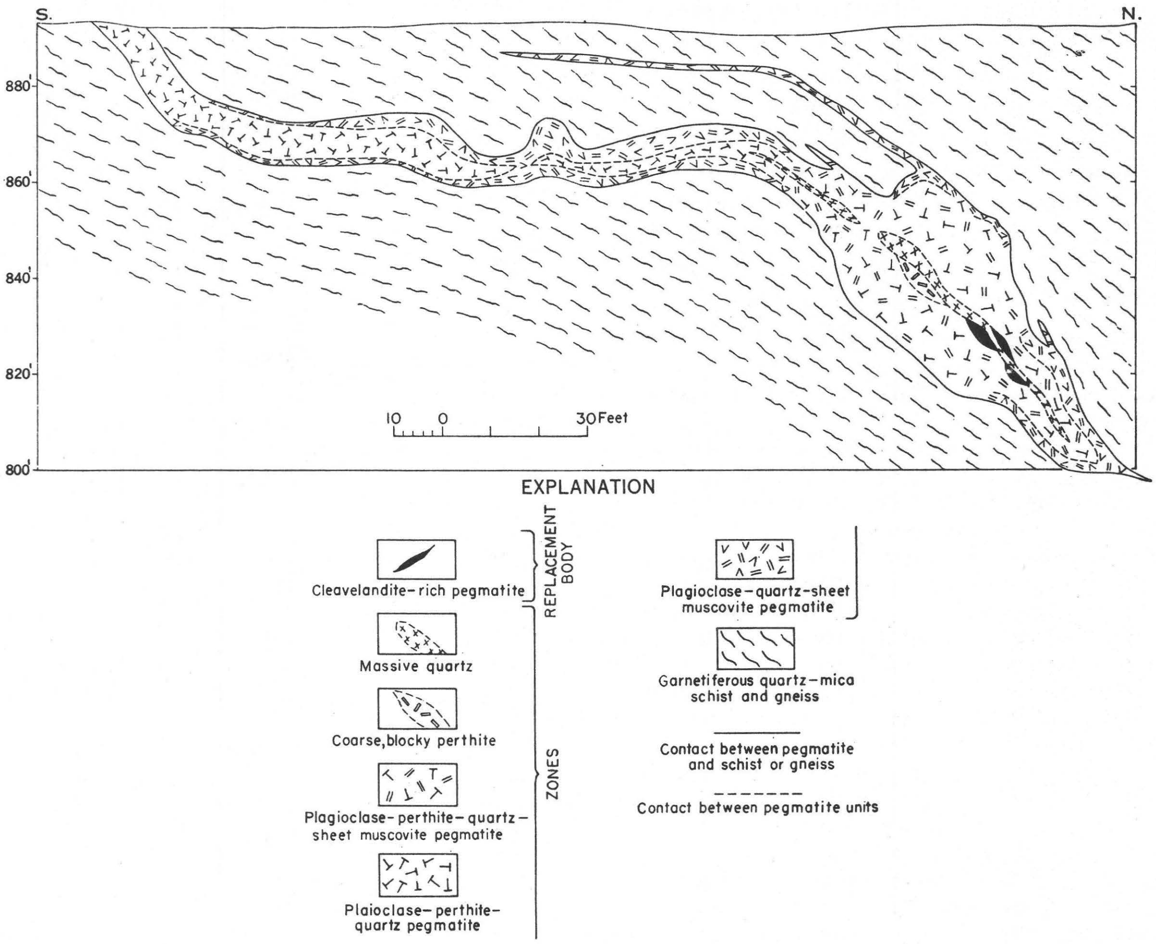

FIGURE 19.—Diagrammatic cross section of the Big Bess pegmatite, Gaston County, N C., showing the distribution of zones and other units.

flanks of these quartz masses, but many become gradational beyond their ends. The textural contrast between the telescope zones and their zonal analogues generally is striking. In several pegmatites of the Shelby-Hickory, Hartwell, and other districts intermediate zones of coarse, blocky perthite are traceable into units of granitoid plagioclase-perthite-quartz pegmatite. The wall zone, though without sharp boundaries with the telescoped unit, is, in most deposits, recognizable. The Big Bess body (fig. 19) is an exception. Less common are gradations of coarse, blocky perthite and coarse, blocky plagioclase zones into units of coarse-grained perthite-plagioclase pegmatite, as well as gradations of core-margin zones of blocky perthite, middle intermediate zones rich in coarse "A" muscovite, and outer intermediate zones rich in coarse plagioclase into plagioclase-perthite-quartz-muscovite units beyond the ends of the core segments.

An unusual complete exposure of down-dip telescoping of zones is provided by the workings of the Big Bess mine, Gaston County, N. C. The pegmatite dike is 4 ft to more than 25 ft thick and dips gently northward in quartz-mica schist. It is nearly flat where exposed in a large open-cut and consists of a thin quartz-plagioclase border zone, a plagioclase-quartz wall zone exceptionally rich in coarse book muscovite, and an inner zone of coarse-grained plagioclase-perthite-quartz pegmatite (fig. 14). As traced back toward the outcrop into a more steeply dipping part of the dike, the inner zones merge gradually to form a granitoid aggregate of plagioclase, perthite, and quartz. A different gradation is present in another steeply dipping part of the dike, exposed as a thick bulge near the pit face and in extensive underground workings. Segments of a tabular quartz core are fringed here and there by coarse perthite that forms a thin, very discontinuous inner intermediate zone, and both are flanked by a telescoped unit of coarse-grained plagioclase-perthite-quartz-muscovite pegmatite. Farther down dip, where the dike thins near the limit of the underground workings, this unit is traceable into a distinct plagioclase-quartz-muscovite wall zone and a mica-poor plagioclase-perthite-quartz outer intermediate zone (fig. 19).

SEQUENCES OF MINERAL ASSEMBLAGES IN ZONES

Many types of lithologic sequences have been recorded from polyzonal pegmatites in the southeastern Piedmont. Those involving three zones are characteristically simple, and similar sequences commonly occur over entire districts. Pegmatites with five or more zones, in contrast, are much more complex, and many lithologic combinations are possible. Such combinations follow certain definite patterns, as will be pointed out later, but so large a variety of minerals is involved that many individual zone successions are known. The following combinations of zones are discriminated wholly on the basis of common minerals and are typical of those recorded from pegmatites in the southeastern Piedmont:

1. Border zone, plagioclase-quartz wall zone (with or without mica), and quartz core.
2. Border zone, plagioclase-perthite-quartz wall zone (with or without mica), and quartz core.
3. Border zone, plagioclase-quartz wall zone (with or without mica), and quartz-perthite core.
4. Border zone, plagioclase-perthite-quartz wall zone (with or without mica), and quartz perthite core.
5. Border zone, plagioclase-quartz wall zone (with or without mica), blocky perthite intermediate zone, and quartz core.
6. Border zone, plagioclase-quartz wall zone (with or without mica), perthite-plagioclase-mica-quartz outer intermediate zone, blocky perthite inner intermediate zone, and quartz core.
7. Border zone, plagioclase-perthite-quartz wall zone (with or without mica), and perthite-plagioclase-quartz core (with or without mica).
8. Border zone, plagioclase perthite-quartz wall zone (with or without mica), perthite-plagioclase-quartz intermediate zone (with or without mica), and quartz core.
9. Border zone, quartz-perthite wall zone, and quartz core.
10. Border zone, plagioclase-quartz wall zone (with or without mica), plagioclase-perthite-quartz-mica outer intermediate zone, perthite-plagioclase-quartz-mica middle intermediate zone, blocky perthite inner intermediate zone, and quartz core.
11. Border zone, plagioclase-quartz wall zone (with or without mica), blocky plagioclase outer intermediate zone, blocky plagioclase-perthite-quartz-mica middle intermediate zone, blocky perthite inner intermediate one, and quartz core.
12. Border zone, plagioclase-quartz wall zone (with or without mica), plagioclase-perthite-quartz-mica outer intermediate zone, plagioclase-perthite-quartz and perthite-plagioclase-quartz middle intermediate zones, blocky perthite inner intermediate zone, and quartz core.
13. Border zone, plagioclase-quartz wall zone (with or without mica), and blocky perthite core.
14. Border zone, plagioclase-perthite-quartz wall zone (with or without mica), and blocky perthite core.
15. Border zone, plagioclase-perthite-quartz wall zone (with or without mica), perthite-plagioclase-quartz intermediate zone (with or without mica), and blocky perthite core.
16. Border zone, quartz-mica wall zone, and plagioclase-quartz core.
17. Border zone, quartz-mica wall zone, plagioclase-quartz intermediate zone, and quartz core.
18. Border zone, quartz-mica wall zone, plagioclase-perthite-quartz intermediate zone (with or without mica), and quartz core.
19. Border zone, quartz-mica wall zone, plagioclase-perthite-quartz outer intermediate zone (with or without mica), perthite-plagioclase-quartz inner intermediate zone (with or without mica), and quartz core.

The characteristic distribution of the zones representing several of these sequences is shown in figure 20.

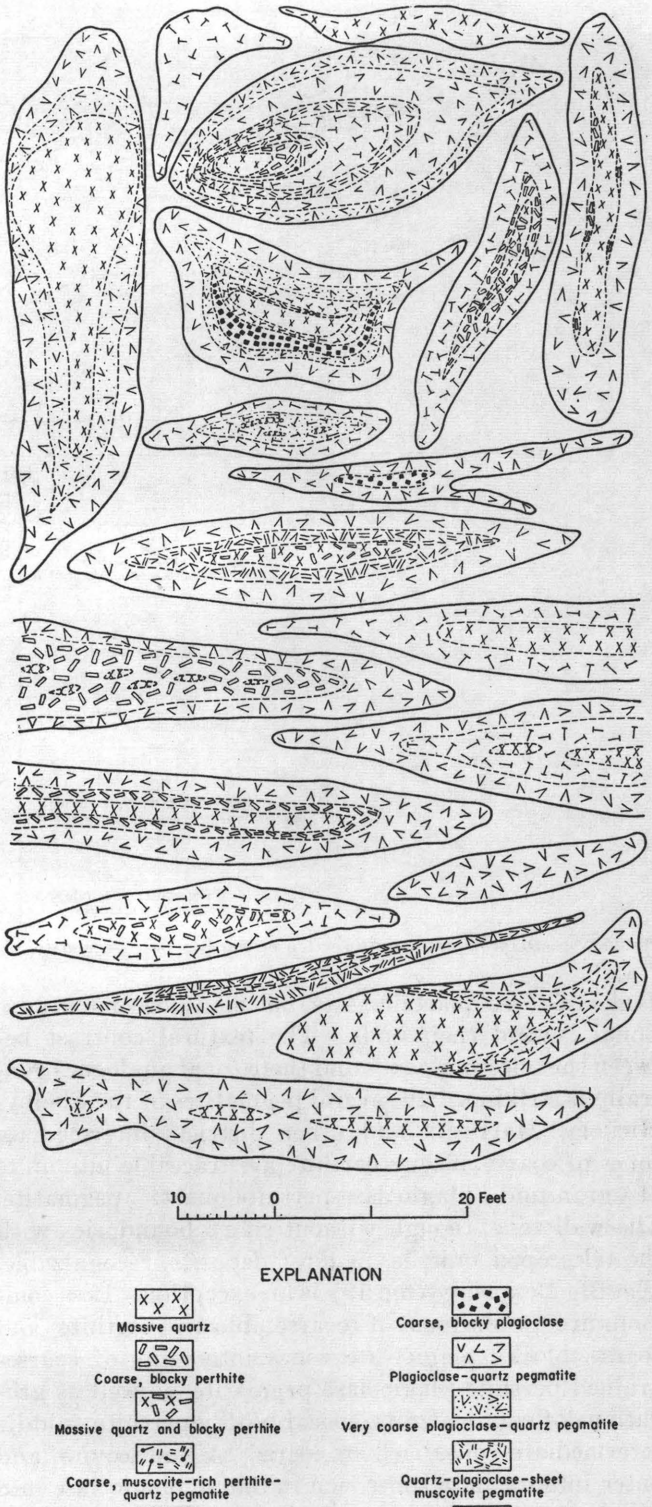

FIGURE 20.—Idealized plans, showing the characteristic distribution and lithology of zones in pegmatites of the southeastern Piedmont.

Even though many individual combinations of rock units are possible wherever five or more zones are present, a single broad pattern or general sequence is characteristic of all those zoned mica-bearing pegmatites in the Southeastern States that are sufficiently well exposed to be examined in detail. It seems to be entirely compatible with sequences for zoned pegmatites throughout the remainder of the United States (Cameron, Jahns, McNair, and Page, 1949, pp. 59–70). The following sequence for mica-feldspar pegmatites of the Southeastern States, which does not include coverage of the tin-spodumene pegmatites of North Carolina and South Carolina or the tin-bearing pegmatites of Alabama, is based solely upon occurrence of the most common pegmatite minerals. The right-hand column shows corresponding designations in a more general sequence for major pegmatite districts in the United States (Cameron, Jahns, McNair, and Page, 1949, pp. 61, 63). The center column gives the mineral assemblage.

A.	Quartz-muscovite, with or without biotite	Variant of 1
B.	Quartz-plagioclase-muscovite, with or without biotite	Variant of 1
C.	Plagioclase-quartz-muscovite	1
D.	Plagioclase-quartz	2
E.	Plagioclase-quartz-muscovite	Variant of 2
F.	Plagioclase	Variant of 2
G.	Plagioclase-perthite-quartz-muscovite, with or without biotite	Variant of 3
H.	Plagioclase-perthite-quartz	Variant of 3
I.	Quartz-perthite-plagioclase with or without muscovite, with or without biotite	3
J.	Perthite-quartz-muscovite	Variant of 4
K.	Perthite-quartz	4
L.	Perthite	Variant of 4
M.	Perthite euhedra-quartz	Variant of 4
N.	Quartz	11

Members of this sequence are listed in the order of their occurrence from the walls of the pegmatite inward. They do not correspond to zones, but are merely minerals or mineral combinations that form readily recognizable rock types.

No pegmatites contain all fourteen members of the above sequence, and distinctly zoned pegmatites contain only three or four. Regardless of the number of zones in a given pegmatite, however, the order of occurrence of its component mineral assemblages is consistent with that shown. Thus, if the border zone of a three-zone pegmatite is composed of quartz and muscovite, the wall zone might also be quartz-muscovite pegmatite or it might be some other member of the sequence and the core might be any member at the same position or lower in the list than the wall zone. Similarly, if the border zone is quartz-perthite-plagioclase pegmatite (member *I* in the list), no inner zone will have a lithology of a type shown higher on the list (members *A*–*H*).

No exceptions to this general order are known in zoned mica-bearing pegmatites of the southeastern Piedmont. Similar relations hold for the tin- and lithium-bearing pegmatites, although their treatment here would necessitate the addition of at least two other assemblages to the sequence listed.

Lack of member-by-member correspondence between the sequence of mineral assemblages in a given pegmatite and the sequence outlined can be caused by one or more of the following factors:

1. One or more members of the general sequence may not be present in the pegmatite. This is true of nearly all pegmatite bodies.

2. Two or more zones in the pegmatite may be telescoped into a single unit. The lithology of such a unit represents a combination of the individual zones and hence corresponds to the part or parts of the general sequence that they represent.

3. Some mineral assemblages in the pegmatite may not be present as such in the general sequence, owing to their characterization on the basis of minerals other than quartz, plagioclase perthite, muscovite, and biotite.

4. Two or more zones in the pegmatite may correspond to a single member of the general mineral-assemblage scheme, owing to their discrimination on the basis of textural differences only.

5. Some assemblages of minerals in the pegmatite may not appear to correspond to members of the general sequence, either because one constituent is locally present in unusually large proportions (as in a mica shoot) or because it is a very minor part of the unit.

Most border and wall zones in the southeastern Piedmont are equivalent to *A* and *B* in the general scheme of mineral assemblages. They are characteristically rich in quartz and plagioclase, with or without muscovite. Some contain biotite. Some outer zones contain perthite, especially in simply zoned pegmatites; hence they correspond in lithologic character to the intermediate zones of other pegmatites richer in plagioclase. Both intermediate zones and cores vary greatly in lithologic character. The cores of most bizonal pegmatites are composed of any assemblage of minerals listed between *A* and *I* in the general sequence, but in polyzonal pegmatites the cores correspond to units in the range *H*–*N*. Many mica-rich zones that fringe pegmatite cores correspond to member *G* or member *I* of the general sequence. They lie against quartz cores in pegmatites or parts of pegmatite bodies where perthite or perthite-quartz zones are not developed, but elsewhere they are separated from the cores by one or both of these zones.

The consistency of mineral-assemblage sequences from pegmatite to pegmatite and from district to districe is useful for economic studies and exploration. Book muscovite, for example, ordinarily occurs in zones corresponding to members *A*, *B*, *C*, *G*, or *I* of the general sequence. Recognition of any one lithologic unit in a given pegmatite commonly provides a basis for directing attention toward other parts of the pegmatite, if the general zonal structure is known. Identification of the border-zone material in terms of the general sequence immediately determines the maximum number of commercial mica-bearing zones (not shoots) that might be present in the pegmatite, although it by no means indicates that any or all of them will be present.

COMPOSITE PEGMATITES

Many pegmatites in the southeastern Piedmont appear to be composite bodies in the general sense that they consist of distinctly different rock types, each of which is assignable to a different stage of emplacement. Thus most fracture fillings and replacement units, if strictly interpreted, combine with the preexisting zones to form composite bodies. All these units, however, consist of closely related pegmatite, as is true of those pegmatites whose internal structure was complicated during consolidation by repeated fracturing and introduction of new material. Commonly these are layered, but the layers rarely differ greatly from one another in composition.

Some pegmatite bodies, in contrast, contain one or more related intrusive masses of markedly different composition, texture, or both. In general such masses are demonstrably different in age from the host pegmatite, and they include a variety of rock types. The occurrence of a tabular mass of coarse-grained pegmatite in much finer grained pegmatite of different composition at the Scott mine, Hart County, Ga., seems to have been caused by the injection of coarse material into already consolidated intrusive rock. Several other pegmatites in the Hartwell district contain lenses and more irregular masses of fine-grained granitic rock. The central part of the Rosa Evans sill, Rockingham County, N. C., is a fine- to coarse-grained granite, and its contacts with the enclosing pegmatite suggest that it was injected into the central part of a thick pegmatite sill to form a composite body.

MINERALS OF THE PEGMATITE AREAS

OCCURRENCE

More than 150 minerals have been recognized in the rocks of the principal pegmatite districts in the southeastern Piedmont, and doubtless many others will be added to the list as more detailed investigations are made and as additional unweathered rock is exposed during the course of mining and exploration. Some of the minerals occur only in the country rock or in deposits not genetically related to the pegmatites, but most are found within the pegmatites and many occur in such rocks only.

The most abundant minerals are biotite, microcline (chiefly as perthite), muscovite, sodic plagioclase, orthoclase, and quartz. As shown in table 3 (compiled from published sources and the results of original work), they are common in both the pegmatite and country rock of all the districts. The most common accessory species in the pegmatites are apatite, beryl, spessartite, sulfide minerals, and tourmaline.

TABLE 3.—*Occurrence of minerals in pegmatite areas of the southeastern Piedmont*

A, Abundant; C, common; S, sparse; R, rare; r, very rare; ?, reported, but possibly in error; a, absent or not known. First letter in each entry refers to pegmatite, the other to country rock and nonpegmatitic deposits]

Mineral	Amelia district, Va., and outlying areas to north	Areas in west-central western part of Virginia Piedmont	Ridgeway-Sandy Ridge district, Va.-N. C., and adjacent areas	Shelby-Hickory district, N. C.	Tin-spodumene belt of Carolinas	Hartwell district, Ga.-S. C., and outlying areas in South Carolina	Thomaston-Barnesville district and outlying areas in Georgia	Alabama districts
Essential pegmatite minerals:								
Albite, calcic	A, A	C, A	C, A	C, A (both)	S, A (both)	C, A (both)	C, A	C, A (both)
Albite, sodic (other than cleavelandite)	A, C	C, C	C, C				R, C	
Biotite	C, A	C, A	C, A	C, A	S, A	C, A	C, A	C, A
Cleavelandite	A, a	R, a	a, a	R, a	a, a	a, a	a, a	a, a
Microcline and orthoclase	A, A	A, A	A, A	A, A	A, A	A, C	A, C	A, A
Muscovite	A, A	A, A	A, A	A, A	A, A	A, A	A, A	A, A
Oligoclase and oligoclase-albite	A, A	A, A	A, A	A, A	S, S	A, A	A, A	A, A
Quartz	A, A	A, A	A, A	A, A	A, A	A, A	A, A	A, A
Other minerals:								
Actinolite	r, C	r, C	r, C	a, S	a, R	a, R	a, R	a, R
Adularia	a, a	a, a	a, a	r, a	a, a	a, a	a, a	a, a
Allanite	R, a	R, a	R, a	a, a	a, a	a, a	r, a	a, a
Almandite (garnet)	r, A	r, A	r, C	r, C	R, C	a, S	a, C	a, C
Altaite	a, a	a, a	a, a	a, r	a, a	a, a	a, a	a, a
Amblygonite	a, a	a, a	a, a	a, a	S, a	a, a	a, a	a, a
Amphiboles (other than hornblende)	a, r	a, S	a, r	a, R	a, r	a, r	a, r	a, r
Analcite	r, a	a, a	a, a	R, a	a, a	a, a	r, a	a, a
Anatase	a, a	a, a	a, a	a, R	a, R	a, r	a, a	a, a
Andalusite	a, a	a, a	a, a	a, a	a, S	a, a	a, r	a, a
Andesine	a, S	a, S	a, C	r, S	a, S	a, R	a, C	a, R
Andradite	?, R	a, r	a, R	a, S	a, R	a, a	a, R	a, a
Anglesite[1]	r, a	a, a	a, a	a, a	a, r	a, a	a, a	a, a
Ankerite	r, a	a, a	r, a	R, R	R, R	a, a	a, a	a, a
Apatite	R, R	R, A	R, a	S, C	S, C	R, a	S, a	R, a
Aragonite	a, a	a, a	a, a	r, a	a, a	a, a	a, a	a, a
Argentite	a, a	a, a	a, a	a, r	a, r	a, a	a, a	a, a
Arsenopyrite	R, a	a, a	a, a	r, a	a, C	a, a	a, a	a, a
Augite	r, C	a, C	a, C	a, S	a, S	a, R	a, S	a, R
Autunite	a, a	a, a	R, a	R, a	a, a	a, a	a, a	a, a
Barite	a, a	a, a	a, a	a, a	a, C	a, S	a, S	a, S
Becquerelite	a, a	a, a	r, a	a, a	a, a	a, a	a, a	a, a
Bertrandite	r, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Beryl	S, a	r, a	R, a	S, a	C, a	R, a	S, a	R, a

See footnotes at end of table.

TABLE 3.—*Occurrence of minerals in pegmatite areas of the southeastern Piedmont*—Continued

[A, Abundant; C, common; S, sparse; R, rare; r, very rare; ?, reported, but possibly in error; a, absent or not known. First letter in each entry refers to pegmatite, the other to country rock and nonpegmatitic deposits]

Mineral	Amelia district, Va., and outlying areas to north	Areas in west-central western part of Virginia Piedmont	Ridgeway-Sandy Ridge district, Va.-N. C., and adjacent areas	Shelby-Hickory district, N. C.	Tin-spodumene belt of Carolinas	Hartwell district, Ga.-S. C., and outlying areas in South Carolina	Thomaston-Barnesville district and outlying areas in Georgia	Alabama districts
Other minerals—Continued								
Bismite [1]	a, a	a, a	a, a	a, a	a, a	a, r	a, a	a, a
Bismuth	a, a	a, a	a, a	a, a	a, a	a, r	a, a	a, a
Bismutite [1]	a, a	a, a	a, a	a, a	a, a	r, a	a, a	a, a
Bronzite	a, S	a, R	a, S	a, S	a, S	a, a	a, a	a, a
Brookite	a, a	r, a	a, a	a, r	a, a	a, a	a, a	a, a
Calcite	S, S	r, C	r, C	R, S	S, S	a, R	a, a	a, a
Cassiterite	r, a	a, a	a, a	a, a	S, r	a, r	a, a	R, a
Celestite	a, a	a, a	a, a	a, r	a, a	a, a	a, a	a, a
Cerussite [1]	R, a	a, a	a, a	a, a	a, r	a, a	a, a	a, a
Chalcocite	R, a	a, a	a, a	a, a	a, R	a, a	a, a	a, a
Chalcopyrite and other copper sulfides	R, R	a, R	a, a	r, S	R, R	a, a	a, R	a, a
Chlorite	R, A	a, A	R, A	R, A	R, A	R, A	R, A	R, A
Chromite	a, r	a, r	a, R	a, r	a, a	a, a	a, a	a, a
Chrysocolla [1]	r, r	a, a	a, a	a, a	a, r	a, a	a, a	a, a
Clinozoisite	r, S	a, S	r, S	a, S	a, R	a, R	a, R	a, R
Columbite-tantalite	S, a	R, a	a, a	[2] r, a	[2] S, a	a, a	a, a	a, a
Cookeite	a, a	a, a	a, a	a, a	r, a	a, a	a, a	a, a
Cordierite	a, a	a, r	a, a	a, r	a, r	a, a	a, a	a, a
Corundum	a, a	a, r	a, a	a, R	a, S	a, R	a, S	a, r
Covellite	a, a	a, a	a, a	a, a	a, r	a, r	a, a	a, a
Cuprite [1]	a, a	a, a	a, a	a, a	a, r	a, a	a, a	a, a
Cyrtolite	r, a	a, a	a, a	a, a	a, a	r, a	a, a	a, a
Diopside	a, a	a, r	a, r	a, a	R, S	a, a	a, C	a, a
Dolomite	R, r	a, S	a, R	r, S	a, C	a, a	a, a	a, a
Dufrenite	a, a	a, a	a, a	a, a	r, a	a, a	a, a	a, a
Dumortierite	a, a	a, a	a, a	r, r	r, a	a, a	a, a	a, a
Enargite	a, a	a, a	a, a	a, r	a, a	a, r	a, a	a, a
Enstatite	a, S	a, R	a, S	?, S	a, S	a, a	a, a	a, a
Epidote	R, C	r, C	r, C	a, C	a, C	a, S	a, C	a, S
Eucryptite	a, a	a, a	a, a	a, a	R, a	a, a	a, a	a, a
Euxenite	r, a	r, a	a, a	a, a	a, a	r, a	a, a	a, a
Fergusonite	r, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Fluorite	R, r	a, r	a, a	r, a	a, a	a, a	a, a	a, a
Gadolinite	a, a	r, a	a, a	a, a	a, a	a, a	a, a	a, a
Gahnite	r, a	a, a	r, a	a, a	a, a	a, a	r, a	a, a
Galena	R, R	a, a	a, r	?, R	a, a	a, a	a, a	a, a
Goethite [1]	C, C	R, C	R, C	C, C	a, C	r, S	r, C	R, S
Gold	a, r	a, r	a, a	r, r	a, R	a, a	a, r	a, a
Graphite	C, C	a, C	a, S	R, C	a, C	a, C	S, A	R, A
Gummite	a, a	r, a	r, a	a, a	a, a	a, a	a, a	a, a
Hatchettolite	r, a	a, a	a, a	a, a	a, a	r, a	a, a	a, a
Helvite	r, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Hematite	S, C	S, C	S, C	S, A	S, C	R, S	S, C	S, C
Hemimorphite	a, a	a, a	a, a	a, r	a, a	a, a	a, a	a, a
Hiddenite variety of spodumene	a, a	a, a	a, a	R, a	a, a	a, a	a, a	a, a
Holmquistite	a, a	a, a	a, a	a, a	r, C	a, a	a, a	a, a
Hornblende	R, A	r, A	r, A	r, A	r, A	r, A	r, A	r, A
Hubnerite	a, a	a, a	a, C	a, a	a, R	a, a	a, a	a, a
Hypersthene	a, S	a, R	a, S	a, r	a, r	a, a	a, r	a, a
Ilmenite	S, S	r, S	r, R	a, S	R, S	r, R	a, R	a, R
Kaolinite and other clay minerals [1]	A, A	A, A	A, A	A, A	A, A	A, A	A, A	A, A
Kunzite variety of spodumene	a, a	a, a	a, a	a, a	r, a	a, a	a, a	a, a
Kyanite	a, C	a, C	a, C	a, a	a, A	r, C	a, A	R, A
Labradorite	a, A	a, A	a, A	a, C	a, C	a, S	a, C	a, S
Lepidolite	a, a	a, a	a, a	a, a	r, a	a, a	a, a	a, a
Lepidomelane	r, S	a, R	a, r	a, R	a, a	a, r	a, a	a, a
Leucoxene	a, r	a, a	a, r	a, a	r, r	a, a	a, a	a, a
Hydrous iron oxides [1]	A, A	A, A	A, A	A, A	A, A	A, A	A, A	A, A
Lithiophillite	a, a	a, a	a, a	a, a	R, a	a, a	a, a	a, a
Magnetite	R, C	R, C	R, C	R, A	R, A	R, C	R, C	R, C
Manganese oxides [1]	R, S	R, S	R, S	S, C	S, C	S, S	R, S	S, S
Manganotantalite	R, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Marcasite [1]	C, R	a, a	a, a	R, r	a, a	a, a	a, a	a, a
Microlite	R, a	r, a	a, a	a, a	a, a	a, a	a, a	a, a
Molybdenite	a, a	a, a	a, a	a, a	r, r	a, a	a, a	a, a
Monazite	R, a	a, a	a, a	a, C	a, R	r, R	a, r	a, a
Nagyagite	a, a	a, a	a, a	a, a	a, r	a, a	a, a	a, a
Nivenite (variety of uraninite)	a, a	a, a	r, a	a, a	a, a	r, a	a, a	a, a
Olivine	a, C	a, C	a, R	a, R	a, R	a, R	a, R	a, R
Opal [1]	r, R	a, a	r, a	r, r	a, r	a, a	a, a	a, r
Phenakite	R, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Phlogopite	r, a	a, a	a, a	?, a	a, r	a, a	a, a	a, a
Polycrase	a, a	a, a	a, a	a, a	a, a	r, a	a, a	a, a
Purpurite and other secondary phosphate minerals	a, a	a, a	a, a	a, a	R, a	a, a	a, a	a, a
Pyrite	S, C	S, C	S, C	S, A	S, A	S, C	S, A	R, A
Pyrochlore	R, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Pyrope (garnet)	a, a	a, a	a, a	a, a	a, a	a, R	a, r	a, a
Pyrophyllite	a, a	a, r	a, R	a, ?	a, S	a, ?	a, a	a, a
Pyrrhotite	a, a	a, R	a, a	a, a	R, R	a, a	a, a	a, a
Rhodochrosite	a, a	a, a	a, a	a, a	a, R	a, r	a, a	a, a
Rhodolite (garnet)	a, a	a, a	a, a	a, a	a, a	a, r	a, a	a, a
Rutile	r, S	a, R	r, C	r, R	R, R	a, R	a, R	a, a
Samarskite	a, a	R, a	a, a	a, a	a, a	a, a	a, a	a, a
Scapolite	a, r	a, R	a, a	a, a	a, r	a, a	a, a	a, a
Scorodite	R, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Sericite	C, A	S, A	S, A	C, A	C, A	S, A	C, A	S, A
Serpentine	a, C	a, C	a, R	a, r	a, S	a, R	a, S	a, R
Siderite	a, a	a, a	a, a	r, a	a, a	a, a	a, a	a, a
Sillimanite	r, S	r, S	a, C	a, C	r, C	r, C	r, C	r, C
Spessartite	S, C	S, A	R, A	S, C	R, C	R, C	R, A	S, C
Sphalerite	a, a	r, a	a, a	a, a	S, S	a, a	a, a	a, a
Sphene	a, R	a, R	a, R	a, a	R, C	a, r	a, R	a, r
Spinel	a, a	a, a	a, a	a, a	a, a	r, a	r, R	a, r
Spodumene	a, a	a, a	a, a	[3] R, a	[3] A, a	a, a	a, a	a, a
Staurolite	a, r	a, S	a, R	a, R	r, S	a, S	a, r	a, r
Stibnite	r, a	a, a	a, a	a, ?	a, ?	a, a	a, a	a, a
Strengite	a, a	a, r	a, r	a, a	a, a	a, a	a, a	a, a

See footnotes at end of table.

TABLE 3.—*Occurrence of minerals in pegmatite areas of the southeastern Piedmont*—Continued

[A, Abundant; C, common; S, sparse; R, rare; r, very rare; ?, reported, but possibly in error; a, absent or not known. First letter in each entry refers to pegmatite, the other to country rock and nonpegmatitic deposits]

Mineral	Amelia district, Va., and outlying areas to north	Areas in west-central western part of Virginia Piedmont	Ridgeway-Sandy Ridge district, Va.-N. C., and adjacent areas	Shelby-Hickory district, N. C.	Tin-spodumene belt of Carolinas	Hartwell district, Ga.-S. C., and outlying areas in South Carolina	Thomaston-Barnesville district and outlying areas in Georgia	Alabama districts
Other minerals—Continued								
Talc	a, S	a, S	a, R	a, r	a, S	a, R	a, R	a, R
Tantalite-columbite	S, a	r, a	a, a	[2] r, a	[2] R, a	a, a	a, a	r, a
Tetrahedrite	a, a	a, a	a, a	a, ?	a, r	a, a	a, a	a, a
Thorite	a, a	a, a	a, a	a, a	a, a	r, a	a, a	a, a
Thulite	a, a	R, a	r, a	a, a	a, a	a, a	a, a	a, a
Topaz	R, a	a, a	a, a	a, a	a, S	a, S	a, a	a, a
Torbernite	a, a	a, a	r, a	a, a	a, a	a, a	a, a	a, a
Tourmaline	S, S	R, S	R, S	S, S	S, S	C, C	C, C	S, C
Tremolite	a, r	a, R	a, a	a, r	a, r	a, a	a, a	a, a
Triplite	r, a	a, a	a, a	a, a	r, a	a, a	a, a	a, a
Tscheffkinite	a, a	a, R	a, a	a, a	a, a	a, a	a, a	a, a
Uraninite	a, a	a, a	R, a	a, a	a, a	r, a	a, a	a, a
Uranophane and other secondary uranium minerals	a, a	a, a	R, a	a, a	a, a	a, a	a, a	a, a
Vermiculite	r, S	r, R	r, R	R, S	a, S	S, A	S, A	R, C
Vivianite	a, a	a, a	a, a	a, a	r, a	a, a	a, a	a, a
Wolframite	a, a	a, r	a, a	a, a	a, a	a, r	a, a	a, a
Xenotime	a, a	a, a	r, a	?, a	a, a	a, a	a, a	a, a
Yttrialite	a, a	r, a	a, a	a, a	a, a	a, a	a, a	a, a
Zeolite minerals	R, r	r, r	r, r	S, r	R, r	R, r	R, R	R, r
Zinnwaldite	R, a	a, a	a, a	a, a	a, a	a, a	a, a	a, a
Zircon	r, S	r, S	r, S	r, S	r, S	R, S	R, S	r, S
Zoisite	r, S	a, R	r, S	?, S	a, R	a, R	a, R	a, R

[1] Chiefly supergene. [2] Not known whether tantalum or columbium is dominant metal. [3] Listed elsewhere as specific variety.

A few minerals are confined to one or two districts or pegmatite belts, in which they are rather common. Spodumene, for example, occurs in the tin-spodumene belt of the Carolinas and in a small area in Alexander County, N. C., but is not known in other areas. Cassiterite also is a persistent accessory mineral in the tin-spodumene belt, as well as in Coosa County, Ala., but elsewhere it is recorded only as a very rare constituent of a few pegmatites. Similarly, rutile is present in several pegmatites in North Carolina and is a common accessory in parts of Virginia, but it is not known in any South Carolina, Georgia, or Alabama pegmatites. An extreme example of restricted distribution is the occurrence of topaz as a locally abundant constituent of the Morefield pegmatite, Amelia County, Va. This mineral is rare in other parts of the district and has not been noted in the pegmatites of the other Southeastern States.

Actinolite, almandite, chlorite, dumortierite, common epidote, hornblende, kyanite, sillimanite, and several other minerals that occur in some pegmatite bodies may have been derived from wall rock assimilated by the pegmatite solutions, either during or after their emplacement.

Several of the pegmatite minerals owe their development to late-stage hydrothermal or weathering processes. Sericite, for example, occurs along cracks and lines vugs in feldspar, and vermiculite is generally intergrown with biotite, from which it appears to have been derived. Eucryptite, developed by the alteration of spodumene, is present in some North Carolina pegmatites. Limonite, kaolin and other clay minerals, and manganese oxides are the most abundant of the supergene species, and they occur in both pegmatite and country rock. Secondary marcasite coats irregular fracture surfaces in several deposits, and opal also fills fractures in the pegmatites of most Virginia and North Carolina districts. Anglesite, bismite, bismutite, cerussite, and chrysocolla are rare. Most appear to have been derived from the alteration of sulfide minerals.

The most complex mineral assemblages in the pegmatites of the southeastern Piedmont occur in the Amelia district, Va., in the Hiddenite area of Alexander County, N. C., and in the tin-spodumene belt of North Carolina. Several deposits in northwestern South Carolina, in Warren County, N. C., and in the area north of the Amelia district also contain rare or unusual species. In the remainder of the pegmatites, which constitute the bulk of those mined for mica, the general complexity of accessory-mineral suites increases from the southwest to the northeast part of the Piedmont. This geographic relation also appears to hold for the quantitative importance of many individual accessory minerals as well.

The accessory-mineral suites plainly show that beryllium, boron, columbium, manganese, phosphorus, sulfur, tantalum, and titanium are relatively abundant among the rare constituents in the pegmatites of the southeastern Piedmont. Lithium and tin are very abundant in a few areas but are rare elsewhere. Less common constituents, some of which are recorded from only one or two deposits, include arsenic, bismuth, cerium and rare-earth elements, copper, fluorine, thorium, uranium, zinc, and zirconium.

APPEARANCE AND HABIT

HYPOGENE MINERALS

ESSENTIAL MINERALS

FELDSPARS

Plagioclase is the dominant pegmatite feldspar in the Piedmont, although thorough kaolinization makes quantitative estimates difficult or even impossible in the exposed parts of many deposits. Oligoclase and calcic albite are common or abundant in all districts and occur both as very coarse subhedral to euhedral masses and as subhedral to anhedral masses in fine- to coarse-grained plagioclase-quartz and plagioclase-quartz-perthite pegmatite. They are white, bluish to cream gray, or pale yellowish olive. The cleavage surfaces of some grains are marked by the closely spaced ruling of typical polysynthetic twinning, but others show little or no evidence of twinning.

Some of the plagioclase is bent or fractured on a small scale, and in many pegmatites it is thoroughly granulated as well. Coarse crystals in several Amelia district, Va., deposits are not appreciably broken or otherwise distorted, but they are cellular or even skeletal in structure (p. 22).

Median to sodic albite (Ab_{95} to Ab_{100}) occurs chiefly as sugary aggregates that fill fractures in inner pegmatite units and is commonly associated with quartz and green "A" muscovite. It is most widespread in the Amelia district and parts of the Otter River-Moneta area, Va. It is characteristically white to bluish gray, with a pearly luster. Individual grains generally are less than an eighth of an inch in diameter, and many are finely twinned.

Coarse platy crystals of the cleavelandite variety of albite are locally abundant in the Morefield, Rutherford, and Herbb No. 2 pegmatites of the Virginia Piedmont. They also occur locally in the Big Bess and Old Plantation pegmatites of the Shelby-Hickory district of North Carolina but apparently are very rare elsewhere. Individual plates are ⅛ in. to as much as 9 in. long, 1/32 to 3 in. wide, and as much as ⅛ in. thick. They combine to form festoons, kidney-shaped masses, and cauliflower-like growths with pronounced radial structure. In some Virginia deposits they form cellular aggregates of interlocking plates, many of which are distinctly curved or warped. They are typically white to bluish gray, with lustrous surfaces.

Small tabular crystals of sodic albite line some of the cavities in more calcic albite in the Champion pegmatite, and small, thin, transparent white to pale-blue tablets are abundant in the Morefield deposit. Many of the albite aggregates are soft and crumbly, even where unweathered.

Microcline, the potash feldspar in the pegmatites, ranges from sugary aggregates of tiny grains to well-formed individual perthitic crystals 8 ft or more in diameter. Perthite is most common as irregular subhedral masses 3 in. to 2 ft across. It is nearly as abundant as plagioclase in some pegmatites, like those near Bedford and Moneta, Va., but it is distinctly subordinate elsewhere. It is absent entirely from many deposits. Perthite is most abundant in the inner zones of pegmatite bodies, generally as large crystals in massive quartz or as nearly pure aggregates of coarse, poorly formed crystals. It is invariably distinctly less affected by weathering than plagioclase, and fresh or only partly altered masses of it occur in many shallow mine workings or even are exposed at the surface.

The color of the potash feldspar ranges from white and flesh through shades of grey and pale apple green to deep green and blue green (amazon stone). The deep-green varieties are abundant in several pegmatites of the Amelia district and adjacent areas to the north. Some crystals are color-zoned, with either rims or cores greenest. Nearly all the microcline is rather coarsely perthitic, with subparallel platy to spindle-shaped lenses of sodic plagioclase (mainly albite). These lenses are 0.06 in. or less thick, and most measure 0.02 in. or less. Most of the perthitic structure is observable megascopically, but the potash feldspar in a few deposits is microperthitic.

QUARTZ

Quartz, the most widespread mineral, is present in nearly all the pegmatite units and seems to have been formed throughout the period of pegmatite activity. Most is milky white to light gray, but smoky varieties and clear, colorless material occur in many places, generally in wall zones. It generally is massive, and that in the inner pegmatite zones commonly contains crystal impressions of other minerals that grew into it or around which it grew. Small clear prismatic crystals line cavities in many of the pegmatites of the Amelia district, and larger crystals are reported from numerous localities elsewhere in the State and in North Carolina. Nearly all these crystals contain abundant inclusions or gas bubbles or are optically twinned.

Quartz also occurs in graphic granite, most of which is crudely formed. Such material consists of coarse perthite or plagioclase with scattered short, thick spindles of white to smoky quartz an eighth of an inch to nearly an inch in diameter. The spindles are angular or L-shaped in section. Most graphic granite occurs in the central parts of thick pegmatite bodies. The largest masses of nearly pure quartz are in cores, some of which are 10 ft or more wide and more than 200 ft long. The quartz generally is massive and homogenous, but in place it has a distinct planar structure caused by alternating parallel layers of milky and clear or smoky material. Some cores are aggregates of quartz anhedra 1 to 8 in. in diameter, and a few are even coarser. In others the quartz is much granulated and appears as a sugary aggregate of variously oriented fragments. A few quartz cores contain sparsely scattered irregular cavities, the wall of which are crystal faces.

MICAS

Of the several species of the mica group, only muscovite, the potash mica, and biotite, which contains iron and magnesium, are abundant and widespread in the pegmatites of the southeastern Piedmont. Lepidolite, the lithium mica, is a constituent of a few pegmatites in eastern Warren County, N. C. (Ross, C. S., personal communication, July 1946). Zinnwaldite, the lithium-iron mica, occurs only in three pegmatites of the Amelia district, Va. As typically developed in the Morefield pagmatite, it forms bronze-colored crystals 1/4 in. to nearly 12 in. in diameter. Many of these are markedly elongated normal to the cleavage direction.

Muscovite is a silicate of aluminum with potassium and hydrogen [commonly $H_2KAl_3(SiO_4)_3$]. It is chemically very stable and is little decomposed by weathering. It ranges from tiny flakes to tabular crystals several feet in maximum dimension, and some crystal aggregates are even greater in size. Much commercial muscovite occurs in rough crystals or "books," some of which are partly or completely bounded by poorly developed faces. Such books generally are nearly hexagonal or diamond-shaped and are tabular to equant, with their shortest dimension normal to the cleavage direction. Others, however, are elongated normal to the cleavage direction and are characteristically tapered. Twinning is common, chiefly with crystals united along the base or along irregular surfaces nearly perpendicular to the base. The mineral is transparent and nearly colorless when split into thin sheets, but most thick plates are distinctly colored in shades of green, brown, yellow, orange, and pink. Freshly cleaved fragments have a hard and brilliant luster, in contrast to the dull, rough outer surfaces of most books.

Both the green and reddish-brown varieties of biotite occur in the pegmatite districts, although the mineral appears black in all but very thin cleavage flakes. It occurs as scattered foils and small crystals in the outer zones of many pegmatites. It also is present in some inner units as plates and blades 1 in. to 5 ft in maximum dimension. Where fresh it cleaves smoothly into clean, lustrous fragments, but where weathered, as in the near-surface parts of most deposits, it is soft, crumbly, and coated with iron oxides. Many muscovite books are intergrown with biotite or enclose smaller biotite crystals, and some muscovite occurs as well-crystallized inclusions in books of biotite. The cleavages of the two micas generally are parallel.

Vermiculite, formed by weathering of chlorite and biotite, is common in the pegmatite and country rock of most districts. It is micaceous, with soft, pliable, and inelastic laminae. Flakes and books of the vermiculite are silvery white to brown, with a distinct pearly to bronze luster. They expand and exfoliate markedly when heated.

COMMON ACCESSORY MINERALS

APATITE

Apatite [$Ca_5F(PO_4)_3$] is most abundant in wall zones and border zones, as well as in granitoid pegmatites that are not zoned. It occurs as crystalline aggregates and as distinct prismatic equant crystals. Individual crystals are as much as 4 in. long, and some anhedral masses are even larger. The mineral ranges from pale yellowish gray through greenish gray, green, blue green, and blue to greenish brown. Its luster is vitreous to greasy, and in general it resembles beryl. It can be easily distinguished from that mineral, however, by its inferior hardness, as it can be scratched by a knife blade. Garnet and tourmaline are the most common associates of apatite in the pegmatites of Alabama and Georgia. It is readily weathered, hence cannot be recognized in most Piedmont deposits.

BERYL

Beryl [$Be_3Al_2(SiO_3)_6$] has been noted in nearly all types of pegmatite units but is most common in inner zones. It generally appears in granitoid pegmatite as irregular anhedral masses but typically fringes quartz cores as well-developed prismatic crystals. Good crystals also have been noted within quartz cores and some intermediate zones. They range from needles 1/2 in. long and less than 0.01 in. across to prisms 9 ft long and more than 15 in. in diameter, but most are 3 in. or less in diameter. The largest crystals occur at several localities in Amelia and Powhatan Counties, Va., and in Catawba and Gaston Counties, N. C. Some contain inclusions and intergrowths of quartz, or of quartz and feldspar, most of which show a roughly concentric arrangement with respect to the long axes of the host crystals.

Beryl ranges from clear through milky white and shades of yellow and green to light blue. Most of the crystals and irregular masses are translucent to opaque, but some in the Amelia and Shelby-Hickory districts are transparent. Clear emerald, for example, has been mined in Cleveland and Alexander Counties, N. C. Its hardness, crystal form (where present), and lack of good cleavage distinguish the beryl from most other pegmatite minerals. Where colorless or white it resembles quartz and some varieties of feldspar but has a characteristic greasy luster.

CARBONATE MINERALS

Calcite, dolomite, and ankerite are present in many pegmatites of the Virginia and North Carolina districts but have not been recorded from those in the other Southeastern States. Possibly they occur or even are abundant in the latter areas but have not yet been recognized in the deeply weathered pegmatites. These carbonate minerals occur typically as euhedral masses in feldspar, as anhedral masses and equant, tabular, and lamellar crystals in vugs, and as crystals and crystal groups along fractures that transect all pegmatite zones.

The high-temperature tabular form of calcite is characteristic of the vug occurrences. Rarely, small, well-formed individual crystals of this mineral occur along the boundaries of crystals of perthite or of perthite and quartz. In contrast, some anhedral masses of carbonate minerals as much as 5 in. across are known. Several of these contain small books of yellowish-green muscovite and needles of black tourmaline. The carbonate minerals are white, milky, pale yellow and yellowish brown, amber, pink, and rarely very pale green. Nearly all are opaque, but perfectly transparent crystals occur in the Champion and Rutherford pegmatites of Amelia County, Va., and the Mill Race pegmatite of Cleveland County, N. C.

COLUMBIUM-TANTALUM MINERALS

The columbite-tantalite series $[(Fe,Mn)(Cb,Ta)_2O_6]$ consists of columbate-tantalates of iron and manganese, with complete gradation in the components. Much of the material in the pegmatites of the southeastern Piedmont is ferrocolumbite; that is, the iron-manganese ratio is greater than 3 : 1 and the columbium-tantalum ratio is greater than 1 : 1, but ferrotantalite is present in several deposits and manganotantalite is a common accessory constituent of the Morefield and Herbb No. 2 deposits of Virginia. Most of the columbite is high in columbium and low in tantalum. Of the tantalates, only the manganotantalite is very high in tantalum. The columbite-tantalite minerals are black, with dull to lustrous surfaces, and are deep golden and reddish brown to nearly black in thin slices or splinters.

Thinly platy crystals of manganotantalite and ferrotantalite are locally abundant in the albitized wall zones of several pegmatites in the Amelia district and nearby areas. They are black, with many of their bright, fresh surfaces marked by sharp striations and a strong purplish iridescence. Most are small, but 3-in. plates have been obtained. Larger crystals and irregular but generally equant masses occur elsewhere in these pegmatites, as well as in those of other districts (table 3). They are consistently associated with sodic albite, either cleavelandite or aggregates of sugary grains. Members of the columbite-tantalite series are characterized by high specific gravities, by their dark color, and commonly by a platy crystal habit. They are nonmagnetic and hence can be distinguished from ilmenite, which affects a well-pivoted compass needle.

Microlite, essentially a calcium tantalate with some columbium, sodium, fluorine, and other elements, has been found in five Virginia pegmatites, all in Amelia and Powhatan Counties. It is most abundant in the wall zones of the Rutherford, Champion, and Morefield pegmatites, where it forms greenish-yellow to olive-brown octahedra 1/8 to 3/8 in. in diameter. These react weakly when tested qualitatively for uranium. Small crystals and larger irregular masses of honey-yellow, amber, and light to dark reddish-brown microlite are associated with cleavelandite in the Rutherford, Morefield, and Herbb No. 2 pegmatites. This variety of the mineral is heavier than the others, has a higher index of refraction, and is much less radioactive (Glass, 1935, pp. 751–753). It probably contains a higher proportion of tantalum.

Hatchettolite, a uranium-rich microlite, is a very rare constituent of several pegmatites in the Piedmont of Virginia and South Carolina, and samarskite, a complex columbate-tantalate that contains calcium, iron, uranium, thorium, rare earths, and other elements, occurs in at least two pegmatites in Bedford County, Va. Euxenite, fergusonite, polycrase, and pyrochlore, which are essentially columbates of cerium and other elements, also are rare constituents, and each is known to be present in only one or a very few localities. Most are in Virginia and South Carolina.

EPIDOTE GROUP

Common epidote, an aluminum-iron silicate that contains calcium and hydroxyl, is a widespread mineral in the outer parts of some pegmatites, particularly those that contain abundant masses of partly digested wall rock. It is pale green to dark green and occurs typically as small, stubby crystals. Some epidote-smeared joint faces are a bright grassy green.

Zoisite and clinozoisite, iron-free members of the epidote group, fill fractures in feldspar and occur as inclusions in some muscovite books. The characteristic forms are flattened prismatic crystals and crystal clusters, as well as rosettes and sprays of very thin needles. Individual crystals are 1/8 to 6 in. long. Most are colorless to very pale green and are transparent or nearly so. The rose-red to pale-pink manganiferous variety thulite is much less common and occurs only in parts of the Ridgeway-Sandy Ridge district and near Bedford, Va. It forms radiating fibrous aggregates, generally between the laminae of mica books.

Allanite, which contains cerium in addition to the usual constituents of the epidote group, forms needles and slender, pencil-shaped crystals as much as 18 in. long and 3/8 in. in diameter. They are black, with resinous to splendent luster, and are sharply and deeply striated parallel to their elongation. The mineral occurs sparingly in many pegmatites and is most common in some of the large dikes that have been worked for commercial feldspar. It is typically associated with massive quartz and biotite, though by no means restricted to the innermost zones. Much is partly weathered to dull-brown earthy masses, and some crystals are surrounded by yellowish to brownish stains. Many crystals are weakly radioactive, and tiny fragments occur at the centers of pleochroic haloes in some biotite books.

GARNET

Spessartite, the manganese-aluminum garnet, and almandite, the iron-aluminum garnet, are common in the wall zones and border zones of some pegmatites, where their characteristic forms are well-developed crystals less than a quarter of an inch across, and rounded crystals and crystalline aggregates as much as 2 in. in diameter. In general both large and small individuals are scattered evenly through the pegmatites in which they occur. The garnet is lustrous and salmon-colored, cinnamon, or wine red where fresh, but it is dull and buff, tan, dark gray, or black where partly altered. Many crystals are completely altered to aggregates of chlorite flakes that are stained with manganese oxides, and others appear as clayey patches of manganese oxides in thoroughly kaolinized pegmatite. Some partly altered crystals are rimmed and veined with fine-grained, pale-green chlorite.

Inclusions of garnet occur sparingly in both muscovite and biotite, chiefly in muscovite as highly flattened and transparent crystals. A garnet apparently low in manganese is the main constituent of a fracture filling that crosses the A. F. Hoyle pegmatite, Cleveland County, N. C. Garnet also is associated with small book muscovite in the quartz-core segments of many pegmatites in South Carolina and Georgia, and thin layers and streaks of crystals and granular aggregates occur in the massive quartz of several Virginia deposits.

Nearly all the garnet in the pegmatites of the southeastern Piedmont comprises varieties intermediate between pure spessartite and pure almandite, with the manganese garnet spessartite predominating (Hewett, D. F., oral communication, Dec. 1945). A specimen from the Wheatley mine, Bedford County, Va., which consisted of spessartite and almandite in a 2 : 1 proportion, was analyzed by Charles Milton with the following results:

SiO_2	36.71	CaO	0.39
Al_2O_3	19.59	TiO_2	.28
Fe_2O_3	None	MnO	28.72
FeO	13.55		
MgO	.18		99.42

Index of refraction:
Calculated (Charles Milton), 1.808.
Measured (J. J. Glass), 1.805.

The iron-rich garnet andradite occurs in the border zone of several Amelia County pegmatites, but it is confined to the wall rock in all other districts. The magnesium-bearing varieties of garnet, chiefly pyrope and rhodolite, occur in the country rock in parts of western South Carolina and northern Georgia.

SULFIDE MINERALS

Sulfide minerals are sporadic in their occurrence. Pyrite is widespread and has been identified in many pegmatites in which unweathered material is exposed. It is present, for example, in diamond-drill cores obtained from several Alabama and Georgia pegmatites. It occurs typically as small grains, as well-formed crystals, and as larger, irregular crystalline masses in feldspar and quartz. Braided veinlets of pyrite occur in the quartz of some deposits. The mineral commonly is associated with carbonates and locally with chlorite and zeolites. In the Mitchell Creek pegmatite, Upson County, Ga., pyrite inclusions occur in book mica as very thin wafers with square outlines, whereas those in the Hawkins mica mine, Stokes County, N. C., are circular. They are flattened parallel to the cleavage of the mica and range in diameter from less than 1/32 to nearly 1 in.

Chalcopyrite is less abundant than pyrite but is reported as occurring in pegmatites in the Amelia district, the Shelby-Hickory district, and the tin-spodumene belt of the Carolinas. It is associated with cleavelandite in the Virginia pegmatites and apparently is a late mineral. Arsenopyrite and galena are rare but occur in the Amelia district. Some galena masses weighing a pound or more are recorded. Pyrrhotite, molybdenite, stibnite, and chalcocite also are rare, and an unidentified silvery sulfide mineral is present along fractures in massive quartz at the Randolph Mica Co. mine in Alabama. Sulfides undoubtedly are much more abundant and widespread than present exposures of pegmatite indicate, owing to the ease with which most of them are oxidized and removed by circulating waters.

TOURMALINE

Tourmaline, a complex silicate of boron and aluminum with hydroxyl, alkalies, and alkaline earths, is a widespread minor pegmatite constituent. It occurs in or near cores of massive quartz, chiefly as needles and pencillike crystals 4 in. in maximum length, and also is in the marginal parts of some pegmatites as abundant small prisms and radiating aggregates of crystals. Sprays of flattened crystals occur along the cleavage planes of mica books in several deposits of the Shelby-Hickory and Hartwell districts (fig. 40). Small pods of a vermicular intergrowth of quartz and tourmaline are present in a few Alabama pegmatites.

The iron-rich schorl is the only variety of tourmaline thus far recorded from the pegmatites of the southeastern Piedmont. The typical lustrous, bluish- to brownish-black prismatic crystals are deeply and sharply striated. Many resemble allanite crystals but are readily distinguished from them by their characteristic triangular cross sections. Many of the crystals have been fractured and "healed" with quartz, and others are separated into stubby segments by fissures developed parallel to the basal parting direction.

OTHER ACCESSORY MINERALS

Spodumene, amblygonite, and associated lithium minerals are common or abundant in the tin-spodumene belt of the Carolinas. Hiddenite, the clear green variety of spodumene, and a little kunzite, the clear lilac variety, are present in Alexander County, N. C., but no spodumene occurrences are known elsewhere in the Piedmont. In the Alexander County deposits the mineral forms small, tabular, deeply striated crystals, many of which project into vugs. In the tin-spodumene belt to the southeast it is much more abundant and occurs as white to cream-colored or pale-green laths, some of which are as much as 10 in. wide and 3 ft. long. Most are fractured normal to the base, or nearly so, and are veined with microcline, quartz, and sugary albite. Crystal faces are rare.

The distribution of beryllium minerals in the southeastern Piedmont is an interesting contrast to the restricted occurrence but local abundance of lithium minerals. Beryl is nowhere as abundant as spodumene, but it is present in all the pegmatite districts. Other beryllium minerals, however, are known to occur only in Virginia pegmatites, in which they are rare. Small, dull-black masses of gadolinite, a beryllium-yttrium-iron silicate, occur in the inner parts of at least two large pegmatites in Bedford County, Va. Some of the masses are veined with yttrialite. Bertrandite ($H_2Be_4Si_2O_9$); helvite, a complex silicate-sulfide of beryllium, manganese, iron, and zinc; and phenakite (Be_2SiO_4) are present only in the Amelia district, Va. Small prismatic crystals of bertrandite are associated with beryl and cleavelandite, and tiny crystals and grains line vugs in cleavelandite of the Rutherford pegmatites. Transparent and colorless rhombic crystals and transparent to milky-white masses of phenakite are present in the Rutherford and Morefield pegmatites. Some are as much as 5 in. in maximum dimension and resemble the Morefield topaz in general appearance.

Cassiterite, the tin oxide (SnO_2), is sparse but widespread in quartz-muscovite rocks that form the outer parts of many pegmatite bodies in Coosa County, Ala., and in the tin-spodumene belt of the Carolinas. Partly faced crystals and irregular "slugs" are as much as an inch in diameter, but angular grains less than an eighth of an inch in diameter are the most common forms. The mineral is deep tan to very dark brown in color, with a dull to vitreous and splendent luster. Like the columbium-tantalum minerals, it has a high specific gravity, but it can be distinguished from them by its characteristic buff to light-tan streak. Dull-gray to black cassiterite is associated with cleavelandite in at least three pegmatites of the Amelia district, Va., where it forms angular fragments and masses 2 in. in maximum diameter.

Topaz, essentially an aluminum fluosilicate, is abundant in the Morefield pegmatite, where it forms crystals and irregular crystalline masses of exceptional size. Some are 3 ft. or more in maximum dimension, with weights of 300 lb. or more. The mineral generally is milky white to cream-colored, but some small crystals are clear and colorless. A single perfect cleavage and a high specific gravity distinguish the topaz from beryl, fluorite, phenakite, and other associated species.

Rutile, the titanium oxide, (TiO_2), is a sparse but widespread pegmatite accessory in some parts of the Virginia and North Carolina Piedmont, where it occurs as small grains, irregular masses, and aggregates of grains 0.01 to 2 in. in diameter. It is reddish brown to dark violet or black, with a brilliant luster.

Uranium-bearing minerals apparently are restricted to isolated occurrences elsewhere in Virginia and in South Carolina. Uraninite, including the rarer variety nivenite, is present as small, heavy black masses, mainly in late-stage quartz and albite. Much is surrounded by crusts of gray, yellow, brown, or orange uranophane, gummite, and other alteration products. The secondary uranium minerals resemble bismutite and associated secondary bismuth minerals, which are recorded as occurring in the Shelby-Hickory district and the South Carolina Piedmont, but in general are much harder and have a bright luster.

Cyrtolite, a uranium-bearing thorium mineral related to zircon, occurs chiefly as small grains in massive quartz. The quartz around each grain is dark and smoky.

Staurolite occurs in small grains in a few pegmatites in the tin-spodumene belt of the Carolinas.

Phosphate minerals other than apatite are very rare. Auerlite, a phosphate-bearing variety of thorite, has been noted in one locality in South Carolina. Autunite and torbernite, yellow and green hydrous phosphates of uranium and calcium and of uranium and copper, respectively, fill fractures that transect the inner zones of the Knight pegmatite. They generally form thin, scaly coatings on other minerals. Dufrenite and vivianite, hydrous iron phosphates, are rare constituents of the tin-spodumene pegmatities of North Carolina, in which they form massive to fibrous greenish, brownish, and dark-gray crusts. Monazite, a thorium-bearing phosphate of the cerium or rare-earth elements, is associated with tantalum-columbium minerals in several pegmatities of the Amelia district and also occurs in many pegmatites in South Carolina and the Shelby-Hickory district. Typical forms are small, flattened, yellow to reddish-brown crystals with a dull to bright luster and very thinly tabular dark-brown crystals with bright surfaces. Many are coated with scales of yellowish and yellowish-green muscovite. A few pegmatites in the Carolinas contain very small quantities of xenotime, essentially a yttrium phosphate. The zirconlike crystals are prismatic and pale green or dark brown. Freshly broken surfaces have a vitreous luster.

Ilmenite, sphene, spinel, and zircon occur in the granitoid outer parts of pegmatites and in fractures that cut across their inner parts. Corundum and graphite in some deposits probably were derived from digested country-rock material, but such a derivation is not apparent in pegmatites in which they are abundant. Fluorite and magnetite occur mainly as flattened inclusions in muscovite. Scorodite, sericite, and zeolites fill fractures that transect all pegmatite units.

The distribution and general rarity of the accessory minerals are shown in table 3. More detailed descriptions of many species can be found elsewhere in the published record; see, for example, Glass (1935, pp. 741–768), Hess (1940), Kesler (1942), and Palache, Davidson, and Goranson (1930).

SUPERGENE MINERALS

Kaolin and other clay minerals are present in the near-surface parts of nearly every Piedmont rock mass that contains feldspars. Most have been derived from plagioclase feldspars by weathering, and they generally form white to cream-colored aggregates of typical clayey appearance. They range from tiny veinlets in feldspar crystals to nearly homogeneous masses tens of feet in maximum dimension. All gradations exist between rocks containing minor kaolin and masses of kaolin that enclose only irregular fragments of quartz, mica, and other minerals resistant to chemical decomposition.

Iron oxides, chiefly limonite and goethite, are as widespread as kaolin. Most are derived from the weathering of amphiboles, biotite, chlorite, sulfide minerals, and vermiculite, and the kaolin-rich pegmatite around such minerals or remnants of them ordinarily is stained buff, tan, reddish, or deep brown. The iron oxides in the kaolin of some deposits appear to have been derived from mafic constituents of the country rock, from which they were carried by circulating ground waters. Manganese oxides, formed by alteration of manganese-bearing minerals, are common associates of the iron oxides. They occur as thin films, crusts, and larger, irregular masses and are most abundant in deposits that are rich in garnet.

White, gray, and black opal fills fractures in many pegmatites of the Virginia and North Carolina districts. Tiny prismatic crystals of quartz and spheroidal aggregates of marcasite occur in some of these fracture fillings. J. B. Mertie, Jr. (oral communication, 1945), suggests that some large quartz crystals, now imbedded in clay, formed by supergene processes. Anglesite, bismuth, bismutite, cerussite, chrysocolla, and scorodite are rare pegmatite constituents that appear to have been derived from hypogene arsenic, bismuth, copper, iron, and lead minerals. Some are pseudomorphs. Clear-cut examples of these include prismatic masses of bismutite pseudomorphic after bismuthinite and roughly cubic aggregates of sugary anglesite pseudomorphic after galena.

PARAGENESIS

The essential and accessory minerals of the pegmatites in the southeastern Piedmont appear to have been developed in sequences that represent an appreciable time range. Some of the minerals were formed at the expense of wall-rock material, others crystallized directly from pegmatite solutions, and still others were developed by replacement of preexisting pegmatite minerals. As the minerals gradually formed, they either were corroded by solutions with which they were no longer in equilibrium or were surrounded by other minerals that crystallized from these solutions. In many places they were subsequently fractured, with deposition of new material in the fractures. Elsewhere they were partly or completely replaced by the products of late-stage hydrothermal solutions that penetrated them along fractures and along other, less conspicuous avenues of access. The pegmatites, as now exposed, are plainly the result of progressive development of new minerals and the attack and local obliteration of minerals that were formed earlier. The entire process was complex and differed in detail from deposit to deposit, but the broad underlying pattern seems to have been uniform throughout the districts.

Only three general criteria can be considered reliable as independent means of establishing significant age differences between minerals. These are direct determination of age, transection of structures and textures, and pseudomorphism. Direct determination of age is plainly limited in application. Distinct age differences commonly are demonstrated by the transection of structures and textures in the earlier minerals. Crystal boundaries, cleavage patterns, zonal structure, perthitic structure, and twinning are typical features whose transection is readily recognizable in most instances. Relations are especially clear wherever single masses of the later mineral cut across unoriented aggregates of an earlier mineral or minerals. The occurrence of a given mineral as a pseudomorph after an earlier one is an excellent criterion, provided the previous existence of the earlier mineral can be established.

Other indications of age differences include the occurrence of a mineral or mineral aggregate consistently in or with another mineral whose age relations are known, along contacts between other minerals, as included masses oriented in accordance with cleavage directions in the host mineral, and as vug or other open-space fillings in another mineral. All these features should be interpreted with considerable caution, as in many instances they may well lack real significance.

A modified and expanded form of determining the age of a mineral from its occurrence in or with another whose age relations are known is very useful in the southeastern Piedmont, where the relative ages of some pegmatite minerals cannot be determined by direct means. A mineral that consistently occurs in a granitoid border zone, for example, generally can be regarded as earlier than a mineral characteristic of the adjacent wall zone, particularly if none of the pegmatite seems to have been altered by late-stage solutions. Such an age assignment is derived from the age relations of the respective zones, which are determined by direct observations or by analogy from better-known relations in other pegmatite deposits. Additional indirect evidence or geochemical data also can be used in many instances, but these and other criteria have been discussed elsewhere in the literature (Bastin, Graton, Lindgren, Newhouse, and Short, 1931; Grout, 1932; Schouten, 1946) and hence need no further treatment here.

The maximum age difference between the earliest and the latest hypogene minerals in a single pegmatite body probably varies greatly from one such body to another, and there seems to be little evidence on which estimates of such time spans can be based. Regardless of quantitative age relations, however, a general paragenetic sequence can be recognized. Such a sequence for the essential pegmatite minerals of the southeastern Piedmont is shown in figure 21, and the sequence for most of the accessory minerals is shown in figure 22. In these diagrams the relative time of mineral development is correlated with the formation of the outer zones and inner zones of most pegmatites and with the development of fracture fillings and replacement bodies, a generally hazardous procedure that is permissible here because of the uniformity of pegmatites throughout the Piedmont. The relative quantities of minerals formed at a given time are shown in a general way by the heights of the black areas. The size of each area thus represents the general abundance of the corresponding mineral throughout the entire southeastern Piedmont. It should be emphasized, however, that the indicated relations are little more than qualitative, as no accurate data on mineral proportions are now available.

Considerable overlap in periods of formation is characteristic of the pegmatites. The age relations shown in figure 21 are superficially like the typical zone se-

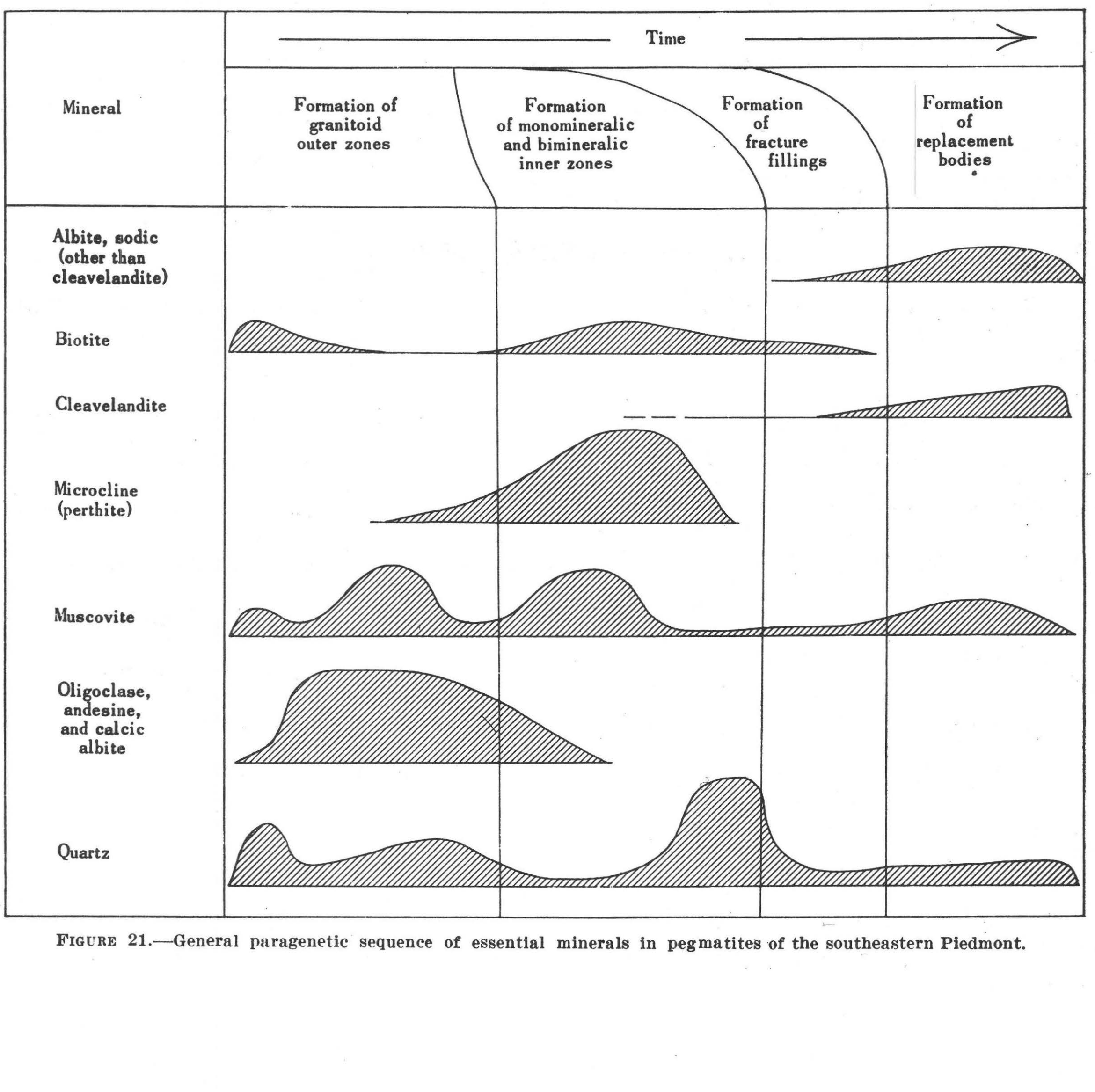

FIGURE 21.—General paragenetic sequence of essential minerals in pegmatites of the southeastern Piedmont.

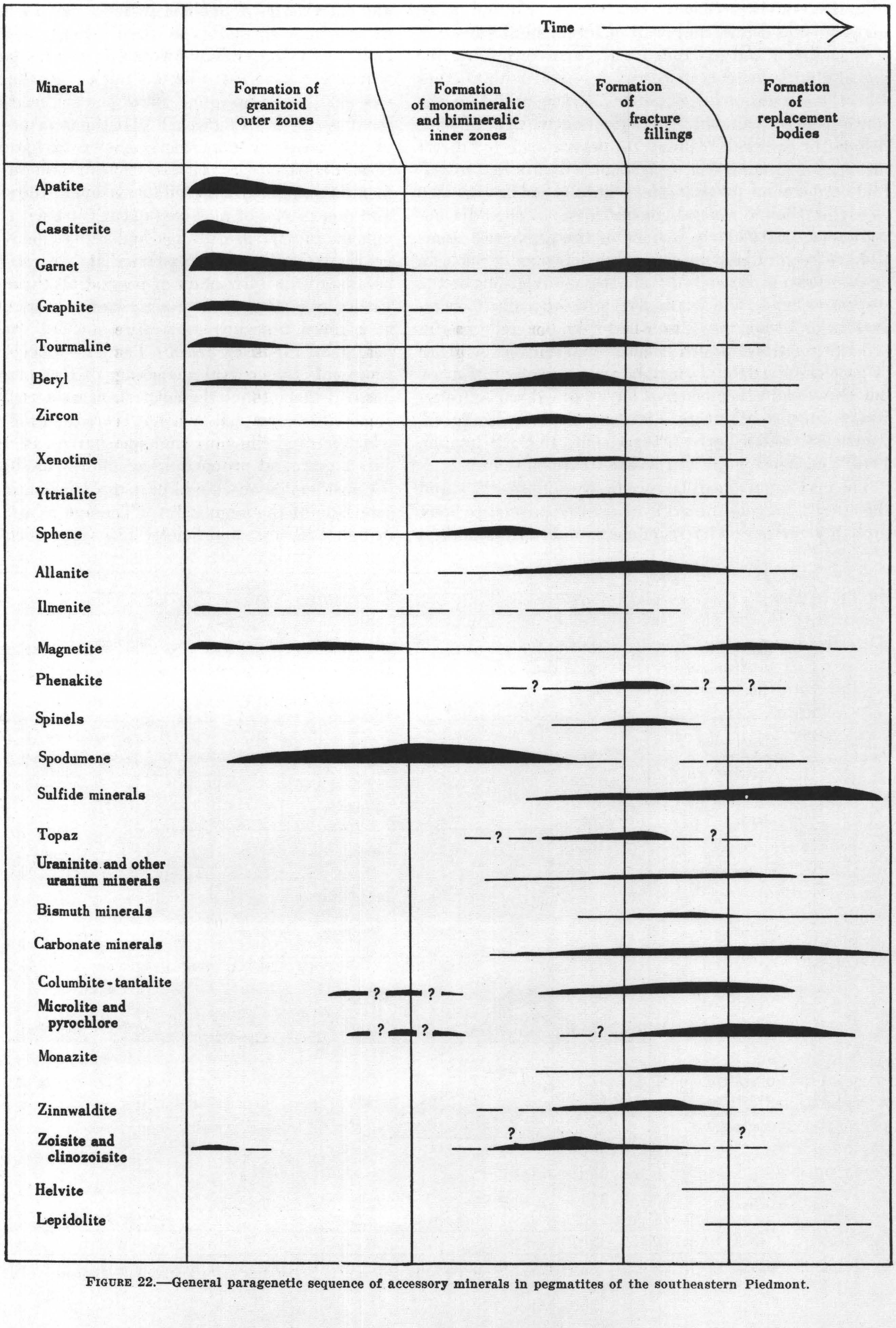

FIGURE 22.—General paragenetic sequence of accessory minerals in pegmatites of the southeastern Piedmont.

quences and the general sequence of zonal lithology described on previous pages, but they differ in some details. The number of minerals formed at a given time according to the diagram is only a possible maximum, and the number actually formed at that stage in most pegmatites is less. For example, the plagioclase member of the idealized sequence of zonal lithologies (member *F*, p. 29) is known to occur at an early stage in the development of inner zones of pegmatites that contain both plagioclase and potash feldspar. It is essentially a monomineralic unit, yet four other minerals might form at such a stage—provided, of course, the stage is assigned on the basis of zonal texture, as in figure 21, rather than on the basis of the mineralogy of adjacent zones, as in the general sequence.

Quartz was developed in the pegmatites of the southeastern Piedmont during all stages but in general was most abundant at the beginning and at the end of zone formation. The general sequence of feldspar crystallization was oligoclase and calcic to median albite-perthite-sodic albite, with the sodic albite characteristic of units younger than zones. Both biotite and muscovite were relatively abundant at more than one stage, and four well-defined "humps" are present in the muscovite part of the diagram.

The development of accessory minerals is correlated in figure 22 with the formation of pegmatite units and hence with the development of the essential minerals. Detailed discussion of specific field relations is beyond the scope of this section of the report, but all are compatible with the broad features shown in the diagram. The relations between minerals developed during the same general stage vary from deposit to deposit and even place to place within a single deposit. Thus some zinnwaldite crystals in the Morefield pegmatite appear to have grown against or around masses of topaz, whereas others contain plates of topaz whose shape and position were controlled by the basal cleavage of the host mica. Such irregularities in the age relations of nearly contemporaneous minerals tend to obscure the broad, relatively simple paragenetic history of most pegmatites, yet they present no problem once the time overlaps are recognized.

ORIGIN OF THE PEGMATITES

SOURCE RELATIONS

Pegmatite and granitic intrusive rocks are closely associated in the Southeastern States, both locally and on a regional scale. Neither the granitic rocks nor the pegmatite masses have been markedly affected by the metamorphism that altered the older metamorphic rocks, but both are known to be older than the rocks of Triassic age. They have been classed by most geologists as late Paleozoic in age. Common structural features in several districts and the distribution of the pegmatites with respect to major granite bodies suggest common foci of intrusion. The pegmatites of the Amelia district and areas to the north, for example, are near the irregular north end of a very large, elongate granitic body or series of bodies, and those of the Ridgeway-Sandy Ridge district and nearby areas lie between the ends of two somewhat smaller bodies (pl. 1). Similar relations in the Alabama and Hartwell districts already have been noted.

Swarms of satellitic sills and dikes of granitic rock occur around some of the larger intrusive masses and are similar in position and general structure to many of the pegmatites. The granitic and nearby pegmatitic rocks in most areas are alike in general composition, and they range from quartz monzonitic to quartz dioritic over the entire Piedmont belt (p. 8). Moreover, the areal distribution of reddish-brown and green muscovite and other pegmatite minerals in the western Virginia districts is systematic with respect to the large granitic masses. Maurice (1940, pp. 173–178) has recorded variations in the composition of plagioclase from pegmatities in the Spruce Pine district of the Blue Ridge province, and the distribution of the variants over the entire district appears to be related to several bodies of granodioritic and quartz dioritic rock. Similar studies have not been made in the Piedmont province.

Some pegmatites occur within, rather than adjacent to, stocks and large sill-like masses of intrusive rocks, either as well-defined sills and dikes or as less regular bodies that fade outward into the host rock. The extremely irregular shape of many small bodies of non-muscovite-bearing pegmatite in the "western"-type granite near Shelby, N. C., suggests that the host rock was not wholly consolidated at the time the pegmatite was emplaced. The pegmatite solutions evidently were not guided by clearly defined fractures, but instead crystallized around scattered centers in the granite. Both this granite and this type of pegmatite are characterized by accessory monazite, whereas the mica-bearing pegmatites and the granites in adjacent areas contain very little monazite. Some mica-bearing pegmatites in the "eastern"-type granite, in Gaston County, penetrate the host rock in a very complex way and probably are not much younger than the granite.

The exposed granite is not necessarily the "parent rock" of the pegmatite in a given area, but in general the pegmatites appear to be related to the same magma that gave rise to the granite. The evidence for such a genetic relation is not equally complete or equally well developed in all districts, as evidence is moderately good only in the Alabama, Shelby-Hickory, and Ridgeway-Sandy Ridge districts.

MODE OF EMPLACEMENT

The emplacement of the pegmatites appears to have been controlled by primary layering and other planar structures in the igneous rocks, by bedding, foliation, and schistosity in the metamorphic rocks, and to a greater degree by fracturing in both rock types. Some dikes and discoidal lenses, like those in the Amelia, Hartwell, and Thomaston-Barnesville districts, were controlled by one or two fracture sets with consistent orientation over wide areas, and three joint sets apparently governed the emplacement of the tin-spodumene pegmatites of the Beaverdam Creek area, Gaston County, N. C. (Kesler, 1942, p. 256, pl. 1). In contrast, a single set of many closely spaced fractures provided access for series of parallel pegmatites at the Banister and Garner mines in the Hartwell district. Pegmatites in some other areas reflect fractures of unsystematic orientation or fracture groups of very small

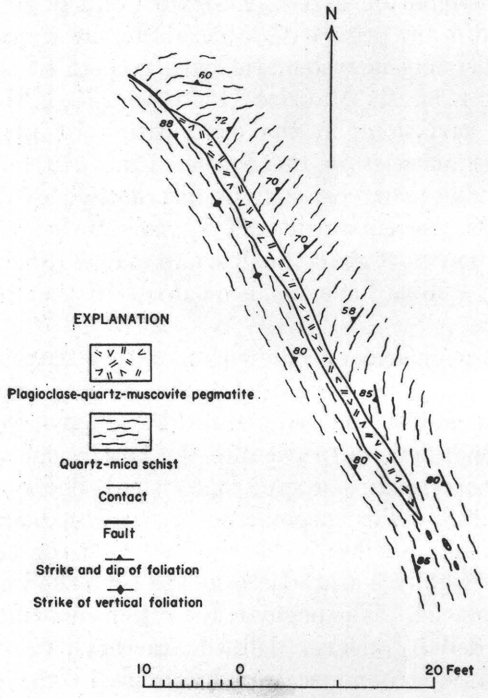

FIGURE 23.—Pegmatite lens in a fault zone, 19-ft. level of the Monteiro mine, Goochland County, Va.

extent. Some elongate pegmatite bodies mark the positions of former fault planes or fault zones. Movement before pegmatite emplacement is evidenced by drag of country-rock structures in opposite directions on opposite sides of the pegmatites, by entirely different orientation of the country-rock structures on opposite sides, or by the occurrence of different rocks on opposite sides of discordant pegmatites (fig. 23).

Pegmatite sills and concordant pods are common in the Ridgeway-Sandy Ridge and Alabama districts, as well as in parts of the Thomaston-Barnesville district and the tin-spodumene belt of the Carolinas. Some are enclosed by distinctly foliated or layered igneous rocks of granitic to gabbroic composition, but most lie within micaceous or hornblendic schists and gneisses. A pinching and swelling along the strike and down the dip is characteristic, and many deposits comprise chains of small pegmatite lenses at or very near single horizons in the country rock. Injection of pegmatite along the crests and keels of plunging folds led to the development of several concordant troughlike bodies in the Thomaston-Barnesville and Alabama districts. Other troughlike pegmatites consist of a fracture-controlled limb and a concordant limb, and such composite control appears to have been involved in the development of many of the more irregular bodies. Thus sill-like apophyses branch from several dikes in the Amelia district, and, conversely, some large sills in the Ridgeway-Sandy Ridge district are complicated by discordant branches (fig. 6). Many pegmatites in granite are very irregular, and their emplacement probably was little guided by fractures or other structures in the enclosing rock.

Most of the pegmatites that have been prospected and mined appear to have been more or less confined between the walls of the planar structural features along which they were injected. The adjacent rocks are appreciably distorted around many pegmatites, particularly irregular ones. Such distortion ranges from simple bulging of metamorphic rocks around pegmatite lenses and tongues to severe crumpling, contortion, and even dislocation that cannot be ascribed to movements before emplacement of the pegmatite. Such pegmatites evidently gained their present positions mainly by shouldering aside masses of the wall rocks, with subordinate stoping, assimilation, and replacement.

In strong contrast to this general group are the pods of pegmatite in injection gneisses formed wholly or in part by replacement of country rock. Although most are small and few have been worked for mica and other minerals, they are exceedingly abundant and may well constitute the bulk of pegmatite material in some areas. Many appear to have soaked through the walls of fractures and other guiding structures, but others are not distributed in any recognizably systematic way. Many owe their existence to replacement of preexisting rock, presumably by very mobile solutions, as well as to direct crystallization from pegmatite liquids. This is demonstrated by textures and structures inherited from the replaced rock and by some of the gradational contacts between pegmatite and wall rock. Around most deposits of this type there is little country-rock distortion that can be ascribed to injection of the pegmatite. The general relations of these "replacement pegmatites" are contrasted in figure 24 with those of pegmatites formed by mechanical injection of liquid material. Many of these replacement pegmatites may have formed somewhat earlier than the mica-bearing pegmatites, but in the same period of intrusive activity.

Gradations between these two general types of pegmatite can be observed. The pegmatite sills at the Hawkins and De Shazo mines of the Ridgeway-Sandy

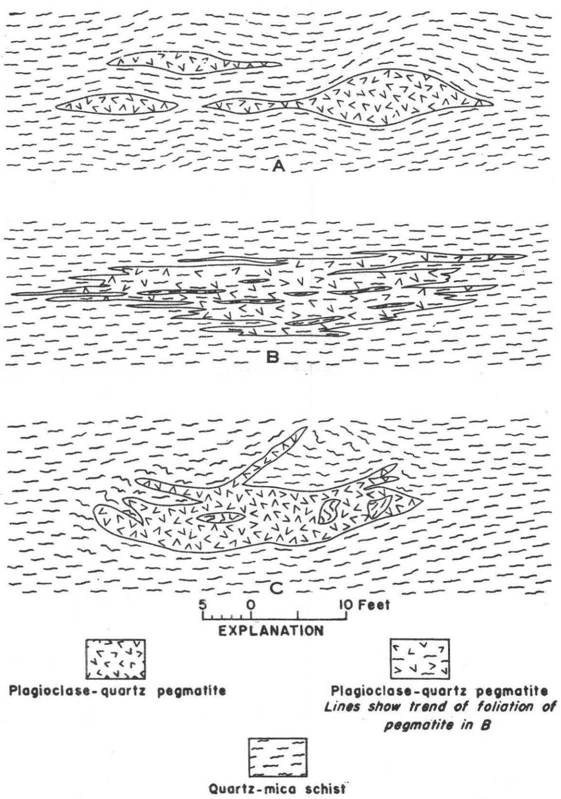

FIGURE 24.—Typical relations between pegmatite and wall rock. *A*, Mechanically injected pegmatite lenses, with wall-rock schist forced aside. *B*, Irregular mass of replacement pegmatite, with wall-rock structure little disturbed. *C*, Mechanically injected pegmatite body with many broken-off inclusions of wall rock.

Ridge district, for example, appear to have been forcibly injected into the country rock, and in places they transect the wall-rock structure at distinct angles (figs. 8 and 9). A few mica books that lie along their margins, however, probably grew from the pegmatite into the wall rock. The foliation planes of the schist are partly bent around most of them but end abruptly against the others. Some wall-rock material may have been incorporated into the growing books, whereas other material was rejected. Scattered feldspar crystals in the schist adjacent to other deposits (fig. 5) may well have had a similar origin.

DEVELOPMENT AFTER EMPLACEMENT

TWO-PROCESS CONCEPT OF PEGMATITE ORIGIN

Most earlier theories of pegmatite gnesis involved the concept of simple injection and consolidation. As outlined by Kemp (1924), the nature of the pegmatite-forming solutions and the mechanism of their emplacement were the chief points of discussion. A different concept, which placed emphasis on the development of pegmatites by more than one general process, was clearly outlined much earlier by Brögger (1890), and other workers subsequently elaborated on his views—among them Rogers (1910, pp. 217–218), Makinen (1913, p. 22), Ziegler (1914), Galpin (1915, p. 27), Laubman and Steinmetz (1915–20), Lacroix (1922, pp. 310, 355–356), and Foye (1922). According to this concept, an original material of simple composition is formed by crystallization from a cooling magma. Following this "magmatic stage" are one or more "hydrothermal stages," during which original or primary material is acted upon by hydrothermal solutions and is partly or completely replaced by a new group of minerals. The composition of the hydrothermal solutions generally is very complex.

This two-process theory was treated in detail by Fersmann (1923a, 1923b, 1924) but did not gain wide acceptance in this country until after 1925, in which year Cook, Hess, Landes, and Schaller all published the results of their mineralogic studies.

Many geologists have accepted most elements of the two-process theory and have applied it to pegmatites in all parts of the world. The reports of Fraser (1930), Palache (1934), Hitchen (1935), Jenks (1935), Switzer (1938), and Cameron, Larrabee, McNair, Page, Shainin, and Stewart (1945) deal with pegmatites in New England. Hess (1940) wrote on North Carolina and Pegau (1928; 1929; 1932, pp. 44–49) on Virginia pegmatites, whereas papers by Schaller and Henderson (1926, p. 8), Landes (1928, 1932, 1935b), Hess (1933a), Just (1947, pp. 28–30, 46–48), McLaughlin (1940), and Jahns (1946) deal with various areas in the West. More general discussions are those of Schaller (1927, 1933), Spence (1932, pp. 1–4), and Landes (1933; 1935, pp. 81–86; 1937). Among foreign authors, Gevers (1936) has written on South African pegmatites and Bjørlykke (1937a, 1937b) on Norwegian pegmatites, and Anderson (1928, 1931), Derry (1931), and Fersmann (1931) have contributed discussions of more general scope.

The views of these men, however, differ greatly in detail. Some, for example, believe that the material deposited during the magmatic stage was very simple in composition, consisting mainly of potash feldspar with subordinate quartz whereas others have interpreted the bulk of pegmatite and many or most of the pegmatite minerals within some areas as products of the magmatic stage. Many opinions intermediate between these two extremes are recorded in the literature. To what extent they represent differences of opinion on like features is difficult to determine, but probably most of the differences of view or of emphasis stem from variations in the pegmatites themselves from one area to another.

Some geologists have been reluctant to postulate two distinct mechanisms of pegmatite development, but instead are inclined to regard pegmatites as the result of a single broad crystallization process, complicated by (1) late-stage reaction between earlier-formed minerals and adjacent residual solutions and (2) the filling of open spaces created by fracturing during consolidation. This interpretation will be found, for example, in reports by Wright (1932, p. 103), Stockwell (1933, pp. 44–45), Maurice (1940, pp. 179–185), Shaub (1940, pp. 675–678), Uspensky (1943), Quirke and Kremers (1943), de Almeida, Johnston, Leonardos, and Scorza (1944), and Johnston (1945, pp. 1040–1042).

Many, if not most, geologists who have studied pegmatites have carefully pointed out that their conclusions apply only to specific deposits or groups of deposits and cannot satisfactorily explain the origin of others. It is clear that much discussion has been the outgrowth of later efforts to apply a single theory of origin to all pegmatites, even though it may have been restricted to a single variety of pegmatite by the original proposer. Some advocates of the two-process theory, for example, may intend no application to pegmatites other than complex members of the general potash feldspar group (Schaller, 1925, p. 279; Hess, 1933b), in which primary plagioclase may be a very minor constituent. Excluded from this truly granitic group are the mica-bearing quartz monzonitic, granodioritic, and quartz dioritic pegmatites so common in the Southeastern States and New England, the pegmatites of basic composition, and several other types. Maurice (1940, pp. 182–183) discusses this question in some detail and concludes that many past disagreements might well be ascribed more to differences in the implied usage of the terms "pegmatite" and "granite pegmatite" than to intrinsic differences in genetic interpretation of the features of any given deposit.

LATE-STAGE PEGMATITE FEATURES

The unzoned pegmatites in the southeastern Piedmont are similar to most other granitoid dike rocks, so far as features formed after emplacement are concerned. They are mineralogically rather simple and probably are representative of the magmatic stage of pegmatite development. The pegmatites that were formed by the replacement of country rock also are granitoid aggregates of uniform texture and simple mineralogy, although some are complicated by numerous inclusions and septa of partly digested wall rock.

The zoned pegmatite bodies are not so simply explained. The age relations of the zones can be demonstrated in many pegmatites and in others can be assigned by analogy with reasonable assurance, but the way in which these units were formed is much less clear. Where fracture fillings and replacement bodies are present, they generally form structural patterns that are superimposed on the concentric or quasiconcentric patterns of the zones; hence a broad division of pegmatite units into two age groups can be made. Most fracture fillings and replacement bodies were formed after development of all the enclosing zones, although some are contemporaneous with nearby inner zones in some pegmatites. A few antedate the formation of cores and, rarely, inner intermediate zones, but all such units are younger than the zones in which they occur. The division of pegmatite units into two slightly overlapping age groups is compatible in general with the mineralogic relations described by the supporters of the two-stage concept of pegmatite development.

ZONES

Many zones are veined or otherwise transected by apophyses from adjacent zones that lie nearer the centers of the containing pegmatite bodies, as already pointed out, but nowhere has the reverse relation been observed. Moreover, many zonal contacts show small-scale corrosion of one zone by the minerals of the zone next inside, and the reverse of this relation has not been noted. Finally, wherever the minerals of a given zone are veined, corroded, and partly replaced by minerals characteristic of an adjacent zone, the adjacent zone is the one on the inside, rather than that toward the wall of the pegmatite. Thus the border-to-core sequence of zone development is strikingly consistent from one pegmatite body to another.

Suggestions of comb structure occur along the walls and the inner parts of numerous pegmatite bodies. The open spaces no longer exist, evidently having been filled by later material that crystallized nearer the centers of the bodies (fig. 25). It cannot be denied, however, that this structure is not a wholly reliable criterion of the age relations, as many coarse euhedra of feldspar, mica, and other pegmatite minerals are known to have been developed by replacement of the material into which they project. The structure is best used, therefore, as a supplementary criterion. Another suggestive relation is the general increase in grain size of pegmatite zones from the walls inward. The composite pegmatites, which consist of rock masses that were emplaced at distinctly different times, constitute the only important exception.

Any of three general modes of formation must be considered in accounting for the spatial and age relations of pegmatite zones (Cameron, Jahns, McNair, and Page, 1949, pp. 99–105):

1. Development by successive deposition under open-system conditions, with repeated introduction of new material along the channelway in which the pegmatite grows.

2. Development in two stages, with crystallization of granitoid rock from essentially magmatic pegmatite solutions of simple composition and subsequent replacement by one or more groups of hydrothermal solutions under open-system conditions.

3. Development by fractional crystallization of pegmatite magma in place, with incomplete reaction between consolidated material and rest liquid.

Most zoned pegmatites, with their typical concentric or quasi-concentric internal structure, are not readily

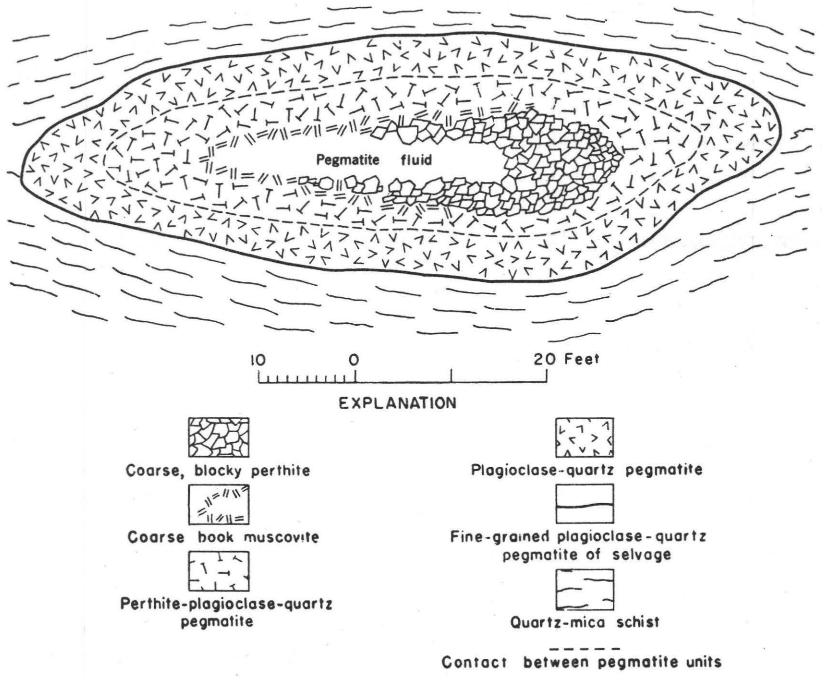

FIGURE 25.—Coarse crystals of muscovite and perthite forming comb structure during a possible intermediate stage of zone development. A quartz core presumably would later occupy the space filled by pegmatite fluid in the diagram.

explained as products of successive deposition under open-system conditions. Such an origin would account for the age relations of the zones but would be incompatible with the known enclosure of inner zones by outer zones in many well-exposed pegmatites. The apophyses that can be traced from some zones across earlier-formed pegmatite were developed from solutions moving outward from the attached zone and therefore cannot be interpreted as feeders from which those zones grew. Few even extend outward as far as the walls of the enclosing pegmatite body. Inasmuch as not all pegmatites are fully exposed, however, it cannot be demonstrated that all outer units fully enclosure the inner ones; hence the possible development of some zones by a process akin to fissure filling must be admitted.

No evidence has been found for the wholesale replacement of pre-existing pegmatite by the material that constitutes zones. This is negative evidence against a two-stage origin for zones, to be sure, but it is in sharp contrast to the widespread replacement features in other, later units. The consistent sequence of zonal lithologies from pegmatite to pegmatite and from district to district, together with their known age relations, can be satisfactorily explained in terms of a two-stage origin only if exceptionally uniform conditions of replacement are postulated. Such conditions include the replacement of preexisting pegmatite by various types of solutions in the same order—both in time and in space—from one pegmatite body to another.

Development of zones by fractional crystallization of pegmatite magma in place is in full accordance with all known features in the pegmatites in the Southeastern States. Such an origin would not involve open-system conditions, but instead would be characterized by those of a "restricted system," closed to the extent that no solutions are added to it after emplacement of the pegmatite body and before zonal development is complete, but open to the extent that some material escapes during crystallization and that there is some reaction between pegmatite and wall rocks. The bulk composition of the zones in pegmatites can be correlated with the compositions of other genetically related rocks in many districts, and the general sequence of soda-lime feldspar to potash feldspar is characteristic of those that are quartz monzonitic to quartz dioritic in composition.

Fractional crystallization generally is accompanied by reaction between crystals and rest liquid, and this is indicated in pegmatites by the corrosion of many zone minerals. Remnants of such minerals generally can be interpreted as residuals from reactions in a crystallizing igneous mass. Incomplete zones seem best explained as products of local crystallization within the cooling pegmatite bodies or as remnants of more extensive units that were partly removed by reaction with residual solutions. Such a general mode of zonal development is entirely analagous with the processes of differentiation ordinarily assigned to many other igneous rocks not characterized by such coarseness of grain, as was demonstrated, for example, by Lawson (1891, p. 153), Harker (1894), Grout (1918), Foslie (1921), Tyrrell (1928), and Hurlbut (1939).

FRACTURE FILLINGS AND REPLACEMENT BODIES

The genetic implications of fracture fillings are obvious, as they were developed within rocks sufficiently well consolidated to yield to stresses by fracturing. They commonly transect variously oriented masses of one or more minerals, and most are characterized by "matching" walls. Walls that do not match bound some fracture fillings that contain numerous inclusions of country rock, as well as some that have slightly corroded their original walls. The earliest-formed fracture fillings generally are traceable into the pegmatite zones from which they were developed as apophyses, and the latest appear to have been derived at least in part from sources outside the masses of pegmatite in which they occur.

Replacement bodies, ranging from simple enlargements of fracture fillings to broad masses whose structural control is not evident, are formed by replacement of preexisting pegmatite, commonly zonal material. In general they are younger than most or all of the zones in the host pegmatite. They are most readily recognized by means of pseudomorphic crystal forms, textures, and structures and by means of their transection of earlier features in a manner other than simple open-space filling. Where replacement units are fracture-controlled off-shoots of pegmatite zones, their genetic relations are clear, but where they are younger than all the exposed zones the source of the replacing solutions becomes a problem.

In many pegmatites with scattered replacement masses of quartz, sugary albite, and muscovite, the amount of late-stage material is so small that it might well be the product of residual solutions within the pegmatite bodies. Replacement bodies that constitute large parts or even the bulk of pegmatites, on the other hand, are not so easily explained. It seems more likely that they were derived from sources farther away, perhaps even outside the pegmatite bodies. Thus some may have been developed under open-system conditions.

Some evidence of open-system replacement has been recognized in the southeastern Piedmont, but it is confined to only a few pegmatites. Some of these, like the Rutherford No. 2 in Amelia County, Va., have downward-extending "roots" that may consist at least in large part of replacement material. These might be interpreted as feeder channels for the replacing solutions. In other pegmatites, a careful reconstruction of the zonal pattern before replacement and a study of the host and replacing minerals indicate that appreciable quantities of certain constituents were introduced and that other constituents were released for deposition elsewhere. Thus, for example, the widespread conversion of perthite to cleavelandite and muscovite by soda-rich solutions in the Herbb No. 2 and other Virginia pegmatites probably released excess potash, which may well have escaped into the country rock.

The correspondence of the bulk composition of zones in a pegmatite to the composition of large masses of genetically related intrusive rock no longer holds if the composition of large replacement units is added to obtain the composition of an entire complex pegmatite body. Thus many pegmatites that are genetically related to granodioritic masses in the Southeastern States are granodioritic in terms of zonal composition but are richer in soda and rarer elements if the bulk composition of both zones and other units is considered. Some pegmatites within a well-defined district contain few fracture fillings or replacement bodies, whereas neighboring ones of similar age and structure are very rich in such material. Therefore the composition of the zones is more consistent and more susceptible to satisfactory correlation with related igneous masses than the composition of the pegmatites as a whole. This feature is more simply explained in terms of the addition of late-stage material from external sources to form pegmatites with large or widespread replacement units than in terms of the emplacement of pegmatite material in a given area as sills, dikes, and other bodies that differ markedly from one another in original composition.

ECONOMIC ASPECTS OF THE PEGMATITE MINERALS

MUSCOVITE

PROPERTIES

CRYSTAL FORM AND CLEAVAGE

Muscovite crystallizes in the monoclinic system but is nearly hexagonal in symmetry. Its characteristic occurrence as tabular to equant rough crystals or "books" already has been noted, and there are all gradations between crystals with perfectly developed faces and those whose outer surfaces are very irregular, pitted, or marked by impressions of adjacent crystals of mica or other minerals. Most well-developed crystals are hexagonal or rhombic in outline, with four or more faces forming the margins of cleavage pieces (figs. 26 and 27). The simplest crystals comprise basal and prismatic faces, but clinopinacoidal and other modifying faces are common.

The symmetry of muscovite crystals is clearly shown by percussion figures. If a cleavage plate of sheet mica is struck sharply by a punch or thick needle with a dulled point, a partial or complete six-rayed pattern of cracks is developed. Two of the cracks, generally deeper and longer than the other four, intersect the cleavage surface to form a single line parallel to the trace of the clinopinacoidal face (fig. 27). The others form two lines that are nearly parallel with the trace of the prismatic faces (Walker, 1896; Sterrett, 1923, p. 12).

A second type of figure can be developed by firmly pressing a dulled point against the piece of mica. Like the percussion figure, this pressure figure is six-rayed wherever complete, but generally only two or three rays are developed. Some pressure figures are formed simultaneously with percussion figures, and the two have common centers. One set of cracks is normal to the principal direction of the percussion figure, and the others are normal to the prism faces (fig. 27). The cracks of the pressure figure coincide with distinct glide or parting planes in the host crystal and meet the cleavage planes at an angle of about 67°.

Both percussion and pressure figures are very useful in determining the crystallographic orientation of mica books, especially where no crystal faces are present. In this report the orientation of other features is generally described in terms of percussion- and pressure-figure directions, which serve as convenient references.

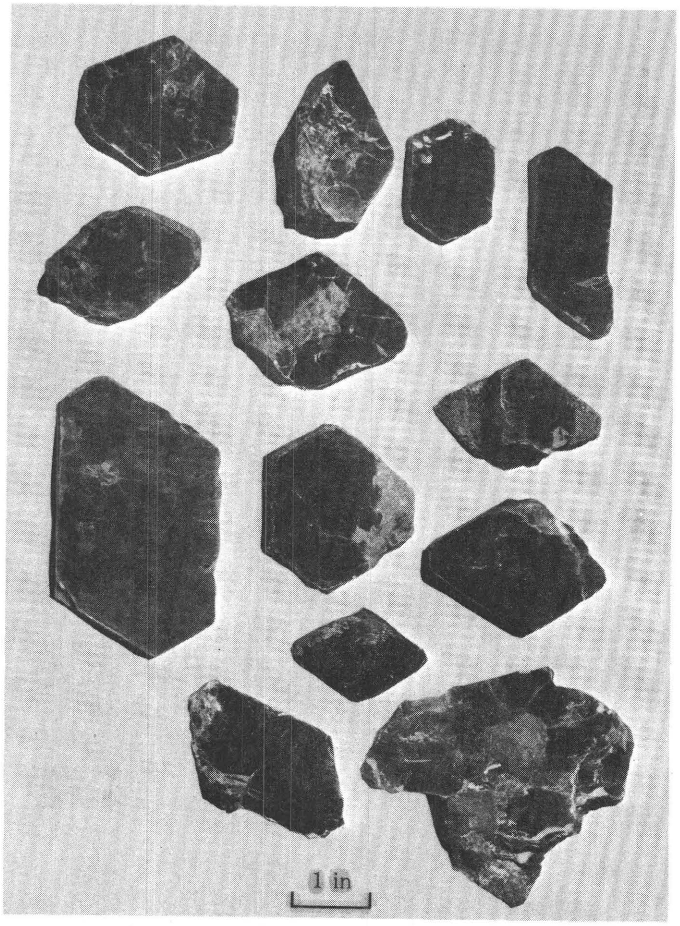

FIGURE 26.—Small hexagonal and rhombic muscovite books from the Mitchell Creek pegmatite, Upson County, Ga. Note the inclusions of quartz and apatite.

The edges of most crystals or books of muscovite are twisted, crushed, tangled, and irregularly intergrown with other minerals and hence must be cut away before the remaining material can be split into films or thin sheets. Owing to their elasticity, strength, and almost perfect cleavage, undistorted books or parts of books readily yield films less than 0.001 in. (1 mil) thick. Films of uniform thickness and flat or very nearly flat surfaces are commercially the most desirable, and books that yield such films are said to be free splitting. The films can be tested easily for constancy of thickness by means of micrometers or by polarized-light measurements.

Some mica does not split uniformily, but tears into irregular partial films. Such material commonly separates evenly and easily in some places, but very imperfectly in others. It is known as "locky," "tied," "gummy," "tangled," "tanglesheet," "tanglefoot," or "tacky." The designation "tanglesheet" also is applied to coarse aggregates of irregularly intergrown books, which commonly form masses of "bull mica" several feet in maximum dimension. Discontinuity of cleavage and lockiness generally is caused by a partial intergrowth of books or of laminae in a single book, by internal distortion of the book, or by finely divided inclusions. Many locky books do not differ markedly in appearance from those that split freely and evenly.

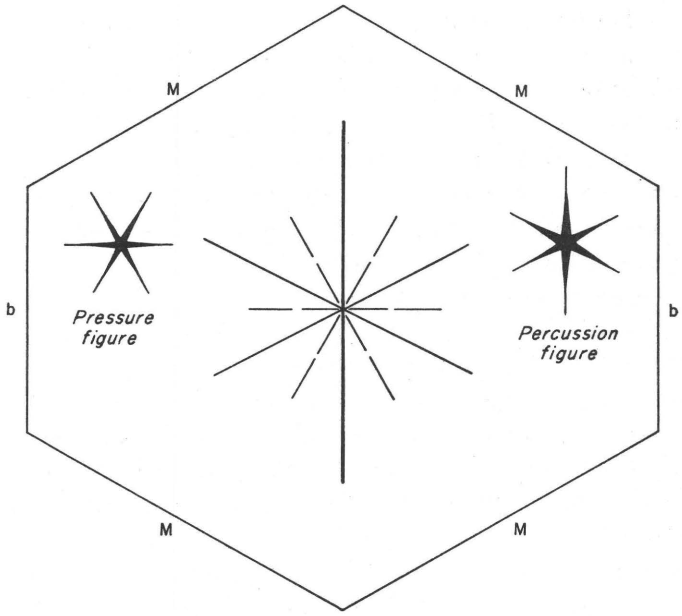

FIGURE 27.—Cleavage plate of muscovite, showing the orientation of percussion and pressure figures with respect to the prism (*M*) and clinopinacoidal (*b*) faces.

The hardest varieties of muscovite commonly are more difficult to split than softer varieties, but numerous exceptions are known. Many very dark colored varieties also are not free splitting, but others yield large, uniform sheets. There appears to be some correlation between lockiness and the presence of disseminated flakes, shreds, and very thin plates of biotite and chlorite, especially in the hard micas that are brown, brownish olive, or buff. The effects of larger inclusions are clearer. Prismatic crystals of apatite and quartz, for example, commonly lie nearly normal to the mica cleavage and hence are like nails driven through a series of thin boards. Such mica is said to be "tied," "nailed," or "nail-locked." Similar tying is the result of small elongate crystals of muscovite or biotite that are oriented oblique to the host crystal.

The most freely splitting mica in the southeastern Piedmont generally occurs in plagioclase-quartz pegmatite, whereas much of that in plagioclase-quartz-perthite pegmatite is locky. Most of the flat books are hard and free splitting, but tying by inclusions of quartz, tourmaline, and other minerals is common in some deposits of such districts as the Thomaston-Barnesville, Hartwell, and Alabama.

HARDNESS, FLEXIBILITY, AND ELASTICITY

The hardness of mica varies from one deposit to another, less commonly from one book to another, and in some instances it varies within a single book. In general, the brown, cinnamon-brown, and buff micas are harder than the greenish-olive and green varieties of the deposits in the southeastern Piedmont. Where other factors are equal, the hardest varieties are the least flexible. Relative degrees of hardness are readily determined by judging the ease with which sheets of known thickness can be cut, by bending them slightly, or by tapping them against a thick piece of wood or a knuckle of the hand. Pieces of very hard mica sound like glass when shaken together.

Flexibility and elasticity are important properties, especially in mica that must be bent sharply without breaking or must be exposed to unusual jarring or vibration. To meet most commercial specifications a sheet of mica one two-hundredth of an inch (5 mils) thick must return promptly to its normal planar condition after being wrapped around an ordinary lead pencil and then released. Flexibility and elasticity are most seriously affected by cracks, holes, and other structural defects. Most of these are easily recognized, but some extremely thin and fine cracks commonly escape detection. These are known as hair cracks or hair lines. Films of mica in which some laminae are hair-cracked generally fail when bent, especially if the flaws are abundant or if they extend through considerable thicknesses of the films. Such mica is termed "brittle."

Where exposed to the weather for long periods, muscovite loses its luster and gradually becomes soft, pliable, and "punky." This weathering is chiefly a mechanical process involving the separation and splitting off of cleavage laminae by moisture, temperature changes, and vegetation, acting either singly or in combination. Some chemical attack reduces many of the separate laminae to lusterless, opaque, crumbly flakes. Any inclusions of magnetite or hematite that are present in such mica generally are altered to hydrous iron oxides. Softness is a minor defect in most of the southeastern Piedmont districts, even where the pegmatites are thoroughly weathered.

STRUCTURAL IMPERFECTIONS

REEVES

"Reeves," or "cross grains," are lines, striations, shallow corrugations, or small, narrow folds that lie in the plane of cleavage. Some are simple, closely spaced flexures or crenulations, presumably caused by stress during or after crystallization of the mica. Others, however, are formed by discontinuities in incomplete sheets or laminae. As traced across a mica book, such laminae die out abruptly along straight lines but commonly reappear along parallel straight lines beyond. Where the distance between lines is very small—and the space from which the laminae are missing thus is very narrow—the reeves appear only as fine hair lines, but where laminae are missing over greater distances the spaces are occupied by adjacent laminae warped downward from above and upward from below. The depth of such reeves is a function of the number of missing laminae, and their spacing is a function of the distribution of, or discontinuities in, the laminae.

Reeves are perpendicular to the traces of the prism and clinopinacoidal crystal faces and hence are parallel to the rays of the pressure figure. "A" ("housetop," "roof," "fishtail," "V-ridge," or "spearhead") mica is

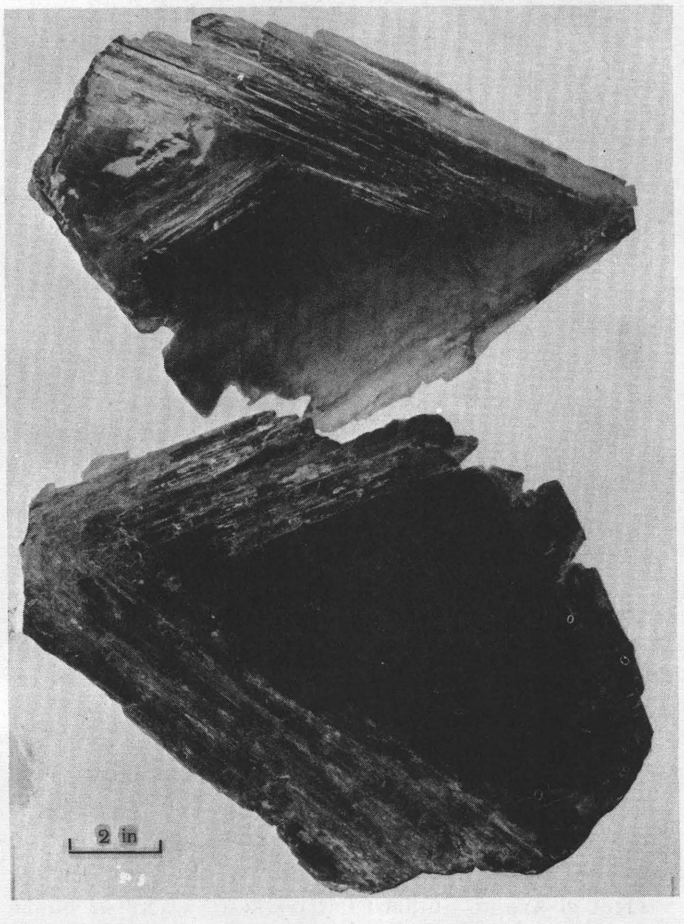

FIGURE 28.—"A" structure in large cleavage sheets of muscovite. Typical flat-A sheet below. Color zoning shows at left edge of sheet above.

distinguished by two series of reeves that intersect at an angle of about 60° (figs. 28–30). The third series representing the cross bar of the "A" is not present, so that the structure actually resembles the letter "V." Typically a single pair of "A" reeve groups extends across an entire mica book, with the point of the "A" very near one edge. Such books rarely show well-developed crystal faces.

More than two directions of reeves are present in many books, and the relation of "A" structure to crystal directions is best shown in books with reeves that extend in six directions from a common center. More detailed descriptions and interpretations of these and other structural features have been published elsewhere (Jahns and Lancaster, 1950).

Some "A" books, in which the imperfections are shallow, widely spaced, or otherwise not seriously developed, can be split into sheets of commercial value. "A" structure is developed only near the edges of other books

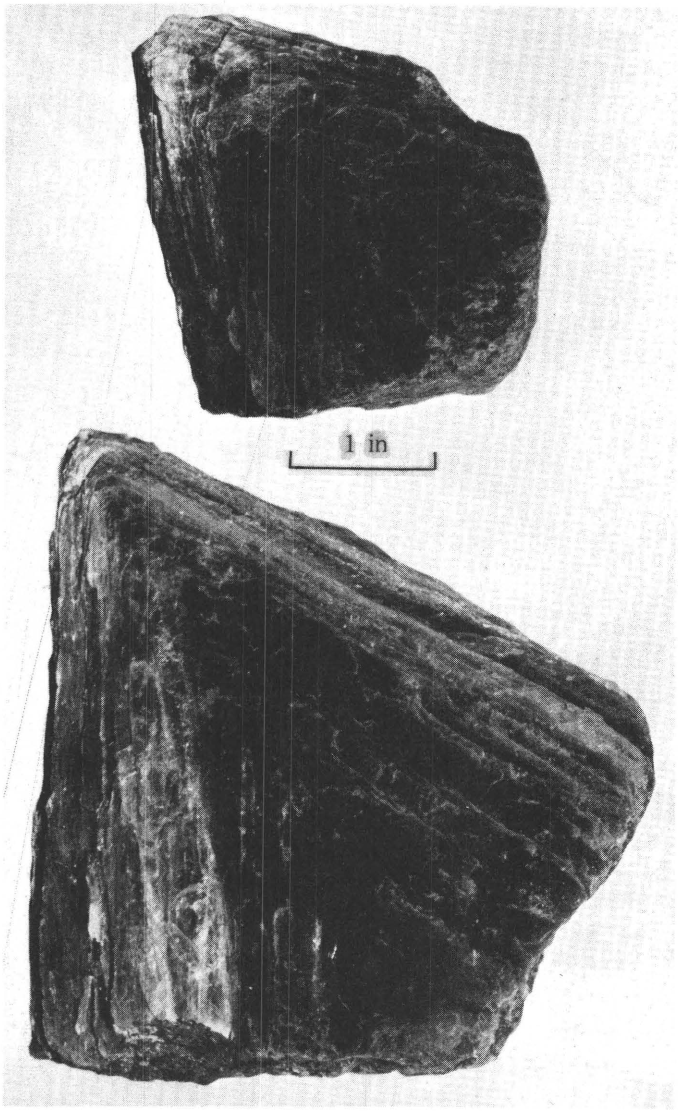

FIGURE 29.—Typical "A" books of muscovite.

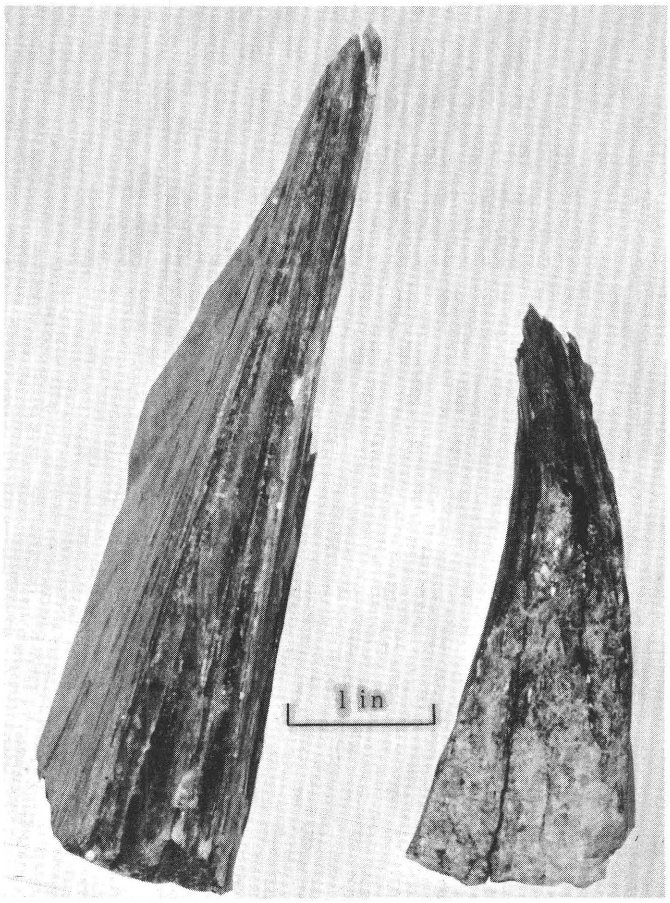

FIGURE 30.—Side view of same muscovite books as in figure 29, showing wedge structure.

(fig. 28), and flat sheets of good quality can be split from their inner parts after the reeved material is trimmed away. Very large trimmed sheets have been obtained from such "flat-A" mica in many mines in the southeastern Piedmont. In still other mica the reeves are confined to certain sheets or groups of sheets, so that imperfect material can be split out and good sheets obtained from the remainder of the books. Much "A" mica, however, is so seriously marred that all of it must be classed as scrap.

"Herringbone" ("fishbone," "fishback," "feather," or "horsetail") mica is marked by reeves that intersect at an angle of about 120°. They characteristically flank a central line or strip of reeves to form a pattern resembling that of a feather or the skeleton of a fish (fig. 31). The central line or strip generally is perpendicular to the trace of the clinopinacoidal crystal face. Most herringbone books contain few flat sheets.

Combinations of "A" and herringbone structures occur in some books, particularly those of the flat-A type. The herringbone reeves generally are discontinuous and irregularly distributed in such mica. Books not marred by "A" or herringbone structure commonly contain a single set of reeves. If these are thin and fine, the material is sometimes referred to as "hair-lined," but such reeves are not to be confused with the hair lines and hair cracks previously discussed.

"A" mica is present and nearly all Piedmont pegmatites and is abundant in many. Most occurs in the inner units of zoned pegmatites, particularly along the margins of quartz cores, and many of these books are very large. Although "A" reeves are developed in the brown and reddish-brown micas of some deposits, the structure is much more common in the green and olive-colored varieties. Herringbone structure is similar to "A" structure in occurrence but is less widespread.

FIGURE 31.—Typical herringbone structure in rough mica crystal.

WEDGING

"Wedge" structure, or "wedging," is caused by the interlayering of sheets of unequal size. Some sheets extend entirely across the mica books, whereas others taper out at intermediate points. Books in which incomplete laminae extend inward from all edges commonly are externally regular in shape, but owing to their internal wedging they yield no sheet mica. Books in which a preponderance of incomplete laminae extends inward from one edge are markedly thicker on one side than on the other (figs. 29–31). Wedge structure is common in herringbone and "A" micas, and the term "wedge-A" is used in contradistinction to "flat-A." Herringbone and most wedge-A books consist almost wholly of scrap, whereas many flat-A books contain appreciable quantities of sheet material. Not all wedged mica is marked by reeves, but the amount of wedging generally is greater in reeved than in unreeved mica. Wedge angles of 25° or more are common in "A" books. Small, thickly wedged "A" books are known as "chub-A."

WARPING AND RIPPLING

"Rippled," "ribbed," "ridged," or "creped" mica is marked by waves or ridges, generally shallow, that are not assignable to "A" structure or to other reeve groups. Some ripples are traceable along their strike into broad warps, and some into fractures or partings, whereas others die out abruptly. In general these minor warps or crenulations are spaced much farther apart than typical reeves, and good sheet material can be recovered from parts of many rippled books. Sheets that are only slightly affected are termed "wavy," and mica that is bent on a broad scale is said to be "warped," "buckled," or "cupped." Another type of deformation, known as "cleavage stepping," comprises small, sharp, subparallel monoclinal flexures that typically distort the cleavage faces into series of broad, low steps.

Unlike reeving, most warping and rippling appear to result from deformation of the mica after, rather than during, crystallization. Rippled mica in many deposits is markedly abundant along and near faults and joints formed after pegmatite emplacement, although in others it cannot be correlated with such features in a clear-cut manner.

Piedmont mica deposits are characteristically free from serious defects of this sort, as is reflected in the high quality of sheet mica obtained from the Thomaston-Barnesville, Shelby-Hickory, and Amelia districts.

RULING

One of the commonest structures in mica books is "ruling," or "secondary cleavage," which occurs as regular, sharply defined parting planes that intersect the basal cleavage plane at an angle of nearly 67° (figs. 32 and 33). These partings are parallel to the rays of the pressure figure. Only one set is present in many books, but two or all three sets occur in others. Their traces on cleavage surfaces intersect at angles of about 60°, and where all three sets are present they commonly separate the sheets into triangular or hexagonal fragments. Many sheets ruled in two directions are similarly separated into rhombic or diamond-shaped fragments or into strips and laths.

The structure generally continues through the entire thickness of severely ruled books, but in others it is confined to certain layers, in which it extends partly or entirely across the cleavage faces. Where one set of

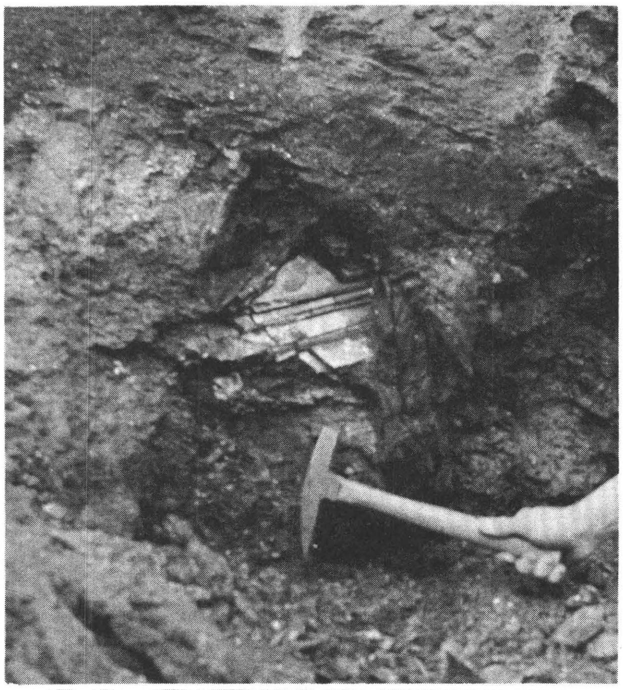

FIGURE 32.—Ruled mica book in kaolinized pegmatite, Big Bess mine, Gaston County, N. C.

ruling planes is well developed, the mica is thereby separated into strips or ribbons that commonly are less than an inch wide (fig. 32). In some mica the individual ribbons are silverlike or hairlike, and accumulations of such slivers are termed "hair mica." Ribbons in some large books, on the other hand, are as much as 4 or 5 in. wide and hence yield satisfactory sheets if free from other defects.

Ruling appears in much "A" and herringbone mica; it either coincides in direction with the striations and corrugations or forms the cross bar of the "A." It is more common, however, in unreeved books, where its distribution is of prime importance in determining the sizes of sheets that can be trimmed out. Like warping and rippling, ruling is the result of distortion from movements after crystallization. It is most intense in books that occur near faults and shears and also is developed in some books near blast holes, where it generally forms small hexagonal or rhombic patterns.

COLOR

Most muscovite is distinctly colored, especially in sheets one-sixteenth of an inch or more thick. Thick sheets and plates have been variously described as "red," "ruby," "rum," "red rum," "green," "amber," "yellow," "gray," "white," "water-colored," and "black," with or without modifying terms indicating tints, shades, or intermediate hues. Much confusion has arisen from duplication and inconsistencies in the usage of these terms. "Amber mica," for example, is the common trade name for phlogopite, and the term "amber" hence is not wholly desirable for muscovite. Deep brownish-to greenish-olive muscovite is termed "water-colored" in North Carolina, whereas the same designation is applied to very light green mica in northern New Mexico. "White" and "gray" are used either to describe very pale mica or to distinguish any thinly split muscovite from the amber phlogopite. Some micas with many air bubbles or clouds of minute light-colored inclusions also are referred to as "gray." "Black" is applied to muscovite with abundant inclusions of magnetite or hematite, and also to dark-brown, greenish-brown, or black biotite ("blackjack"). "Red" mica either contains numerous inclusions of brightly colored goethite and hematite or is interlayered with iron-stained clay.

In general the color of commercial muscovite in the Southeastern States, as viewed by light transmitted through cleavage pieces, ranges from drab and pinkish buff through reddish brown and shades of brown and green to pale yellowish green and yellow (Jahns, 1945). The colors of sheet mica from more than 1,600 deposits have been determined by Frances H. Jahns, who made direct comparisons with Ridgway (1912) standards under fixed conditions (Jahns and Lancaster, 1950). No difficulty was experienced in matching the test pieces with the standard colors of the chart, and more than 75 different colors were identified. For simplicity these were grouped into the following seven main categories:

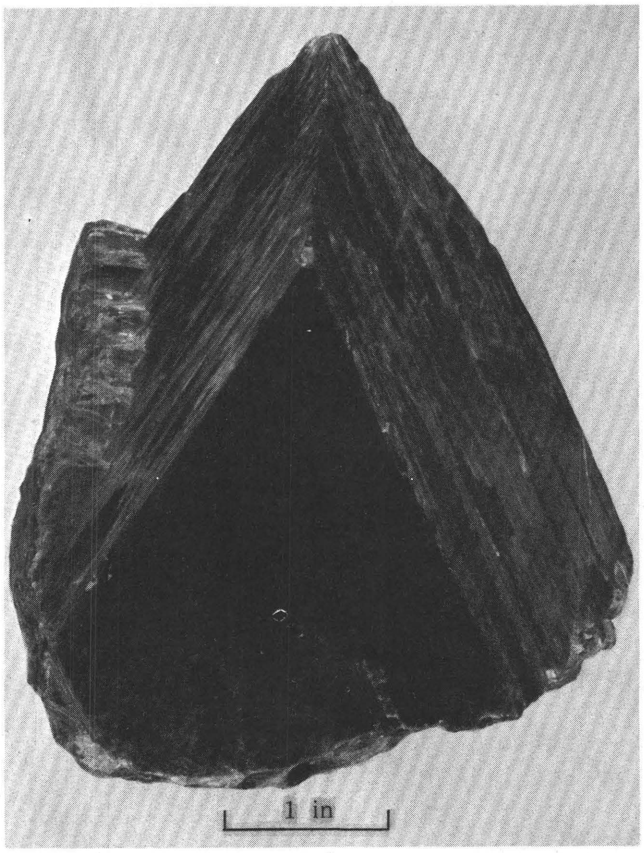

FIGURE 33.—Ruling in a thick mica book showing the angular relations of cleavage and ruling planes.

1. Pinkish buff and drab.
2. Cinnamon brown.
3. Brown.
4. Brownish olive.
5. Yellowish olive.
6. Yellowish green.
7. Green.

None of the groups is sharply bounded, and all gradations between groups adjacent in the list are known. Each is easily subdivided on the basis of light tints and dark shades, as well as in terms of relative brightness or dullness. The darkest shades are browns and brownish olives, and the lightest tints are those of yellowish green, buff, and drab. In general the buff, drab, and cinnamon-brown micas are the so-called "ruby" micas of the trade, and the brown and brownish-olive varieties the so-called "rum" micas. The trade terms are inexact and in many instances actually are misnomers.

Few mica books are colored uniformly throughout. Some are concentrically zoned, with well-defined color bands parallel to crystal outlines. These are called "mine markings" in some districts. Alternating narrow bands of slightly but distinctly differing shades of brown or green characterize the muscovite of some deposits. They are most abundant near the rims of most zoned books but are concentrated near the centers or are scattered throughout others. Crystallographic zoning in still other books appears only as narrow rims or as small centers or cores. Broader color bands are known from many deposits, especially in Alabama, but in general are not so common.

Some pinkish-buff and cinnamon-brown micas, particularly in the Shelby-Hickory district, are marked by distinctive color patterns of grating, gridiron, or chessboard type. The distribution of pattern areas in otherwise uniformly colored sheets is related to crystal directions of the mica, and the patterns commonly are confined to certain sectors of the host books. Stripes of slightly different color are oriented parallel to the pressure-figure directions in many books.

The margins of nearly all books are markedly lighter in color than their inner portions. This appears to be a bleaching effect, distinctly later than true crystallographic color zoning. Similar bleached areas flank cracks and surround holes and many inclusions. Their boundaries with unaffected parts of the books are gradational and irregular. Some mica is mottled, with very irregular splotches of one color in a background of a different color. Most of this material is clear, transparent, and of sound appearance.

Although there are many minor variations within individual books, the color of muscovite in the Piedmont deposits is fairly constant within a single shoot or even within a single pegmatite zone. Micas of more than one general color are known from many pegmatites, but they typically occur in separate concentrations within those pegmatites. Where green and brown muscovite occur in the same pegmatite body, the brown is nearer the walls. Those pegmatites with green book muscovite near their walls contain no brown books and generally contain no biotite.

Most of the book muscovite in the southeastern Piedmont is brown and pinkish, in marked contrast to that in the Blue Ridge province. Green mica is common only in the Ridgeway-Sandy Ridge district and in numerous small outlying areas in Virginia, Georgia, and North Carolina. The outer parts of many color-zoned books in the Alabama deposits also are green. Broad and systematic color variations in the mica of some areas appear to be related to nearby masses of intrusive rock that probably are genetically related to the pegmatites. Such variations are particularly clear in the Ridgeway-Sandy Ridge district.

STAINING, INTERGROWTHS, AND INCLUSIONS

PRIMARY STAINS

Primary stains include air stain, mottling and inorganic "vegetable stain," and mineral inclusions and intergrowths. These blemishes were formed during or soon after crystallization of the mica and hence are not related to the present surface of the deposit in which they occur. They are as likely to increase with depth as to decrease. Secondary stains, in contrast, occur only at or near the surface and characteristically are absent from those parts of the deposit beneath the oxidized zone.

Air-stained mica contains flattened pockets, tiny bubbles, or groups of closely spaced bubbles that are filled with gas. It is very rare in the Piedmont deposits, and where it is confined to certain sheets it can be removed by careful splitting. In general, the effects of air inclusions on the splitting and electrical qualities of muscovite are not as serious as the effects of most mineral stains, and moderately to heavily air-stained mica is unsatisfactory for only certain types of specialized electrical equipment.

Some mica is marked by a pale-green, yellowish, or greenish-brown discoloration that is termed "vegetable stain." Where it is inorganic and essentially primary, such stain comprises minute scales or finely divided aggregates of chlorite, biotite, or material rich in ferrous iron. Individual crystals and mineral masses cannot be recognized megascopically or even with low magnifications under the microscope. Most primary, inorganic vegetable stain is evenly distributed as extremely thin, curdy aggregates (fig. 34). Where similar material occurs as separate clumps, it generally is referred to as "mottling." Specks, spots, and lines of such stain also are known. Primary vegetable stain and mottling rarely are so dense that they seriously affect the transparency of mica that is otherwise of good quality. Like air stain, they generally are significant defects in terms of the most exacting end uses only.

Deep grassy-green specks, spots, and lines are sparsely scattered through much book mica. These are like typical primary vegetable stain in general curdy appearance, but individual masses are darker in color and more clearly defined, and they appear to be somewhat more dense than the scales and aggregates that compose most primary vegetable stain (fig. 34). Some mica contains scattered green, brown, or reddish-brown spots and

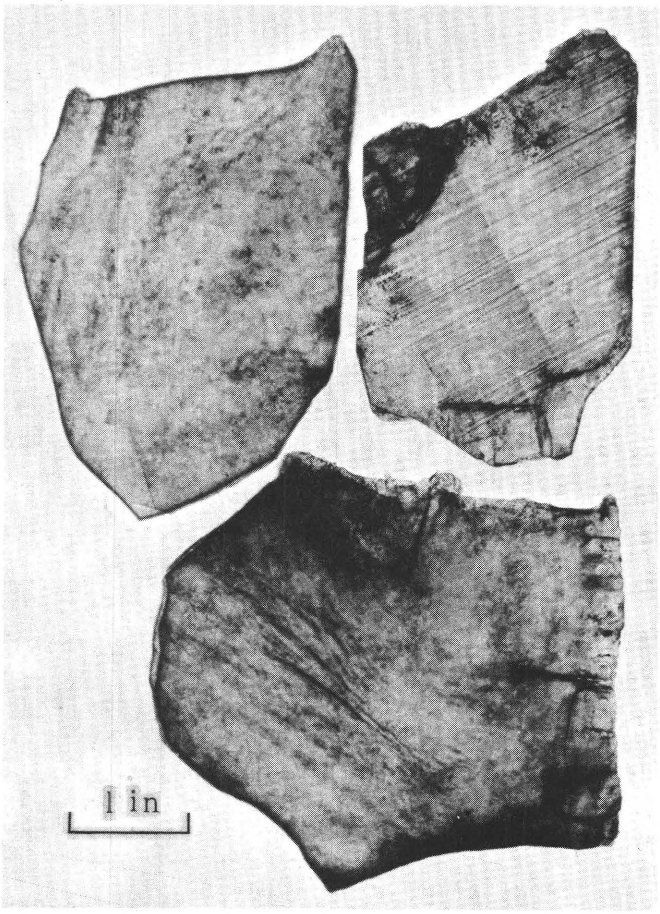

FIGURE 34.—Primary, inorganic vegetable stain and heavy green mottling in thin cleavage plates of muscovite. Note the crystallographic control of stain in the piece at upper left.

"bursts" of curdy stain. Where they are a quarter of an inch or more in diameter, the brown spots are commonly termed "cigarette burns." The name "frog-eye mica" is applied to books that contain brown and green spots with fuzzy edges and dark, well-defined centers. Some spots and bursts are haloes of discoloration that surround tiny inclusions of zircon and allanite, but others contain no recognizable cores of foreign material.

Some mineral impurities occur in muscovite as crystals or crystal groups that extend through considerable thicknesses of laminae, and they must be removed and the immediately surrounding mica trimmed away before the remainder of the host book can be split into sheets. Others are finely divided or thinly flattened between the mica laminae, and the part of the book in which they occur generally is trimmed away and either discarded as scrap or prepared as sheet stock of inferior grade. The proportion, distribution, and type of inclusions, intergrowths, and stain lead to such designations as "mottled," "specked," "spotted," "freckled," "lined," "black," "black-stained," "black-spotted," "lightly stained," "heavily stained," "dotted," "powder-specked," "blotched," and "curdy."

Mineral stain, which comprises intergrowths and inclusions of recognizable crystals, is the most serious of the primary impurities. Among the minerals that occur within books of muscovite are actinolite, albite, allanite, apatite, beryl, biotite, brookite, chlorite, columbite, dumortierite, epidote, fluorite, garnet, hematite, kyanite, magnetite, manganese oxides, marcasite, microcline, pyrrhotite, quartz, rutile, sillimanite, sphene, staurolite, thulite, topaz, tourmaline, vermiculite, zircon, and zoisite. The distribution and shape of many of these minerals, especially magnetite, hematite, and some manganese oxides, are influenced or controlled by crystal directions in the host mica, and it is likely that few of the included minerals are unoriented in the strictest sense.

Magnetite and hematite are the most common inclusion minerals. Magnetite occurs as laths, needles, skeletal forms, and flattened crystals that are six-sided in plan (fig. 35). Some, so thin that they are transparent, are gray to bluish gray or violet. Crystal outlines and prominent parting cracks are oriented in accord with the pressure- and percussion-figure directions. The six-sided crystals are about 9 mm in maximum diameter, with an average of less than 1 mm. The markedly elongated crystals are at least 4 mm in average length, with maximum recorded lengths of 10 cm (Frondel and Ashby, 1937, p. 109). Most inclusions are less than 0.01 mm thick, but some measure as much as 0.1 mm and a few are nearly a millimeter thick.

The inclusions in much of the so-called "specked" and "lightly specked" muscovite are magnetite, characteristically scattered through the books. In some books, however, they are confined to certain sheets or groups of sheets, and in others they occur in well-defined belts parallel to "A" reeves or in concentric zones parallel to crystal faces of the host mica. The thinnest inclusions do not affect the general splitting quality of the muscovite, and sheets and films that enclose such plates, laths, and needles are easily obtained. The thicker inclusions, in contrast, tie the mica on a small scale and seriously impair its filming properties. Such mica is sometimes referred to as "spot-welded," "spot-locked," or "black-pitted."

Hematite, the most abundant and widespread inclusion mineral in commercial muscovite, occurs as flattened skeletal crystals with a hexagonal outline, laths and flattened needles, simple and complex dentritic

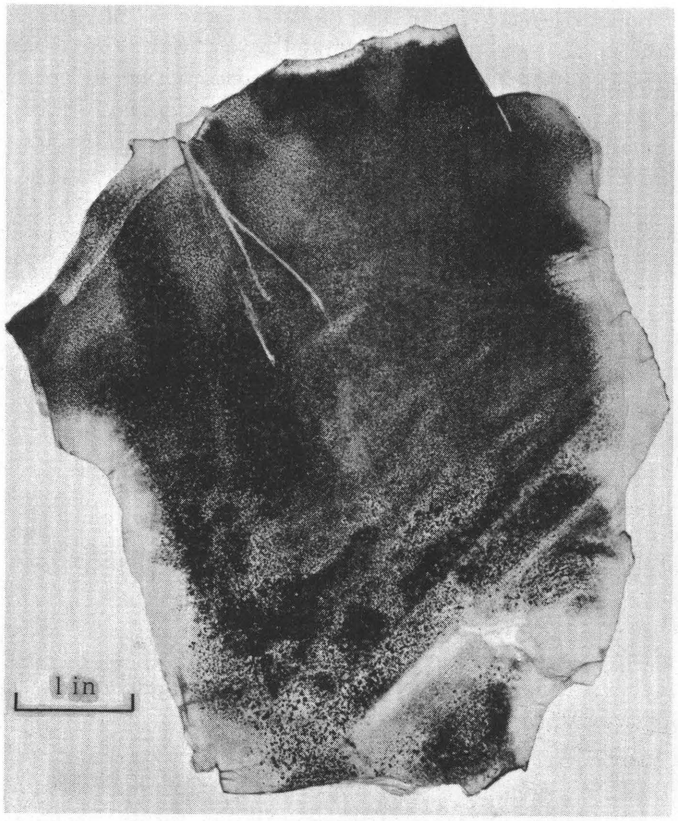

FIGURE 35.—Muscovite heavily stained with magentite and hematite specks. Note the clear areas along the edges of the sheet and along the narrow warps and ripples.

forms, and latticelike forms that are extreme developments of skeletal crystals (figs. 36–39). The lattices are characteristically triangular, with the three elements parallel to rays of the percussion figure or, much less commonly, to the rays of the pressure figure in the enclosing mica. Other elements lie perpendicular to the three principal directions of some lattices, and the symmetry of the whole is hexagonal (fig. 38). The hematite inclusions are black, dark brown, reddish, smoky brown, and buff, and none show the bluish shades of most very thin magnetite inclusions. In general they are more transparent than the magnetite crystals. The dendritic and lattitcelike growths have been identified as hematite, rather than magnetite, in the stained micas of the Southeastern pegmatites. Frondel and Ashby (1937) have summarized the principal differences between magnetite and hematite inclusions in muscovite, chiefly on the basis of detailed studies of collections from the northeastern United States.

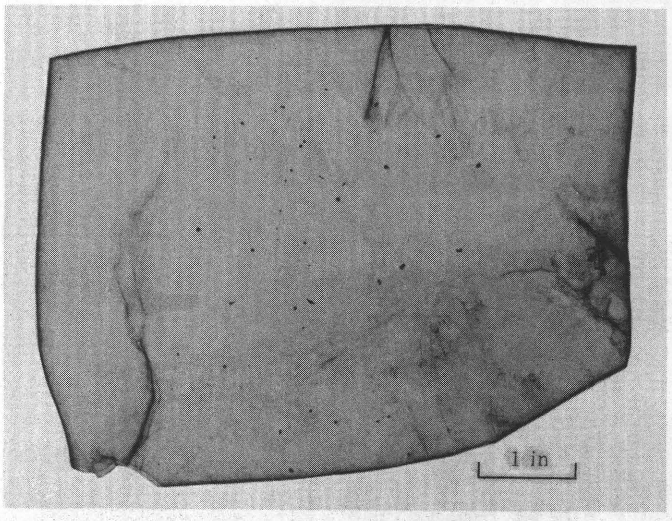

FIGURE 36.—Mica slightly specked with hematite. The areas of air creep around the trimmed edges of the sheet and along the cracks and hair lines are slightly darker than the areas of clear mica. One-inch square shown for scale.

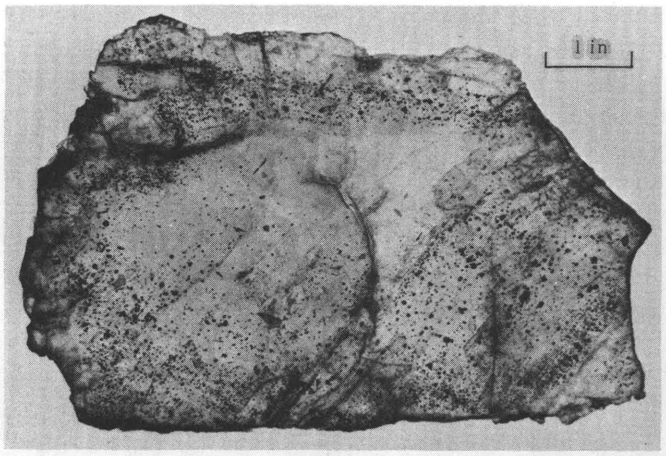

FIGURE 37.—Mica with moderately heavy hematite stain.

Some hematite laths and plates are bounded by smooth and regular crystal faces, but the edges of most are so irregular that they create a feathered or dendritic appearance (fig. 39). All are extremely thin, especially as compared with their areal extent, and they are not separable from the enclosing mica by ordinary mechanical means. Their maximum thickness is considerably less than 0.01 mm, whereas most are several square centimeters in area and individual lattices and skeletal crystals more than 3 ft long occur in a few large books.

The stained portions of some books can be split out, leaving clear sheets of high quality. The stain is con-

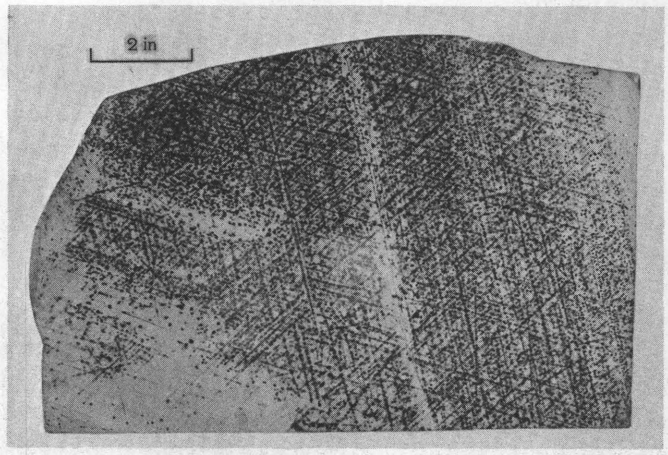

FIGURE 38.—Triangular lattice of irregular hematite spots in a very thin sheet of mica.

fined to the centers or to one or more sides of other books, in which the stained mica can be trimmed away from the clear material.

The outer parts of stained books are characteristically free from inclusions, even where the remainder of the mica is very heavily stained (figs. 35 and 39). Clear mica commonly flanks cracks and parting planes and surrounds holes in books that elsewhere contain inclusions. The distribution of such stains also is influenced by some warping, rippling, and other secondary structures in the mica.

Inclusions of hematite or magnetite appear to have little effect upon the splitting qualities of muscovite, at least so far as its commercial preparation is concerned. Ordinarily the stained parts of books with lattices or spots split as easily and uniformly as the

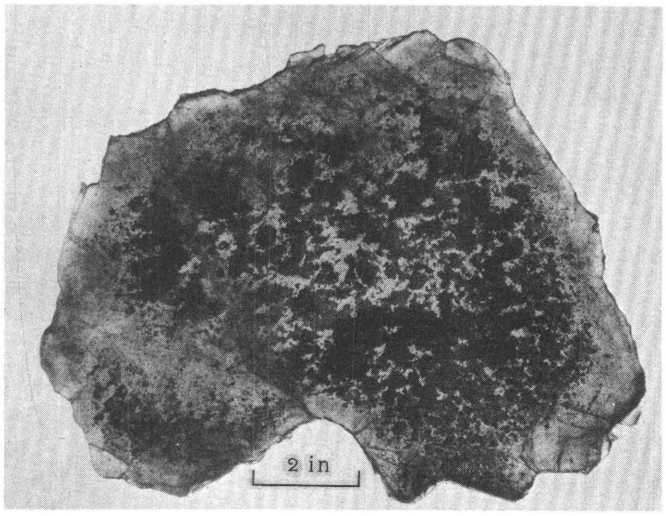

FIGURE 39.—Mica with heavy blotches and tiny specks of hematite. Note the relatively clear margins.

unstained parts, and there is no perceptible tying of sheets. Both hematite and magnetite, however, seriously increase the electrical conductance of the mica in which they occur and hence lower its value. The amount of lowering depends upon the thickness, abundance, and distribution of the inclusions.

Goethite occurs in sheet mica as yellow, orange, red, reddish-brown, or brown scales, stains, and pseudomorphs of other iron-oxide minerals. Most appear to have been formed by alteration of hematite and magnetite inclusions, but some of the most finely divided scales may well have been developed directly by precipitation in the mica.

Quartz and albite are interlayered with some muscovite plates to form composite masses of little or no economic value. The edges of other books are intergrown with these minerals. Books in which quartz, apatite, or tourmaline spindles are present are known as "gritty," "sandy," "stony," or "sand-pitted." Where the axes of such spindles are oblique or perpendicular to the cleavage the impurities effectively tie the books.

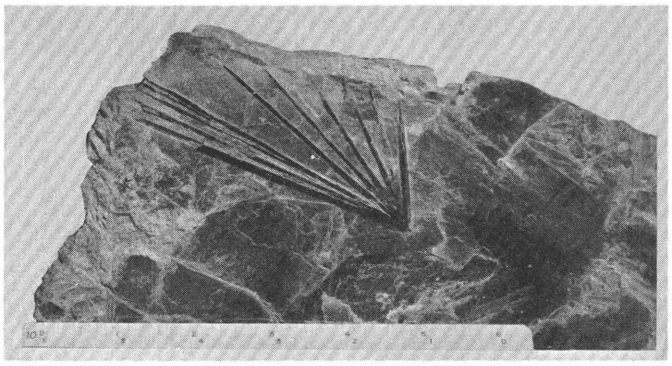

FIGURE 40.—Radiating group of black tourmaline crystals in a mica book from the Big Bess mine, Gaston County, N. C.

Actinolite, allanite, beryl, kyanite, rutile, tourmaline, zoisite, and other species of elongate habit commonly occur as individual crystals, bundles and parallel groups of crystals, sprays, and rosettes (fig. 40). Although they lie parallel to the clevage surfaces, they generally penetrate enough laminae of the mica to affect its splitting properties seriously. Many of the crystals are oriented parallel to rays of the pressure or percussion figures.

Fluorite, garnet, pyrite, and other minerals occur as inclusions that are much flattened parallel to the plane of clevage in the mica (fig. 41). They are characteristically equant in that plane. The flattening is extreme in many books, but in others the inclusions are much thicker and hence tie considerable numbers of mica laminae. The average diameter of garnet inclusions probably is less than 5 mm, although flattened tablets an inch or more in diameter are known. Most are less than 0.3 mm thick, and many measure as little as 0.05 mm. These dimensions also apply to other inclusion minerals of similar habit. The prismatic and other elongated inclusions are of comparable thickness but commonly reach lengths of several inches.

Biotite is intergrown with muscovite in many deposits. Inclusions of biotite in muscovite are common,

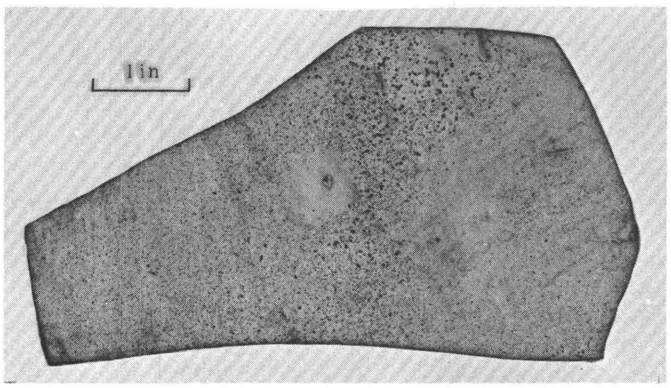

FIGURE 41.—Small flattened inclusion of garnet in a sheet of mineral-specked mica with abundant pale-green inorganic vegetable stain. Note the clear area around the inclusion.

but inclusions of muscovite in biotite are sparse (fig. 42). In some districts the muscovite is intergrown with vermiculite, which presumably formed by alteration of biotite. Where biotite and muscovite are intergrown the cleavages of the two minerals generally are parallel, but the pressure and percussion figures of the inclusions are commonly oriented perpendicular to those of the host. A few inclusions of biotite are elongated normal to their cleavage direction and lie oblique to the enclosing muscovite, thus tying the sheets of the host book.

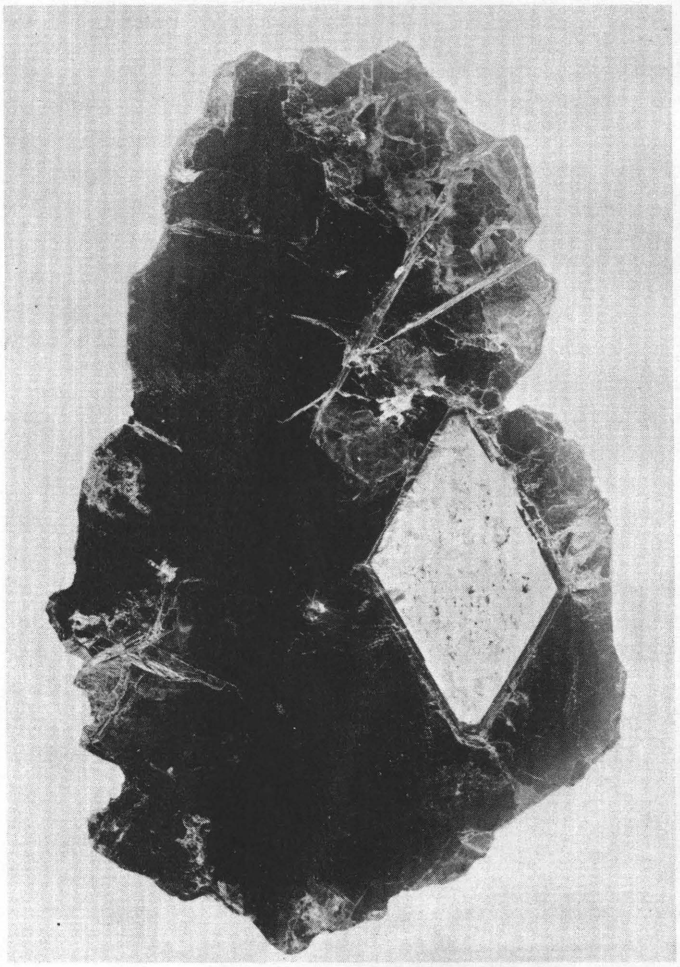

FIGURE 42.—Rhombic crystal of muscovite in biotite, both having the same cleavage planes.

SECONDARY STAINS

Stains of secondary origin include air creep; clay, iron, and manganese stains; and true vegetable stain. Air creep is similar in appearance to some types of air stain. It is merely air that enters the mica sheets from their edges and penetrates them along cleavage planes (fig. 36). In general it is caused by rough handling during preparation of the mica, especially by trimming with shears or a dull knife. This type of stain is easily distinguished from primary air stain, as it does not consist of many small bubbles or larger air pockets that are fully and firmly enclosed. The creep pockets either are connected with the trimmed or natural edge of the sheet or can be so connected by pressing the mica between the thumb and forefinger. They do not constitute a significant defect unless they occupy so many cleavage openings that the transparency of the mica is materially reduced.

Most books that have been exposed to weathering and the action of downward-percolating surface waters are coated with calcite, chalcedony, clay minerals, hydrous iron oxides, manganese oxides, or other secondary minerals. Where they have been deposited by waters that penetrated between the laminae of the mica the value of the books is materially reduced, as the stained portions must be removed by careful splitting and trimming. Books marred chiefly by silica, calcite, and clay minerals are termed "clay-stained," whereas those that are strongly colored yellowish, reddish, or brownish by iron oxides are referred to as "iron-stained." The basis for the term "manganese-stained" is similar.

The organic type of vegetable stain, a truly secondary feature characteristic of the weathered zone in mica deposits, consists of plant material that coats the outer surfaces and some of the cleavage laminae of mica books. Some of the material is carried into the mica by waters that penetrate fractures and cleavage cracks, and some forces its way into the books through the action of growing plants. The near-surface mica of many deposits is veined by the roots of grasses, bushes, and even trees. Most organic vegetable stain is accompanied by heavy clay and iron staining, and books so affected yield little usable sheet material.

ELECTRICAL PROPERTIES

The extremely low electrical conductivity of muscovite is an important basis of most of its commercial uses. Unstained mica is the least conductive and is therefore suited for electrical equipment of the best quality. Many mineral inclusions, particularly of magnetite and hematite, increase the conductivity; hence stained mica generally is used in articles that do not require the most effective insulation. Conducting impurities in sheet muscovite can be detected by means of a high-voltage spark, which causes glowing or small-scale sparking while passing through the mica at or near the inclusions.

The dielectric constant (K) of muscovite is the ratio of the capacitance of a condenser in which the muscovite is the nonconducting substance to the capacitance of a condenser in which air (or, more exactly, a vacuum) is the dielectric. K for sheet mica ranges from 2.0 to about 8.5 but generally is more than 6.5, with an average of about 7.2. It is a property of great significance for many electrical uses but is so uniform in micas that are otherwise of good quality that limiting values are rarely specified by purchasers.

The dielectric strength of muscovite is its ability to resist breakdown or rupture under conditions of high voltage and is defined in terms of the maximum potential gradient that material of a given thickness can withstand. It is tested by means of the high-voltage spark (concurrently with testing for conducting impurities in the mica) or, more commonly, by applying high voltages through spherical or plate-like contact electrodes. Dielectric weakness is caused by pinholes, cracks, tears, and other discontinuities in the mica sheets. Many of these are recognizable in ordinary visual examination, but others are so small or inconspicuous that they are easily overlooked.

A very significant electrical property of mica used in condensers is its power factor (*PF*), which is a measure (expressed in percent) of the loss of electrical energy in a condenser in which the mica is the dielectric. Excessive overheating and damage result from high power losses; hence good condenser mica must have a power factor of less than 0.04 percent at a frequency of 1 megacycle. The Q value, a factor more commonly used in recent years, is the reciprocal of the power factor, so that $Q=1/PF$. The Q value of good condenser mica therefore should be at least 2,500.

OCCURRENCE

TYPES OF DEPOSITS

DISSEMINATED DEPOSITS

Many pegmatites in all parts of the southeastern Piedmont contain book muscovite that is scattered from wall to wall and from crest to keel. These disseminated deposits ordinarily are simple unzoned granitoid aggregates of quartz, feldspar, mica, and a few accessory minerals or consist of very thin border zones and granitoid cores. Most variations within them are textural, although some are distinctly more quartzose along their walls or in their centers than elsewhere. Well-defined mica shoots are rare, but mica is irregularly concentrated near the walls or in quartzose parts of some deposits.

Most pegmatites with disseminated mica are thin sills, dikes, pods, lenses, or chains of lenses, but others are much larger, reaching thicknesses of 30 ft or more. Some sheetlike or thinly lenticular pegmatites contain small core segments of massive quartz or other mica-poor rock and hence are not true disseminated deposits. They differ little from such deposits, however, as mica is scattered through their feldspathic portions, which constitute the bulk of the pegmatite material.

Some of the thin lenses and series of lenses have yielded large quantities of muscovite. Examples of these include the Monteiro-Amber Queen deposit in Goochland County, Va., the Coleman No. 1, De Shazo, and Eanes deposits in the Ridgeway-Sandy Ridge district, and parts of the Brown and Mitchell Creek deposits in Upson County, Ga. A few of the pegmatites, like the Mitchell Creek, are surrounded by irregular, poorly defined aureoles in which the country rock contains abundant coarse mica books. Some disseminated deposits contain large quantities of mica, but the recovery of usable material requires the handling of so much barren rock that mining operations are not always successful. Many others are so mica-poor that they are of no commercial interest whatever.

Most of the muscovite in disseminated deposits forms small, flat, and hard books of fair to good quality. Drab, pinkish buff, and brown are characteristic colors except in many pegmatites of the Ridgeway-Sandy Ridge district, where yellowish and brownish olive prevail. The chief defects are cracks, holes, ruling, and inclusions of quartz, apatite, tourmaline, and other "stony" minerals. "A" structure is developed only in the large books that occur near the centers of some deposits, especially those that contain appreciable quantities of perthite. Inclusions and intergrowths of hematite and magnetite are sparse to rare. In general the quality of the crude mica is better in plagioclase-rich deposits than in those with much potash feldspar.

WALL-ZONE DEPOSITS

Wall-zone concentrations have yielded more mica than any other type, in some districts because of their abundance and in others because of a few exceptionally rich or extensive deposits. Some, like the Amphlett in Cherokee County, Ga., are very thin and occupy the full width of constrictions in pinching and swelling pegmatite bodies. Book mica is disseminated throughout many of the wall zones of this type, but in others it occurs in clearly defined shoots adjacent to crests or keels of core segments, sharp rolls in contacts between pegmatite and wall rock, or other structural features. Other wall zones are much thicker and more irregular and commonly surround large podlike cores or core segments. The Champion and White Peak No. 1 deposits in Virginia are excellent examples. Distinct mica shoots characterize most pegmatites of this type, but the book mica in others is scattered irregularly, with only local suggestions of concentration. The Knight and Big Bess deposits in North Carolina and the M. and G. in Alabama represent a third kind of occurrence, in which blanketlike concentrations of book mica occupy the wall zones of thick but markedly tabular pegmatite bodies. Some of these are very rich.

The proportion and size of mica books rarely are uniform throughout a given wall zone. In addition to the shoots already described, many broader irregularities are present. In most of the tabular pegmatite bodies the hanging-wall part of the wall zone is distinctly richer or leaner than the footwall part, even though both are minable in many instances. In other pegmatites the distribution of mica is still less symmetrical, and concentrations of books are confined to their hanging-wall or footwall parts. Because few wall-zone deposits are coextensive with the wall zones themselves, few are fully "closed"—that is, extend as minable concentrations along both flanks and around the ends of the inner zones.

In many wall zones the proportion of muscovite is greater along and near the margins than elsewhere, although commonly no recognizable shoots are present, and in others the proportion increases progressively from one margin toward the other.

Most wall-zone mica occurs in plagioclase-quartz pegmatite. In general, perthite is distinctly subordinate or absent, and biotite is rare. The books range considerably in size and typically are flat, hard, free splitting, and of good quality. Most are pinkish buff to brown. Cracks, warping, ruling, and inclusions of quartz, apatite, tourmaline, and pyrite are the chief defects. Reeves, "A" structure, and lockiness are widespread in some deposits, especially those that contain a moderate to high proportion of potash feldspar. In others the abundance of these defects increases inward from the outer margin of the containing wall zone. Heavily stained books are common in some deposits, especially in pegmatites with green muscovite only. The stained material does not appear to be systematically distributed in many pegmatites, but in others it is especially abundant in certain parts of the wall zones or in certain parts of shoots.

INTERMEDIATE ZONE DEPOSITS

Intermediate-zone deposits are widespread and abundant in the southeastern Piedmont but have not yielded as much sheet mica as the disseminated and wall-zone deposits. In many respects they are much more irregular than wall-zone deposits, although well-defined mica shoots are characteristic of most. The simplest intermediate-zone deposits are those that flank or envelop cores and core segments. Other core-margin deposits, in contrast, can be traced beyond the ends of quartz cores, where they flank inner intermediate zones rich in coarse perthite.

The size, concentration, and quality of muscovite rarely are uniform throughout intermediate-zone deposits, and the thickness of the deposits themselves varies considerably from place to place. In general they range from fringes of individual large books along the edges of quartz cores to masses of granitoid quartz-feldspar-muscovite pegmatite 10 ft or more thick. Both perthite and plagioclase ordinarily are present, with the potash feldspar dominant in many deposits. Biotite is commonly associated with the muscovite.

The most discontinuous intermediate-zone deposits are near the centers of thick, bulbous pegmatites with a complex internal structure and characteristically are associated with large podlike cores. The Drum pegmatite in Catawba County, N. C., contains a deposit of this type. Other pegmatites, like the Short Tom Smith in Rockingham County, N. C., also are large but are not so distinctly zoned. Poorly defined concentrations of mica occupy much of their inner portions and commonly enclose small, inconspicuous core segments. A third and widespread type of intermediate-zone deposit occurs in thinner and markedly tabular pegmatites as more regular, blanketlike concentrations of mica that are similar in structure to many wall-zone deposits. The Adams, Battles, and Boyt pegmatites in the Thomaston-Barnesville district contain such concentrations.

Intermediate-zone mica, especially core-margin mica, is characterized by "A" and herringbone structures. Prominent and often spectacular concentrations of many large books are typical (figs. 43 and 44). Most of the mica is pale green to yellowish olive and commonly is less stained than wall-zone mica. Where both types of concentrations are present in the same pegmatite body, as in the Drum and W. T. Foster No. 1 of the Shelby-Hickory district, the intermediate-zone books are much larger but of poorer quality. In addition to reeves, prominent defects include cracks, warping, wedging, and inclusions of garnet. Despite the size and abundance of many intermediate-zone books, they ordinarily yield a low proportion of sheet stock; hence such deposits may be less capable of supporting mining operations than many of those in wall zones.

MISCELLANEOUS ZONAL DEPOSITS

Many pegmatites in Alabama contain concentrations of mica that fringe platy masses of quartz. The quartz plates may well be scattered core segments, and the mica concentrations thus may be typical core-margin deposits. They have constituted an important source of mica in the State, as the books generally are abundant, hard, and free splitting. Cracks, reeves, ruling, warping, and quartz inclusions are the principal imperfections. Somewhat similar concentrations fringe inclusions and septa of partly digested wall rock in several pegmatites of the Hartwell and other districts and probably are special types of border-zone and wall-zone deposits. The books are typically hard and flat, but most are small.

Some telescoped zonal units include minable concentrations of mica, and in general the type of mica they contain is the same as that characteristic of the zones into which they can be traced. A few of these deposits, like those in the Big Bess pegmatite, Gaston County, N. C., and several in other parts of the Carolina Piedmont, are rich, but most contain very high proportions of quartz and feldspar.

Book mica is concentrated within and around the margins of many coarse-grained granitoid aggregates of quartz and feldspar that form podlike masses within finer-grained granitoid pegmatite. Most are much richer in quartz than the surrounding rock. Such pod deposits are very common, particularly in large pegmatites of rather simple zonal structure. They are abundant, for example, in the Otter River-Moneta area, Va., where numerous pegmatites have been worked for feldspar. Most of the pods are less than 6 ft in diameter, and many are a foot or less in maximum dimension. Although some are rich in muscovite, the total amount of recoverable mica is rarely large. The size and quality of the books appear to depend in part upon the position of the host pod within the pegmatite body. Thus pods near the walls generally contain small, flat books, whereas many of those at or near the centers of the enclosing pegmatite bodies are marked by "A" and herringbone reeves.

BURR-ROCK DEPOSITS

Burr-rock deposits, in which book muscovite is scattered through quartz, are abundant in several districts. Some have yielded commercial sheet material. The quartz-mica rock forms the border zones of some pegmatite bodies, especially the tin-bearing ones in the Carolinas and in Coosa County, Ala. It occurs in the cores of others and forms sheets, lenses, and irregular pods in the granitoid portions of still others. Some of the tabular masses appear to be fracture fillings but most probably belong to the zone sequence. The mica of many burr-rock masses is recognizably later than the quartz, but in others the two minerals appear to be essentially contemporaneous.

FRACTURE-FILLING AND REPLACEMENT DEPOSITS

Fracture-filling and replacement deposits of muscovite occur in most districts, but nearly all are small and of little commercial interest. They constitute a negligible proportion of the total pegmatite in the region. The mica generally is associated with quartz and sodic albite. Sugary albite is interstitial to small books that fill fractures in the quartz of several pegmatites in the Amelia, Shelby-Hickory, Hartwell, and Alabama districts, and cleavelandite is abundant in the replacement deposits of at least four Virginia pegmatites. Radiating blades and wedged books of mica occur within cleavelandite at the Pat Ayers No. 4 prospect of Alabama and in the Big Bess and Old Plantation mines of the Shelby-Hickory district, N. C. Similar books form rosettes and festoons in parts of several large pegmatites in the Otter River-Moneta area, Va.

Most of the fracture-controlled deposits are small and contain no coarse mica. They occur typically as simple veinlets and more complex branching aggregates and stockworks, generally in massive quartz or coarse perthite-rich pegmatite. Many of the larger replacement bodies in which fracture control is not evident are rich in coarse book mica. Those in the Herbb No. 2, Rutherford, and Morefield pegmatites have yielded small quantities of sheet material, although earlier-formed mica from wall zones has constituted the bulk of production. The mica from the replacement deposits is green, yellowish green, and brownish olive, whereas the wall-zone material is browner. The mica of replacement deposits is of distinctly poorer quality, owing mainly to "A" and herringbone structures, wedging, warping, ruling, cracks, inclusions of quartz, fluorite, and other "stony" minerals, and its typical occurrence in tangled and partly intergrown books. The proportion of recoverable sheet stock is very small.

MICA IN COUNTRY ROCK

Two general types of muscovite concentrations occur in the country rock adjacent to pegmatites: scattered large books and coarse muscovite schist. Permeation of schists, gneisses, and quartzites by pegmatitic solutions has produced coarse-grained, poorly to well foliated feldspathic quartz-muscovite schist in many places, and similar zones of wall-rock alteration surround numerous quartz "veins" and aplite masses. Locally, as in the Clein scrap deposit of Alabama, the alteration is so complete that the rock can be mined, broken up, and sold as scrap mica with little need for beneficiation. In other places the altered rock contains so much quartz and feldspar that it cannot be profitably worked for its mica.

The Mitchell Creek deposit in Upson County, Ga., contains abundant wall-rock muscovite of the second type. Coarse, well-formed books occur in granitic gneiss along the pegmatite contacts, and many of them have no visible physical connection with the pegmatite itself. Some are 4 in. or more in diameter, and many contain sheet material of very good quality. The mica is hard, flat, and free splitting but is marred by cracks and abundant mineral inclusions. Similar occurrences are recorded from deposits in the Ridgeway-Sandy Ridge and Shelby-Hickory districts, but the total amount of mica obtained from them is small.

RELATIVE PRODUCTIVITY OF DEPOSITS

The zonal and disseminated types of mica deposits are most abundant in the southeastern Piedmont. Wall-zone deposits, in which the mica is most commonly associated with plagioclase and quartz, have yielded the bulk of production in all districts. In general they are thicker and more extensive than the other zonal types, contain mica of better average quality, and are more uniform in thickness and richness. Similar relations are characteristic of the New England and southeastern

Blue Ridge regions (table 4). The disseminated deposits, with somewhat lesser average richness, generally contain mica of good quality and are important producers. This is in sharp contrast to the New England districts, where consistently productive deposits of this type are rare (Cameron, Larrabee, McNair, Page, Shainin, and Stewart, 1945, p. 389). Intermediate zones contain some of the richest mica concentrations and some of the largest known books, but they are much more irregular than the wall zones in shape and thickness and their mica yields a distinctly smaller proportion of trimmed sheets. Moreover, the distribution of books within them is typically sporadic. Although such deposits are widespread, few of them have sustained mining operations for long periods of time.

TABLE 4.—*Relative productivity of mica deposits by types*

[Based on amount of trimmed punch and sheet mica produced during World War II]

Type of deposit	Southeastern Piedmont	Southeastern Blue Ridge [1]	New England [2]	Petaca district, N. Mex.[3]
Wall-zone	Very great	Very great	Very great	Very small or negligible.
Intermediate-zone	Moderately great.	Great	Moderate	Negligible.
Disseminated	do	do	do	Very small.
Miscellaneous zonal	Small	Very small	Very small	Very small or negligible.
Burr-rock	Very small	do	None	None.
Fracture-filling and replacement.	do	Small	Very small	Very large.
Country-rock	Small	Very small	Negligible	Very small.

[1] Jahns, Heinrich, Parker, and others (in preparation).
[2] Cameron, Larrabee, McNair, Page, Shainin, and Stewart (1945, pp. 389–391).
[3] Jahns (1946, pp. 88–94).

Quartz-plate and telescoped-zone deposits are of commercial interest in a few districts but in general are of such limited extent and are so variable in mica content that they cannot be worked on a large scale. Many contain mica books of good quality and moderate tc large size, but the proportion of barren material ordinarily is very high. Burr-rock and fracture-filling deposits are very abundant, but prduction of sheet mica from them is a minor proportion of the total. The masses of mica-bearing rock rarely are large, and most of the mica books are small

Late replacement deposits have yielded little commercial mica, because so few large ones are known in the southeastern Piedmont and the average quality of the mica in them is very poor. Similar relations are characteristic of New England and the southeastern Blue Ridge regions, but the small production from the Petaca district of New Mexico is derived almost wholly from concentrations of replacement origin (table 4).

Only a few deposits in the southeastern Piedmont consist of book mica in rock outside the pegmatite contact. At least two of these have been very productive, but the output of all such deposits constitutes a very small proportion of the total.

The mica within a given zone is rather consistent in color, clearness, type and distribution of structural imperfections, and electrical properties, whereas the books from different zones within the same pegmatite commonly differ very strikingly. Green "A" mica, for example, is especially abundant along the edges of quartz cores in many pegmatites, whereas the wall-zone mica in the same pegmatites is buff, cinnamon brown, or brownish olive and is little reeved. "A," herringbone, and wedged books are most abundant in pegmatites and pegmatite zones that are rich in potash feldspar, as well as in some that contain sodic albite, whereas most of the flat books that generally yield material of better quality are in perthite-poor pegmatite. Flat books that are associated with perthite tend to be locky. Most Piedmont pegmatite bodies are so thin that they are mined from wall to core or even from wall to wall, and the distinction between types of mica deposits therefore loses much of its economic significance. In others, however, the shoots are separated by several feet of barren material and are most effectively worked as individual deposits.

Green mica is abundant in the Ridgeway-Sandy Ridge district and in outlying areas in Virginia, Georgia, and North Carolina and also occurs sparsely in the other districts. Moderately to heavily stained books are common in the western part of the Amelia district, in the central part of the Ridgeway-Sandy Ridge district, and locally in the Hartwell and Alabama districts. In addition such material is very abundant in the Cullen-Charlotte Court House, Pittsylvania, Chestnut Mountain, Axton, and Philpott-Martinsville areas of Virginia and in outlying parts of North and South Carolina. Drab, pinkish-buff, and brown mica is much more abundant and widespread than the green and in general contains little iron-oxide stain. Many of the books, however, are marred by inclusions and intergrowths of biotite. Air stain is rare in all types of Piedmont muscovite, but primary vegetable stain and green mottling are locally abundant.

CONTENT, SIZE, AND QUALITY OF MICA

The richness of mica shoots and the mica content of entire pegmatite bodies have not been rigorously determined at many mines and prospects in the southeastern Piedmont. Although mine owners and lessees have been uniformly cooperative in supplying operating data, most of these data are not complete enough for production analyses. Few mine operators, for example, record systematically the tonnage of rock moved, and some do not even have accurate data on the production of mine-run mica. It has been possible, however, to make quantitative estimates in many deposits on the basis of mica-bearing pegmatite left on the walls and backs of workings, fragments of uncobbed material near mine portals, untrammed ore and muck in the workings, and the mica in the breasts themselves. Whenever obtainable, complete production records have served as a basis for comparison with the volume of workings from which the mica was taken. Much of the output of trimmed punch and sheet mica during the period of World War II is known from the accurate records of the Colonial Mica Corp.

Some of the pegmatite bodies with disseminated mica contain the highest over-all proportion of book material. This ranges from less than 1 percent to more than 40 percent, with an average of about 5 percent in those deposits that have been worked on more than a prospecting scale. The mica content of the wall-zone deposits that have been mined averages about 7 percent, with a range from less than 1 percent to about 50 percent. Some of the most productive shoots contain exceptionally rich concentrations or "pockets" of coarse books, but the richest parts of others consist of closely spaced foils and small books. Intermediate-zone deposits contain an average of approximately 5 percent mica, with a range even more extreme than that of the wall-zone concentrations. The proportion of mica in most deposits of other types is less than 2 percent, although burr-rock and some replacement deposits are locally rich.

All the figures cited are based on total mica in the deposits rather than upon recoverable mica. Elimination of fragments lost in the muck and dump material reduces these figures to some extent. In general the wall-zone, intermediate-zone, and disseminated deposits of the southeastern Piedmont appear to yield higher average proportions of muscovite, and the other types similar or somewhat lower proportions, than the corresponding types in New England (Cameron, Larrabee, McNair, Page, Shainin, and Stewart, 1945, p. 390). All types probably contain slightly higher average proportions than those of the pegmatites in the Blue Ridge province of the southeastern United States.

The proportion of trimmed punch and sheet material that can be obtained from the flat books of the wall zones that have been mined averages about 6 to 7 percent, and the books from some large mines yield 10 to 12 percent prepared material. The average lies within the "average range" of 3 to 8 percent cited by Billings and Montague (1944, p. 95) for domestic deposits. Flat books from intermediate-zone deposits contain a slightly lower proportion of recoverable sheet stock, and the proportion of such material in typical reeved books is much lower. Some flat-A books are so large that numerous sheets can be trimmed from them, but others consist wholly of scrap. Thus the average content of sheet material in reeved books is not more than 3 percent in the most productive mines and probably is less than 2 percent in the mines as a whole and less than 1 percent in fracture fillings and replacement deposits. A "grand average" of about 5 percent of trimmed punch and sheet mica can be recovered from the mine-run books obtained from all workable deposits in the southeastern Piedmont.

The ratio of trimmed sheet to trimmed punch material that was obtained from the southeastern Piedmont during World War II was almost exactly 1 : 1, whereas the ratio for the Southeastern States as a whole was slightly lower. The production of sheet comprised full-trimmed, three-quarter-trimmed, and some half-trimmed material. During ordinary periods, when the smaller mica is prepared as punch, rather than as full-trimmed punch (small sheet), the ratio of sheet to punch in the Southeastern States is about 1 : 4 or 1 : 5.

The value of the mine-run books depends in large part upon the size range of the trimmed sheets that they yield. The output from many mines contains little material larger than 3 by 3 in., whereas others yield unusually high proportions of sheets 8 by 10 in. and material of special sizes. In general more than half the production from the Piedmont deposits is in sheets 2 by 2 in. or smaller, and less than one-tenth is in sheets 4 by 6 in. or larger. The largest sheets are obtained from wall-zone deposits and from giant flat-A books in intermediate-zone deposits (figs. 43 and 44).

The quality of recovered sheet mica varies somewhat from one district to another and distinctly from one type of deposit to another. Nearly all properly prepared clear material, however, appears to be of good quality, as shown by electrical tests. On the other hand, less than one-fifth of the recent wartime output was classed as no. 1 on the basis of careful visual tests in the shops of the Colonial Mica Corp. This category corresponds to a mixture of 20 percent clear and slightly stained with at least 80 percent fair stained or better (table 7). These quality data suggest that in any classification scheme that combines visual and electrical tests some structural and other nonelectrical defects will be most responsible for down-grading of the prepared sheet mica.

CLASSIFICATION AND VISUAL GRADING

As taken from the mine, the mica crystals or books are designated as "mine-run," "run-of-mine," "book," or "block" mica. The term "block mica" is more commonly used for partially prepared stock that will yield sheet material, as well as for certain types of imported sheet material, and hence might well be dropped in favor of "book mica." Commercial muscovite is classified primarily as "sheet," "punch," or "scrap," depending upon the type of material obtained from the mine-run books.

"Scrap" includes books, flakes, and fragments that are too small or too marred by inclusions, cracks, holes, or other imperfections to yield acceptable sheet or punch stock, as well as the waste from those books that yield punchings and trimmed sheets. The material removed from the mine-run mica within or near the mine portal, known as "rough" or "cobbed" mica or "mine scrap," ordinarily never reaches the shops where the better mica is split and trimmed. "Bench scrap" is the mica obtained as discarded splittings and trimmings in the preparation of sheet and punch mica; in general it is of distinctly better quality than "mine scrap." In most lots it amounts to more than 90 percent of the mica that is not discarded as mine scrap.

"Sheet muscovite" in the most general sense is any material other than scrap. It is flat or nearly so and is sufficiently free from structural defects to be manufactured into certain shaped products that are used in electrical equipment, stoves, lamps, and other appliances. "Uncut sheet mica" is partly prepared stock that has been freed of obvious scrap, split or "rifted" into plates three-eighths inch or less thick, and trimmed by any of several methods. If it will yield regularly shaped sheets or "patterns" 1½ by 2 in. in minimum size, it is specifically known as "sheet" or "pattern" mica in the New England and Southeastern States and as "plate" mica in the Southwestern States. Gwinn (1943, p. 18) has pointed out that the general term "block mica" is most suitable for such material and has defined it as prepared stock of "random thickness ⅛ inch to less than $\frac{1}{100}$ inch (125 to 10 mils), which contains a usable area of 1½ by 2 inches minimum."

"Punch mica" is difficult to define rigorously, owing chiefly to inconsistencies in the usage of the term. In general, however, it is uncut material capable of yielding punched or trimmed sheets that contain circles at least 1½ in. in diameter but do not contain rectangles as large as 1½ by 2 in. "Circle" mica will yield prepared sheets 2 in. in diameter, and "small punch," "washer," or "washer punch" mica will yield sheets 1 in. in diameter. Most washer mica is little more than scrap, and many users do not recognize it as a separate class. "Punch mica" is sometimes used as a general term, including circle, punch (in the strict sense), and some small punch or washer. The terms "uncut punch" and "uncut circle" are synonymous with "punch" and "circle" as generally used but may be helpful in distinguishing such material from the prepared sheets or punchings. "Trimmed punch," or small-sheet material, is prepared from ordinary punch, generally by knife trimming.

Size grading of sheet mica is based on the area and minimum width of the largest rectangle of a given quality that can be obtained from the block. The usable rectangle must be free from holes and cracks and must meet certain other tolerances. A standard grading method has been outlined by the American Society for Testing Materials (1942, p. 391). The size groups for domestic and Indian sheet mica are summarized in table 5, and a discussion of size grading and simplified charts for grading are included in a report issued by the U. S. Bureau of Mines (Gwinn, 1943, pp. 7–10).

The thickness of mica is determined by means of a machinist's micrometer or a rapid-reading dial gage, and specifications for standard methods of determination have been outlined by the American Society for Testing Materials (1942, pp. 238–242). The minimum acceptable thickness for sheet muscovite generally is 0.007 in.

TABLE 5.—*Domestic and Indian size groups for clear sheet mica, including punch and sheets larger than punch*

[Adapted from charts issued by Colonial Mica Corporation, agent for Metals Reserve Company. Applies to sheets not less than 0.007 in. thick]

Usual domestic grades	Usable area in single rectangle (square inches)		Minimum dimension of one side (inches)	Standard Indian grades
	Minimum	*Maximum*		
Small punch [1]	1	1½	----------	No. 6 small.
Punch [1]	1½	2½	¾	No. 6.
Circle [1]	2½	3	1	No. 5½.
1½ by 2 in	3	4	} 1	} No. 5.
2 by 2 in	4	6		
2 by 3 in	6	10	1½	No. 4.
3 by 3 in	10	12	} 2	} No. 3.
3 by 4 in	12	15		
3 by 5 in	15	24	2	No. 2.
4 by 6 in	24	36	3	No. 1.
	36	48	4	No. A–1 (special).
6 by 8 in	48	60	4	Extra special.
8 by 8 in	60	80	4	Extra extra special.
8 by 10 in	80	100	4	Over extra extra special.
Larger than 8 by 10 in		>100	4	Over over extra extra special.

[1] Included under general term "punch," which applies to mica yielding usable sheets not less than 1 in. in diameter.

Quality designations for sheet mica

Designation	*Description*
Clear	Free from all mineral and vegetable inclusions, stains, air inclusions, waves, or buckles. Hard transparent sheets.
Clear and slightly stained.	Free of all mineral and vegetable inclusions, cracks, waves, and buckles, but may contain slight stains and air inclusions.
Fair stained	Free of mineral and vegetable inclusions and cracks. Hard. Contains slight air inclusions and is slightly wavy.
Good stained	Free of mineral inclusions and cracks, but contains air inclusions and some vegetable inclusions and may be somewhat wavy.
Stained	Free of mineral inclusions and cracks, but may contain clay and vegetable stains and may be more wavy and softer than the better qualities.
Heavy-stained	Free of mineral inclusions, but contains more clay and vegetable stains than stained quality. Distinctly inferior as regards rigidity and toughness.
Black-stained and spotted.	Likely to contain some mineral inclusions consisting of magnetite (black), hematite (red), and hydrous iron oxide (yellow).

Much mica is purchased in this country according to the so-called domestic classification. This fourfold classification and its correlation with the A. S. T. M. categories are as follows:

Domestic classification	*A. S. T. M. designation*
No. 1	20 percent clear and slightly stained; 80 percent fair stained.
No. 2	Good stained.
No. 2 inferior	50 percent stained; 50 percent heavy-stained.
No. 3	Black-stained and spotted.

Quality designations for sheet mica vary according to the visual classification used, and a combined visual and electrical classification recently adopted by the American Society for Testing Materials yields still another set of terms. Interpretations of visual standards differ from one observer to another, but attempts have been made to define the standards and to describe the methods of determination in such exact terms that inconsistencies are reduced to a minimum. The Indian groups, beginning with the best quality, are "clear," "clear and slightly stained," "slightly stained," "fair stained," "good stained," "stained," "heavy-stained," "light-dotted," "black-spotted," and "black-stained." In 1938 the American Society for Testing Materials (1942, p. 392) set up Indian standards as the American standards and designated the foregoing principal qualities. Several of these seven groups are sometimes subdivided into more specific categories.

Mica sold for use in stove manufacture is generally graded as A–No. 1, No. 1, and No. 2, in order of decreasing quality. Moreover, a general twofold classification is more commonly used for all domestic sheet mica; black-stained and spotted material is referred to as "stained" or "electric," and the other types are grouped under the general term "clear." "Clear" micas, according to this usage, include the No. 1, No. 2, and No. 2 inferior categories shown.

PREPARATION AND MANUFACTURE

The first rough separation of mica generally takes place at the mine, either at the face or portal or, later, on the dump. Obvious mine scrap is separated from the better books, from which adhering fragments of quartz, feldspar, and other foreign material are then cobbed. Some of this rough-cobbed or selected mine-run mica is sold to jobbers or manufacturers, but at many mines it is prepared further. The books are split or rifted by means of a 3-in. single- or double-edged blade into plates that generally are less than $\frac{3}{16}$ in. thick. Through skilled handling of the rifting knife, defective laminae are removed with a minimum waste of higher-quality material, and block mica, punch and washer stock, and bench or shop scrap are thereby obtained. In some districts the cobbed mica is commonly split into plates thicker than $\frac{3}{16}$ in., but both these and the thinner riftings are generally known as "plate mica." They constitute a specially selected form of mine-run material.

After rifting, the ragged and broken edges of many plates are removed with the fingers, a process known as "thumb trimming." This is an especially common practice in districts where much of the mica is severely ruled or marked by "A" structure (fig. 43). Some thumb-trimmed material is sold to manufacturers, but most is further trimmed with a knife and its value

FIGURE 43.—Large flat and flat-A mica books at the Ridgeway mine, Henry County, Va., after preliminary rifting and some thumb trimming.

thereby increased (fig. 44). During recent years attempts have been made to employ several forms of blades and saws for mica trimming in the United States, but without much success.

Most Indian mica is knife-trimmed or sickle-trimmed free of cracks and flaws, but domestic procedure is somewhat different. "Half-trimmed" mica, for example, is cut on two adjacent sides with no cracks, reeves, cross grains, or ribs extending from those sides. "Three-quarter-trimmed" mica is cut on all sides, with no cracks or comparable flaws extending from two adjacent sides or into the final pattern area. Only "full-trimmed" mica is comparable to Indian-trimmed material in that it is cut on all sides and contains none of the flaws noted. Moreover, upper limits generally are set on the number and size of "V" or figure cuts on any one piece of mica, as well as on the proportion of pieces with such cuts in a given lot of mica.

FIGURE 44.—Large flat sheets of mica at the Ridgeway mine, Henry County, Va., after knife trimming.

A large proportion of sheet mica is consumed in the form of splittings. These are films 0.0007 to 0.001 in. thick that generally are cleaved from punch and the smaller sizes of sheet stock. Some also are derived from thin films or skimmings that are a byproduct from the rifting of larger sheet material. Splittings are used in the manufacture of built-up mica board and other forms of electrical insulation. Although many mechanical devices have been tested for the preparation of these films, practically all are still split outside the United States by hand methods, generally in places where labor costs are very low.

The cut mica blocks that represent punch, circle, and larger sheet stock are processed into disks, washers, and thin plates of various sizes and shapes. This generally involves additional splitting, followed by trimming, cutting, or stamping into more or less standardized patterns. Most of this material is then cut to final form, if necessary, by the manufacturers of the devices in which the mica is to be used. Composite forms can be built up to any desired thickness by the cementing of individual pieces with shellac, glyptol, or a similar bonding medium. In general only a small proportion of the prepared block material is represented in the finished product. The bulk of such material is skimmed or cut away as waste, which is marketed as scrap of superior grade.

Most scrap mica, including material derived from nonpegmatitic sources, is processed by grinding. It is classified on the basis of its freedom from quartz, feldspar, and other gritty impurities and on the basis of its color when ground. About a third of the mica ground in this country is prepared by wet methods, which yield relatively fine grained material. Most of the coarser, less expensive products are ground dry. The problems and methods of mica grinding are fully discussed in reports published by the U. S. Bureau of Mines (Myers, 1929, pp. 7–8, 14–18; Horton, 1935, pp. 10–12, 28–30).

USES

The uses of mica are based upon its perfect cleavage, remarkably low conductivity of heat and electricity, high dielectric strength, noninflammability, mechanical strength, flexibility, elasticity, transparency, luster, and lubricating properties and the ease with which it can be worked into final form. The degree of emphasis placed upon given properties by the purchaser depends upon the specific end use involved (Wierum, 1938, pp. 11–26; Spence, 1929, pp. 102–120). Flexibility is particularly important, for example, in the "cigarette mica" used in spark plugs for aircraft engines. This material, in films 0.0012 in. or less thick, is wrapped around rod-like spindles a little more than ⅛ in. in diameter. Mica is valued for use in condensers because of its dielectric properties, and, in contrast, the use of mica for windows in furnace walls and doors is founded upon its transparency, heat resistance, and mechanical strength.

A very high proportion of all sheet mica is used as electrical insulating material. Washers, disks, and other small trimmed or stamped forms not only are employed as such but can be built up into rods, tubes, or other articles that are bonded with a suitable cementing material. Simple and composite pieces are used, for example, as tubes, sleeves, studs, washers, bushings, laminations, and thin perforated plates in condensers, transformers, small heating elements, rheostats, fuses, incandescent bulbs, radio and electronic tubes, and various types of coils and in acoustic, X-ray, and other specialized equipment. Thin splittings are built up into mica board or are applied as facing on paper, cloth, and other materials used in the manufacture of heater elements; commutators; boards, panels, and other mounting forms; parts of condensers; and many other electrical devices.

Most coarsely ground mica is used in the manufacture of roofing materials, although the demand for such mica as a refractory is constantly increasing. It also is used for decorative purposes as a coating on wallpaper, as a constituent of certain stuccos, plasters, and cements, or alone as Christmas-tree snow. During recent years increasing quantities of roughly prepared material have been used in foundry facings and in the insulation of buildings or have been manufactured into molded electrical insulation. Mica that has been ground very fine is used extensively in the manufacture of rubber, paints and other protective coatings, lubricants, textiles, and plastics. It is an effective filler and bonding medium, and commonly increases the corrosion, heat, and fatigue resistances of the products.

SYSTEMATIC TESTS

CORRELATIONS BETWEEN END USES AND SPECIFICATIONS

Most raw mica is sold according to requirements specified by the purchaser, with emphasis generally placed upon features subject to grading by careful visual examination. Specifications vary with individual end uses. Manufacturers of Christmas-tree snow, for example, demand only material that is reasonably free from gritty impurities and will yield a white product when coarsely ground. In contrast, it is only natural that fabricators of electrical equipment, the chief users of high-quality sheet muscovite, should set very exacting requirements and thereby reduce the proportion of material that conceivably might cause operational failures.

Correlations between end uses and specifications have been developed for some physical properties of muscovite through long periods of trial and careful study, and appropriate tolerances are recognized and understood within narrow limits. Little basic or empirical information is at hand for other features, however, and specifications concerning them appear to be founded upon less certain ground. Owing to the setting and maintenance of high acceptance standards for some of the less fully understood properties of commercial sheet muscovite, few purchasers consider the possibility that so-called inferior grades of material may well be satisfactory for a given use. The basic effects of color, stain, and inclusions on the electrical properties of muscovite are perhaps least known, and there are serious gaps in the correlation of these with other properties.

In the absence of data that would permit positive assignment of a certain physical feature in a given lot of mica as the cause of an undesirable proportion of failure in finished electrical equipment, any reluctance to lower consumers' specifications is easily understood. On the other hand, the steadily growing demand for muscovite of superior quality, especially during the past two decades, has forced some use of lower-quality mica and even the substitution of other materials. Extreme conservation measures became a practical necessity with the unprecedented demands of World War II, when the entire problem was thrown into sharp relief. The best grades of mica were allocated only for the manufacture of articles in which no other material was judged usable, and supplies were further conserved by the required use of poorer qualities wherever possible, by the use of the smallest sizes possible, by the reduction of wastage and the reclamation of partly spoiled material, and by the substitution of ceramic, treated paper, or other insulating substances wherever practicable.

During the wartime period substitutions were made in great haste and under the stress of expedience, so that many of them were necessarily based on incomplete and empirical information. Nevertheless, the program of conservation was markedly successful in terms of equipment performance. With a return to peacetime conditions, however, there was a partial return to higher specifications for raw sheet muscovite. Such specifications may not be wholly necessary, as already shown by the results of extensive fundamental tests carried out by several organizations during and shortly after the war. Some of these tests involved intensive systematic studies of individual properties, and others were aimed at correlating as many types of data as possible.

EFFECT OF PHYSICAL PROPERTIES ON ELECTRICAL PROPERTIES

Color is a property that has affected the merchantability of muscovite since the days when its chief uses were based largely upon transparency. Light-brown and light-green micas, which yield more transparent sheets of a given thickness, commanded higher prices than darker-colored micas. These higher prices were carried over into periods of increasing electrical uses, when dark-brown and brownish-green micas were "classed as 'No. 2,' even when flawless and clear" (Sterrett, 1923, p. 17). Later, when the scrap-mica industry first expanded into prominence, it was found that the lighter-colored micas yield a whiter ground product; hence such varieties of scrap were sold for higher prices.

In selecting high-quality sheet mica for electrical uses during recent years, purchasers have placed varying degrees of emphasis upon the desirability of ruby mica as contrasted with green and especially dark-green varieties. It has been stated repeatedly that dark or green varieties of muscovite "usually are poorer dielectrics," but the actual basis for such statements is difficult to determine. Although most appear to be generalizations extrapolated from scattered and unsystematic data, they have resulted in the consistently inferior position of green and dark-brown muscovite in the trade. Such micas generally command lower prices than the pinkish-buff and light-brown (ruby) varieties and commonly have a very limited market during periods of low demand for mica of the best electrical grade.

Color, stain, and other physical characteristics of direct commercial application were correlated with some significant electrical properties of sheet muscovite from the southeastern United States in several series of tests. The samples were collected from stockpiles or lots of mine-run books at operating mines, from the walls and backs of mine workings, and from dumps at mines no longer accessible. Electrical tests of mica obtained from 124 mines in 1939 and 1940 were made by the National Bureau of Standards, and several samples were treated in greater detail by two large fabricators of electrical equipment (Kesler and Olson, 1942, pp. 18–30).

Determination of the *Q* value (reciprocal of the power factor) of mica permits its classification according to the latest standard specifications set up by the American Society for Testing Materials (1945, pp. 45–47), provided the electrical conductivity is tested and the usual visual characteristics also are determined. Mica can be divided into three groups on the basis of *Q* value, as shown in table 6. These are designated E–1, E–2, and E–3. E–1 mica that is flat to only slightly wavy, contains no conducting impurities and little or no air stain, and is free from cracks, tears, pinholes, stones, buckles, and ripples corresponds to fair stained or better material in the visual classification and yields films of top quality. It is suitable for all types and sizes of silver and foil electrodes in molded and potted capacitors. This and other quality groups have been summarized and discussed by the American Society for Testing Materials (1945, pp. 46–47, 54–57). Numerous experiments have demonstrated that the Q-meter and spark-coil test set developed by the Bell Telephone Laboratories are satisfactory for classifying mica according to these latest A. S. T. M. standards. (Townsend, 1944a, p. 21, 1944b, p. 8; Coutlee, 1945a, 1945b).

TABLE 6.—*Q and power-factor values for electrical-quality mica groups E–1, E–2, and E–3*

[Based on A. S. T. M. standard specifications]

Q or power-factor group	Form	*Q* value	Power factor	Rapid-method meter reading		
				0.010 in.[1] (0.007 to 0.015 in.)	0.020 in.[1] (0.015 to 0.025 in.)	0.030 in.[1] (0.025 to 0.035 in.)
E–1	Block mica	2,500 minimum	0.0004 maximum	95 to 100	95 to 100	95 to 100
	Mica films [2]	2,500 minimum [3]	0.0004 maximum			
E–2	Block mica	350 to 2,500	0.00285 to 0.0004	87 to 95	77 to 95	71 to 95
	Mica films [2]	1,500 minimum [3]	0.00066 maximum			
E–3	Block mica	50 to 350	0.02 to 0.00285	50 to 87	32 to 77	24 to 71
	Mica films [2]	200 to 1,500 [3]	0.005 to 0.00066			

[1] Thickness of block mica or mica films stacked to this thickness.

[2] Probable minimum *Q* values of molded-type, stacked-foil, or silvered capacitors (1,000 $\mu\mu f$). These will apply when all factors that would adversely influence the *Q* value are under control.

[3] Extensive commercial tests have verified the validity of the *Q* values of capacitors made with group E–1 block mica to a satisfactory degree. However, the ranges for groups E–2 and E–3 are tentative and subject to further verification.

TESTING PROJECT, 1945–46

A very extensive testing project was carried out jointly during the period July 1945–April 1946 by the Geological Survey, the State of North Carolina, the State College of North Carolina, and the Tennessee Valley Authority. Important contributions also were made by the Colonial Mica Corp. and the Georgia Engineering Experiment Station. A total of 2,502 lots containing 237,764 pieces of mica was examined and tested. This material was obtained from at least 850 deposits in the Southeastern States. The electrical testing was done in Asheville, N. C., by F. W. Lancaster, of North Carolina State College, who used the spark-coil test set and the rapid, direct-reading *Q*-meter developed by the Bell Telephone Laboratories. The results of all the investigations of muscovite in the southeastern United States have been described elsewhere (Kesler and Olson, 1942; Jahns and Lancaster, 1950), but some of the important data from the most recent project are summarized in this report.

TESTS OF CLEAR MICA

During the recent systematic investigations visual and electrical tests were made on 416 lots comprising 39,917 pieces of clear muscovite from deposits in the southeastern Piedmont. These lots included raw mica obtained from mines, mine dumps and muck piles, and rifting shops, as well as partly or fully prepared material loaned by several mine operators and by the Colonial Mica Corp. All pieces were rifted, trimmed, and dried prior to testing. Test pieces were split to a thickness within the recommended range for the *Q*-meter that was used. They varied greatly in size, with most pieces in the range from size grades 5 to 7. Many were so badly clay-stained, iron-stained, rippled, reeved, cracked, or otherwise blemished that they could be classed only as washer stock. Many also were marred by green mottling, brown bursts and cigarette burns, small inclusions of biotite, or sparsely scattered spots of hematite and magnetite. They were classed as "clear" only because they lacked the slight to heavy iron oxide stain characteristic of no. 3, electric, mica.

All but 66 of the tested pieces, or nearly 100 percent, lay within the 95 to 100 range on the meter and hence qualified as E–1 mica. Indeed, nearly all of them were within the 97–100 range. Numerous stacks also were tested and were found to be within the E–1 range. Only four lots yielded E–2 material, and one lot contained only a single piece of E–3. One of these lots consisted of very badly broken and clay-stained mica, and all four were marked by scattered inclusions of iron oxides. General descriptions of the mica and the results of the Q-meter test are summarized in table 7. There is little observable correlation between power factor and the color of the mica, or between power factor and amount of mottling, primary vegetable stain, biotite inclusions, brown bursts, or clay stain in the test pieces.

The spark tests verified the presence of cracks and holes in much of the mica, and a few of the scattered magnetite and hematite inclusions in some pieces reacted as conducting substances. Pinholes and hair cracks were much more common than they appeared to be on the basis of careful visual inspection, and they were present in some of the test pieces that had been qualified previously as no. 1 material. The finest hair cracks were most abundant in some pieces of green mica, the pinholes in pinkish-buff and cinnamon-brown mica. Many of these holes evidently were developed by the popping out of tiny zircon inclusions.

TABLE 7.—*Summary of Q-meter tests of clear muscovite from deposits in the southeastern Piedmont*

Mine or prospect	District	County and State	Type of material	Remarks	Electrical tests: Number of lots tested	Total number of pieces tested	Percent E–1	Percent E–2	Percent E–3
Abernathy Long Cut (Hickory) mine.	Shelby-Hickory	Catawba, N. C	6, 7	Clay-stained; pale-green mottling; local small brown bursts.	4	407	100	0	0
Adams mine	Thomaston-Barnesville.	Upson, Ga	5, 5½, 6, 7	Slightly clay-stained; widespread green mottling; sparse brown bursts.	4	634	99+	Tr	0
Amber Queen mine	Outlying Virginia	Goochland, Va	6	Clay-stained	2	77	100	0	0
Anthony prospects	Shelby-Hickory	Cleveland, N. C	5	Clay- and iron-stained	1	55	100	0	0
Archie mine (in Archie Norman group).	do	do	5, 6	Slightly clay-stained	3	359	100	0	0
Arnott mine	Alabama	Randolph, Ala	5½, 6	do	2	367	100	0	0
Bailey mine	Hartwell	Hart, Ga	5, 6, 7	Clay-stained	2	73	100	0	0
Barron (Bennie Barron, Walker Wakefield) mine.	Thomaston-Barnesville.	Upson, Ga	6	Clay- and iron-stained; sparse biotite plates.	1	98	100	0	0
Battles mine	do	Monroe, Ga	4, 5, 5½, 6, 7	Clay-stained; local green mottling; rare brown bursts.	5	729	100	0	0
Baxter, Jack, (Tom Baxter) mine.	Shelby-Hickory	Lincoln, N. C	5, 5½, 6, 7	Heavily clay-stained and iron-stained.	14	1,877	100	0	0
Do	do	do	Washer	do	2	30	100	0	0
Baxter, Jack, prospect	do	do	6	Clay-stained; rare brown bursts	1	86	100	0	0
Beam, Claude, prospect	do	Gaston, N. C	Washer	Clay-stained	1	17	100	0	0
Berry mine	Amelia	Amelia, Va	6, 7	Clay-stained; very pale green mottling.	1	75	100	0	0
Bess mine	Shelby-Hickory	Lincoln, N. C	6, 7	Clay- and iron-stained; very pale green mottling.	1	79	100	0	0
Do	do	do	Washer	Clay-stained	1	18	100	0	0
Big Bess mine	do	Gaston, N. C	5, 6, 7	Slightly clay-stained; local pale-green primary vegetable stain.	3	775	100	0	0
Biggerstaff (Deadman) mine	do	Lincoln, N. C.	5½, 6, 7	Clay-stained; rare brown bursts	3	305	100	0	0
Do	do	do	Washer	do	1	9	100	0	0
Blanton prospect (near Tom Cabaniss mine).	do	Cleveland, N. C	6, 7	Clay- and iron-stained	2	138	100	0	0
Do	do	do	Washer	do	1	18	100	0	0
Blanton, C. Robert, mine	do	do	6. 7	Clay-stained	1	68	100	0	0
Blanton, Cliff, mine	do	do	6, 7	Clay- and iron-stained; local curdy green stain.	8	481	100	0	0
Blanton, Coleman, mine	do	do	5, 6, 7	Clay-stained; local green mottling.	3	205	100	0	0
Blanton, Troy, mine	Outlying South Carolina.	Cherokee, S. C	7	Clay-stained	1	97	100	0	0
Bolding mine	do	Pickens, S. C	6, 7	Intergrowths of biotite	1	21	100	0	0
Bonnett Split (Big Hill) mine	Shelby-Hickory	Cleveland N. C	6, 7	Slightly clay-stained	2	122	100	0	0
Bowen mine	do	do	7	Clay- and iron-stained	1	55	100	0	0
Bowen mine, prospect east of	do	do	6, 7	Clay-stained	1	84	100	0	0
Do	do	do	Washer	do	1	9	100	0	0
Boyt mine	Thomaston-Barnesville.	Upson, Ga	6	Clay-stained; apatite and biotite inclusions; rare brown bursts.	1	16	100	0	0
Bridges, Pleaz, mine	Shelby-Hickory	Cleveland, N. C	6, 7	Clay- and iron-stained	3	261	100	0	0
Do	do	do	Washer	do	1	5	100	0	0
Brittan, Floyd, mine	do	Burke, N. C	5, 6	Clay-stained; much green mottling.	1	70	100	0	0
Do	do	do	Washer	do	1	12	100	0	0
Broomfield prospect	Outlying Virginia	Pittsylvania, Va	5, 6	Very heavily clay-stained; moderately iron-stained.	2	209	100	0	0
Brown mine	Ridgeway-Sandy Ridge.	Stokes, N. C	5½, 6	Clay- and iron-stained	1	133	100	0	0
Brown (Parrish) mine	Thomaston-Barnesville.	Upson, Ga	4, 5, 5½, 6, 7	Clay- and iron-stained; some rows of thin biotite wisps.	3	480	100	0	0
Bumgarner mine	Shelby-Hickory	Cleveland, N. C	6, 7	Slightly clay-stained	2	156	100	0	0
Burgess (L. E. Hunter) mine	Outlying South Carolina.	Anderson, S. C	6	Clay-stained; green and brown bursts.	1	23	100	0	0
Cabaniss prospect	Shelby-Hickory	Cleveland, N. C	6, 7	Clay- and iron-stained	2	224	100	0	0
Do	do	do	Washer	do	1	14	100	0	0
Cabaniss, Tom, mine	do	do	5, 6, 7	Clay- and iron-stained; garnet inclusions.	4	538	100	0	0
Campbell mine	do	do	6	Clay-stained	1	89	40	60	0
Carter mine	Hartwell	Hart, Ga	6	Slightly clay-stained; some biotite intergrowths.	1	73	100	0	0
Do	Thomaston-Barnesville.	Upson, Ga	3, 4, 5, 5½, 6, 7	Clay- and iron-stained; local primary vegetable stain.	3	559	100	0	0

TABLE 7.—*Summary of Q-meter tests of clear muscovite from deposits in the southeastern Piedmont*—Continued

Mine or prospect	District	County and State	Type of material	Remarks	Electrical tests				
					Number of lots tested	Total number of pieces tested	Percent E–1	Percent E–2	Percent E–3
Champion (Jefferson No. 4, Bland) mine.	Amelia	Amelia, Va	5, 5½, 6, 7	Clay-stained	6	963	100	0	0
Chrysolite mine	Shelby-Hickory	Cleveland, N. C	6, 7	Slightly clay-stained	1	265	100	0	0
Coggins prospect	Thomaston-Barnesville.	Lamar, Ga	6	Clay-stained; some green mottling.	1	105	100	0	0
Coleman No. 2 mine	Ridgeway-Sandy Ridge.	Henry, Va	6, 7	Slightly clay-stained	2	88	100	0	0
Do	do	do	Washer	Stained	1	8	100	0	0
Cooke mine	Shelby-Hickory	Cleveland, N. C	6, 7	Clay-stained	1	20	100	0	0
Cooley mine	Hartwell	Elbert, Ga	5, 6, 7	do	3	215	100	0	0
Corley mine	Thomaston-Barnesville.	Upson, Ga	6	do	1	23	100	0	0
Cornwall, Frank (Old J. S. Blanton) mine.	Shelby-Hickory	Cleveland, N. C.	6	do	2	133	100	0	0
Do	do	do	Washer	do	2	24	100	0	0
Cornwell, Charles, prospect	do	do	6, 7	do	1	132	100	0	0
Crawford-Daniel mine	Hartwell	Elbert, Ga	6, 7	Clay- and iron-stained	1	37	100	0	0
Crews prospect road cut near	Outlying Virginia	Charlotte, Va	6	do	1	110	100	0	0
Crews No. 2 prospect	do	do	6	Slightly clay-stained	1	121	100		0
Dagenhart mine	Shelby-Hickory	Alexander, N. C	6, 7	Clay-stained; scattered reddish-brown bursts.	1	32	100	0	0
Do	do	do	Washer	do	1	15	100	0	0
Davis, Walter, mine	do	Cleveland, N. C	6, 7	Slightly clay-stained; local green mottling.	1	97	100	0	0
De Shazo mine	Ridgeway-Sandy Ridge.	Henry, Va	5, 6, 7	Slightly clay stained	4	281	100	0	0
Do	do	do	Washer	Stained	3	33	100	0	0
Dobbin prospect	Amelia	Amelia, Va	do	Clay-stained	1	7	100	0	0
Dolphin, Clinton, mine	Outlying Virginia	Powhatan, Va	7	Slightly clay- and iron-stained	1	127	100	0	0
Drum mine	Shelby-Hickory	Catawba, N. C	5½, 6, 7	Clay- and iron-stained; scattered brown bursts and greenish dendrite spots.	3	279	100	0	0
Do	do	do	Washer	do	1	8	100	0	0
Dycus mine	do	Rutherford, N. C	4, 5, 6, 7	Clay-stained; local large brown bursts; some pale-green mottling.	16	2,801	100	0	0
Eaker, Doris, mine	do	Lincoln, N. C	6, 7	Clay-stained	1	67	100	0	0
Eanes No. 2 mine	Ridgeway-Sandy Ridge.	Henry, Va	6, 7	Clay-stained; very pale green mottling.	2	97	100	0	0
Eanes No. 2 and Garrett mines	do	do	5, 6	Clay-stained	1	54	100	0	0
Evans, Rosa, mine	do	Rockingham, N. C	4, 5, 5½, 6, 7	Abundant primary vegetable stain; local shred of green biotite.	5	882	100	0	0
Do	do	do	Washer	do	1	1	100	0	0
Fortenberry, W. H., prospect	Shelby-Hickory	Cleveland, N. C	6	Clay- and iron-stained	1	110	100	0	0
Foster No. 1 (W. A. Thompson No. 1) mine.	do	Lincoln, N. C	5, 5½, 6	Clay-stained	4	236	100	0	0
Foster No. 2 (W. A. Thompson No. 2) mine.	do	do	5, 5½, 6	do	1	100	100	0	0
Foster, J. L., prospect	do	Cleveland, N. C	6	do	1	24	100	0	0
Do	do	do	Washer	do	1	12	100	0	0
Foster, W. T., (W. A. Thompson) mine group.	do	Lincoln, N. C	4, 5, 5½, 6, 7	Clay-stained; rare brown bursts	7	1,038	100	0	0
Gaillard mine	Hartwell	Anderson, S. C	6, 7	Rare tiny brown dendrite spots	2	210	100	0	0
Gaines, M. L., mine	do	Elbert, Ga	6, 7	Clay-stained; local pale-green mottling.	4	250	100	0	0
Gantt, B. T., prospect	Shelby-Hickory	Cleveland, N. C	6, 7	Clay-stained	2	173	100	0	0
Gantt, M. H., mine	do	do	5, 6, 7	Slightly clay-stained	2	182	100	0	0
Do	do	do	Washer	do	1	9	100	0	0
Garner mine	Hartwell	Hart, Ga	5, 6, 7	Slightly clay-stained; local pale-green mottling.	4	286	100	0	0
Gettys No. 1 and No. 2 mines	Shelby-Hickory	Cleveland, N. C	5, 6, 7	Clay- and iron-stained; tiny reddish-brown dendrite specks.	2	108	100	0	0
Do	do	do	Washer	do	1	9	100	0	0
Gibson, B. S., prospects	Thomaston-Barnesville.	Upson, Ga	6	Clay- and iron-stained	2	322	100	0	0
Glover, Eli, mine	Shelby-Hickory	Cleveland, N. C	6, 7	Clay-stained	3	178	100	0	0
Gold, Mary, mine	do	do	6, 7	Clay- and iron-stained	3	139	100	0	0
Do	do	do	Washer	do	2	15	100	0	0
Green, J. F., mine	do	do	6	Clay-stained	2	91	100	0	0
Gwaltney prospects	do	Alexander, N. C	5, 6	Clay and iron specks; rare brown dendrite specks.	1	36	100	0	0
Do	do	do	Washer	do	1	12	100	0	0
Hallman mine	do	Lincoln, N. C	6, 7	Slightly clay-stained	3	245	100	0	0
Harper-Pierman mine	Hartwell	Hart, Ga	6, 7		1	185	100	0	0
Harris mine	Shelby-Hickory	Cleveland, N. C	6, 7	Slightly clay, iron, and manganese-stained.	2	114	100	0	0
Hawkins (Joe Hawkins) mine	Ridgeway-Sandy Ridge.	Stokes, N. C	3, 4, 5, 5½, 6, 7	Slightly clay-stained; local pale-green mottling.	11	1,457	100	0	0
Herbb No. 1 mine	Outlying Virginia	Powhatan, Va	6	Slightly clay-stained	1	40	100	0	0
Herbb No. 2 mine	do	do	5, 6, 7	Clay-, iron-, and manganese-stained.	2	162	100	0	0
Herndon mine	Shelby-Hickory	Cleveland, N. C	7	Clay- and iron-stained	1	156	100	0	0
Herron mine	Thomaston-Barnesville.	Upson, Ga	5, 6, 7	Clay-stained; local green mottling.	2	204	100	0	0
Hogg mine (core-margin mica)	Outlying Georgia	Troup, Ga	6, 7	Clay-stained; rare garnet inclusions.	1	86	100	0	0
Hole (Jack Hole) mine	Ridgeway-Sandy Ridge.	Stokes, N. C	5, 6	Slightly clay-stained; local faint primary vegetable stain.	1	51	100	0	0
Holland mine	do	Rockingham, N. C	6	Slightly clay-stained	1	92	100	0	0
Houser, Plato, mine	Shelby-Hickory	Lincoln, N. C	5, 6, 7	Clay-, iron-, and manganese-stained; rare brownish bursts.	5	474	100	0	0
Do	do	do	Washer	do	2	14	100	0	0
Houser, Plato, No. 2 mine	do	do	6	Clay-stained	1	37	100	0	0
Hoyle, A. F., mine	do	Cleveland, N. C	5, 6, 7	Clay-stained; local curdy brown stain.	3	417	100	0	0
Hudson prospect	do	Burke, N. C	7	Clay-stained	1	132	100	0	0
Humphries, W. H., prospect	do	Cleveland, N. C	6, 7	Clay-stained; local greenish mottling.	2	740	100	0	0
Hunt mine	do	do	6, 7	Local brown bursts	2	251	100	0	0

TABLE 7.—*Summary of Q-meter tests of clear muscovite from deposits in the southeastern Piedmont*—Continued

Mine or prospect	District	County and State	Type of material	Remarks	Electrical tests				
					Number of lots tested	Total number of pieces tested	Percent E-1	Percent E-2	Percent E-3
Indian Graveyard mine	Shelby-Hickory	Cleveland, N. C.	6, 7	Slightly clay-stained; local primary vegetable stains.	2	111	100	0	0
Indiantown (Mull) mine	do	do	6, 7	Clay-stained; rare brown dendrite specks.	1	141	100	0	0
Jimmy mine (in Archie Norman group).	do	do	Washer	Clay-stained	1	7	0	100	0
Johnson mine	Thomaston-Barnesville.	Upson, Ga.	5, 6	Clay-stained; rare tiny brown bursts.	2	416	100	0	0
Jones mine	Shelby-Hickory	Cleveland, N. C.	6, 7	Clay-stained	1	114	100	0	0
Jones No. 1 mine	Ridgeway-Sandy Ridge.	Henry, Va.	6, 7	Clay-stained; some pale-green mottling.	1	31	100	0	0
Do	do	do	Washer	do	1	17	100	0	0
Jones No. 2 mine	do	do	6, 7	Clay- and iron-stained; local pale-green mottling.	1	112	100	0	0
Do	do	do	Washer	do	1	9	100	0	0
Kay mine	Outlying North Carolina Piedmont.	Rutherford, N. C.	5, 6	Clay-stained	1	8	100	0	0
Do	do	do	Washer	Clay-stained; includes biotite	1	8	100	0	0
King (Norman and Cecil) mine (in W. T. Foster group).	Shelby-Hickory	Lincoln, N. C.	5, 6	Clay-stained; wisps and laths of green biotite.	3	403	100	0	0
Do	do	do	Washer	do	1	18	100	0	0
King, Marvin, prospects	do	Cleveland, N. C.	6, 7	Slightly clay-stained; rare brown bursts.	1	79	100	0	0
Lattimore mine	do	do	6, 7	Clay-stained	2	215	100	0	0
Leatherman, Pink, mine	do	Lincoln, N. C.	6, 7	do	2	175	100	0	0
Do	do	do	Washer	do	1	7	100	0	0
Ledford mine	do	Cleveland, N. C.	5, 6, 7	Clay- and iron-stained	1	120	100	0	0
Ligon mines	Amelia	Amelia, Va.	6, 7	Scattered green dendrite specks	2	203	100	0	0
Do	do	do	Washer	do	2	16	100	0	0
M. and G. mine	Alabama	Clay, Ala.	4, 5, 5½, 6	Clay-stained; some pale-green mottling.	3	406	100	0	0
Maria (Old Pinchbeck, Smith) mine.	Amelia	Amelia, Va.	6	Clay-stained	1	152	100	0	0
Martin mine	Shelby-Hickory	Cleveland, N. C.	4, 5, 6	do	3	410	100	0	0
Martin, J. T., prospects	do	do	7	Clay- and iron-stained	1	40	100	0	0
Mauldin mine	Thomaston-Barnesville.	Upson, Ga.	5, 6	Clay-stained; locally abundant brown bursts; rare primary vegetable stain.	2	366	100	0	0
Do	do	do	Washer	do	1	18	100	0	0
Mauldin Road prospect	do	do	7	Iron- and clay-stained; sparse tiny brown bursts.	1	182	100	0	0
Mauney, Bailey, mine	Shelby-Hickory	Cleveland, N. C.	6, 7	Clay-stained	2	239	100	0	0
Mauney, S. S., (Homestead, M. M. Mauney) mine.	do	do	5½, 6, 7	Slightly clay-stained	6	739	100	0	0
Maurice mine	do	Rutherford, N. C.	6	do	1	183	100	0	0
Merck (Old Hope) mine	Outlying Georgia	Hall, Ga.	3, 5, 5½, 6, 7	Clay- and slightly iron-stained; very pale green mottling.	7	1,044	100	0	0
Do	do	do	Washer	do	1	14	100	0	0
Metcalf mine	Shelby-Hickory	Cleveland, N. C.	6, 7	Slightly clay-stained	2	198	100	0	0
Mill Race mine	do	do	5½, 6	Clay- and iron-stained; rare pale-green dendrite spots; biotite intergrowths.	2	187	100	0	0
Mitchell Creek mine	Thomaston-Barnesville.	Upson, Ga.	3, 4, 5, 5½, 6, 7	Slightly clay-stained; biotite intergrowths; apatite and pyrite inclusions; rare brown bursts.	8	1,169	100	0	0
Do	do	do	Washer	do	4	30	100	0	0
Monteiro (Monteiro Tract) mine.	Outlying Virginia	Goochland, Va.	2, 3, 4	Slightly clay-stained	1	16	100	0	0
Moose mine	Shelby-Hickory	Catawba, N. C.	6, 7	do	3	142	100	0	0
Do	do	do	Washer	do	2	26	100	0	0
Do	do	Cleveland, N. C.	do	Clay-stained	1	12	100	0	0
Morefield mine	Amelia	Amelia, Va.	6, 7	Slightly clay-stained; some pale-green mottling and brown bursts.	4	744	100	0	0
McCraw No. 1 (Old Pinchbeck No. 2) mine.	do	do	6, 7	Clay-stained; rare brown bursts.	1	65	100	0	
McCraw No. 2 (Old Pinchbeck No. 3) mine.	do	do	6, 7	Clay-stained	1	113	100	0	0
McCraw No. 3 (Old Pinchbeck No. 1) mine.	do	do	6, 7	Clay- and iron-stained	1	112	100	0	0
McGinnis, F. G., mine	Shelby-Hickory	Cleveland, N. C.	5, 6	Clay-stained	4	355	100	0	0
McSwain, G. B., mine	do	do	5, 6	Clay- and iron-stained; sparse brown to green dendrite specks.	2	101	100	0	0
New Bethel M. E. Church prospect.	Hartwell	Elbert, Ga.	7	Clay- and iron-stained	1	73	100	0	0
Norman-Thompson (W. H. Thompson) mine (in Archie Norman group).	Shelby-Hickory	Cleveland, N. C.	6	Clay- and iron-stained; rare brown bursts.	2	127	100	0	0
Patterson mine	do	Alexander, N. C.	5	Clay- and iron-stained; local biotite intergrowths.	1	45	100	0	0
Do	do	do	Washer	do	1	7	100	0	0
Patterson, Bun (Old Carroll mine).	do	Cleveland, N. C.	6	Clay- and iron-stained; rare pale-green mottling.	1	16	100	0	0
Peeler No. 1 mine	do	do	7	Slightly clay-stained	1	22	100	0	0
Powell (Sugar Barrel) mine	do	do	6, 7	Slightly clay-stained; local pale-green mottling.	1	142	100	0	0
Putnam mines	do	do	6, 7	Slightly clay-stained	2	169	100	0	0
Randall and Indiantown mines.	do	do	6, 7	Local pale-green mottling	1	93	100	0	0
Reed mine	do	Burke, N. C.	6	Clay-stained; sparse brown dendrite spots.	1	24	100	0	0
Do	do	do	Washer	do	1	14	100	0	0
Ridgeway mine	Ridgeway-Sandy Ridge.	Henry, Va.	do	Clay-stained	1	5	100	0	
Royston, road cut out of (on road to Elberton).	Hartwell	Hart, Ga.	6	Clay and iron-stained	1	35	100	0	0

TABLE 7.—*Summary of Q-meter tests of clear muscovite from deposits in the southeastern Piedmont*—Continued

Mine or prospect	District	County and State	Type of material	Remarks	Electrical tests				
					Number of lots tested	Total number of pieces tested	Percent E–1	Percent E–2	Percent E–3
Rutherford mines	Amelia	Amelia, Va	4, 5, 6, 7	Pale-green mottling	2	549	100	0	0
Do	do	do	Washer	do	1	11	100	0	0
Rutherford No. 2 mine	do	do	4, 5, 5½, 6	Slightly clay-stained; local pale-green mottling.	3	276	100	0	0
Saunders No. 2 mine	Outlving Virginia	Hanover, Va	5, 5½, 6		2	241	100	0	0
Scism prospect	Shelby-Hickory	Cleveland, N. C	5, 6, 7	Clay-stained	1	40	100	0	0
Self, E. R., (Old Neale) mine	do	Gaston, N. C	5, 6, 7	Clay- and iron-stained; rare brown bursts; sparse light-brown mottling.	5	383	100	0	0
Shelbv-Hickory district (localities unknown).	do	North Carolina	6, 7	Clay-stained; rare brown bursts	4	543	100	0	0
Sigmon mine	do	Catawba, N. C	6	Pale-green mottling; biotite intergrowths.	1	91	100	0	0
Smith, Short Tom (Ben Smith) mine.	Ridgeway-Sandy Ridge.	Rockingham, N. C	2, 5, 6, 7	Slightly clay-stained; very pale green mottling.	3	93	100	0	0
Spangler, D. H., prospects	Shelby-Hickory	Cleveland, N. C	6, 7	Clay-stained	2	128	100	0	0
Spangler, T. N. (Reuben Spangler) prospects.	do	do	6, 7	Slightly clay-stained	1	93	100	0	0
Spencer mine	Ridgeway-Sandy Ridge.	Stokes, N. C	6, 7	Clay-stained; local pale-green mottling.	1	138	100	0	
Steele mine	do	do	5, 6, 7	Clay- and iron-stained; local green mottling.	3	404	100	0	0
Stevens Rock (Marshall, Sullivan, McKinney) mine.	Thomaston-Barnesville.	Upson, Ga	5, 6	Slightly clay-stained; much green mottling; rare brown bursts; biotite and pyrite inclusions.	1	68	100	0	0
Do	do	do	Washer	do	1	20	100	0	0
Stroud, Lax, mine	Shelby-Hickory	Rutherford, N. C	6	Clay- and iron-stained	1	36	100	0	0
Stroud, T. C., prospects	do	Cleveland, N. C	6	Clay-stained	1	36	100	0	0
Tallant prospect	do	Catawba, N. C	6	do	1	152	100	0	0
Taylor, Nettie, mine	Amelia	Amelia, Va	6, 7	Clay-stained; pale green mottling.	2	308	100	0	0
U. S. Highway 220, prospect on.	Ridgeway-Sandy Ridge.	Rockingham, N. C	6, 7	Clay-stained	1	172	100	0	0
Unknown mine	Unknown	Georgia	5, 5½, 6	do	1	114	95	4	1
Unknown mine	do	do	6, 7	Clay- and iron-stained	1	72	100	0	0
Unknown mine	do	Virginia	6, 7	Slightly clay-stained	1	30	100	0	0
Vaughn, Early mine	Thomaston-Barnesville.	Lamar, Ga	5, 5½, 6	Clay- and iron-stained; rare green mottling; rare brown bursts.	5	494	100	0	0
Warlick, Clyde, mine	Shelby-Hickory	Cleveland, N. C	6, 7	Clay-stained biotite intergrowths	2	110	100	0	
Waterhole mine	Hartwell	Hart, Ga	5	Clay- and iron-stained	1	45	100	0	0
Weathers mine	Shelby-Hickory	Cleveland, N. C	6	Clay,- iron-, and manganese-stained.	2	180	100	0	0
Do	do	do	Washer	do	1	15	100	0	0
Webb mine	do	do	6, 7	Clay-stained; local pale-brownish mottling.	2	234	100	0	0
White Peak No. 1 (Purcell, Miller) mine.	Outlying Virginia	Powhatan, Va	6	Clay-stained	3	122	100	0	0
Do	do	do	Washer	do	2	26	100	0	0
Wingo mine	Amelia	Amelia, Va	6, 7	Rare pale-green biotite wisps	1	112	100	0	0
Wood (Cully, Lon Allen) mine.	Hartwell	Hart, Ga	6	Clay- and-iron stained	1	24	100	0	0
Wright prospect	Shelby-Hickory	Cleveland, N. C	7	Clay-stained	1	112	100	0	0
Young, Noah, mine	do	Burke, N. C	6	Heavily clay- and iron-stained	1	65	100	0	0
Total					416	39,917			

TESTS OF STAINED MICA

The testing program included the study of 264 lots that contained a total of 28,434 pieces of clear and stained mica. More than two-thirds of the pieces were typical no. 3 or electric mica, with sparse to abundant specks, spots, blotches, and laths of magnetite and hematite. In addition, many were marred by clay stains, biotite inclusions, and other imperfections like those present in the clear mica just described. The stained material comprised sheets rifted and trimmed from books obtained at mines and storage sheds and several lots of prepared sheets loaned by mine operators. All were tested in the same manner as the clear mica.

Many lots, including several large ones, contained little or no E–2 or E–3 mica. In general these were composed of slightly stained material, commonly with scattered spots of iron oxides. Twelve lots of moderately to heavily stained mica contained appreciable quantities of E–2 and E–3 pieces. Chief among these was a 15,987-piece lot from the Knight mine, Rockingham County, N. C., which tested 61 percent E–1, 23 percent E–2, and 16 percent E–3. The results of the tests and the general descriptions of the mica are summarized in table 8. There appears to be a partial correlation between the power factor and amount of stain in that most of the E–2 and E–3 pieces were heavily stained, but numerous exceptions were encountered. Some pieces that qualified as E–1, for example, were more densely stained than many with a higher power factor. The lack of correlation between power factor and several other properties that was noted in the clear mica also appears to be characteristic of the stained material.

Cracks, tears, and holes were easily recognized in the spark tests, and in addition many of the spots and patches of stain in the sheets reacted as conducting substances. The correlation between the proportion of conducting inclusions or intergrowths and the density of stain in a given lot of mica was imperfect, so that some heavily stained test pieces qualified, not only as E–1, but also as free from conducting impurities.

TABLE 8.—*Summary of Q-meter tests of stained muscovite from deposits in the southeastern Piedmont*

Mine or prospect	District	County and State	Type of material	Remarks	Electrical tests: Number of lots tested	Total number of pieces tested	Percent E-1	Percent E-2	Percent E-3
Abernathy Long Cut (Hickory) mine.	Shelby-Hickory	Catawba, N. C.	Washer	Scattered hematite spots and biotite shreds; pale-green mottling.	1	8	100	0	0
Abernathy Water mine	do	do	6, 7	Sparse hematite and magnetite spots and specks.	1	79	100	0	0
Archie mine (in Archie Norman group).	do	Cleveland, N. C.	Washer	Sparse hematite specks and spots.	1	11	100	0	0
Bailey mine	Hartwell	Hart, Ga.	do	Rare magnetite spots and hematite specks.	1	12	100	0	0
Baxter, Jack, prospect	Shelby-Hickory	Lincoln, N. C.	6	Specks and spots of hematite; some lattices.	1	86	100	0	0
Beam prospect	do	do	6, 7	Sparse laths and specks of magnetite.	1	50	100	0	0
Do	do	do	Washer	do	1	13	100	0	0
Beam, Claude, prospect	do	Gaston, N. C.	6, 7	Sparse magnetite and hematite specks.	2	263	100	0	0
Berry mine	Alabama	Tallapoosa, Ala.	5, 6, 7	Spots and laths of hematite	2	277	100	0	0
Do	do	do	Washer	do	1	15	100	0	0
Blanton, C. Robert, mine	Shelby-Hickory	Cleveland, N. C.	do	Rare magnetite spots	1	8	100	0	0
Blanton, Cliff, mine	do	do	do	Rare magnetite spots and specks; local green mottling.	7	81	94	6	0
Boyt mine	Thomaston-Barnesville.	Upson, Ga.	do	Biotite plates and hematite spots.	1	7	100	0	0
Bridges, Pleaz, mine	Shelby-Hickory	Cleveland, N. C.	6, 7	Magnetite spots and laths	1	5	100	0	0
Burgess (L. E. Hunter) mine	Outlying South Carolina.	Anderson, S. C.	Washer	Scattered biotite flakes and rare magnetite specks.	1	8	100	0	0
Cabaniss, Alma, mine	Shelby-Hickory	Cleveland, N. C.	6	Rare hematite specks	1	20	100	0	0
Cabaniss, Tom, mine	do	do	Washer	Sparse magnetite specks; garnet inclusions.	1	18	100	0	0
Campbell mine	do	do	do	Sparse hematite specks and spots; rare magnetite.	1	7	0	100	0
Carpenter mine	do	do	6, 7	Scattered magnetite specks, spots, and laths.	2	163	100	0	0
Carter mine	Hartwell	Hart, Ga.	Washer	Rare magnetite spots and specks	1	7	100	0	0
Champion (Jefferson No. 4, Bland) mine.	Amelia	Amelia, Va.	do	Sparse magnetite specks and spots, with locally abundant biotite shreds.	1	9	100	0	0
Collum (McCray) mine	Alabama	Tallapoosa, Ala.	6, 7	Scattered hematite specks, spots, and blotches; much primary vegetable stain.	5	998	100	0	0
Do	do	do	Washer	do	1	8	100	0	
Collum "quartz-blowout" mine.	do	do	5, 6, 7	Scattered hematite specks and much curdy green stain.	2	324	100	0	0
Do	do	do	Washer	do	1	13	100	0	0
Cooley mine	Hartwell	Elbert, Ga.	do	Rare spots and specks of magnetite.	2	18	100	0	0
Corley mine	Thomaston-Barnesville.	Upson, Ga.	do	Sparse spots and specks of magnetite.	1	22	100	0	
Cowpens mine	Outlying South Carolina.	Spartanburg, S. C.	6	Rows of magnetite specks and spots.	1	92	100	0	0
Crawford-Daniel mine	Hartwell	Elbert, Ga.	Washer	Rare magnetite spots	1	7	100	0	0
Crews No. 1 prospect	Outlying Virginia	Charlotte, Va.	5, 6, 7	Iron oxide lattices	1	185	86	3	11
Crews No. 2 prospect	do	do	Washer	Scattered hematite spots	1	8	100	0	0
Drum mine	Shelby-Hickory	Catawba, N. C.	5½, 6, 7	Rare specks of magnetite and hematite.	3	297	100	0	0
Dycus mine	do	Rutherford, N. C.	Washer	Magnetite specks, spots, and laths; some pale-green mottling.	4	52	100	0	0 0 0
Eanes No. 2 mine	Ridgeway-Sandy Ridge.	Henry, Va.	do	Sparse specks and spots of magnetite; very pale green mottling.	1	7	100	0	0
Eanes No. 2 and Garrett mines	do	do	do	Rare magnetite spots	1	5	100	0	0
Elliot, L. R., mine	Shelby-Hickory	Cleveland, N. C.	6	Scattered plates and wisps of biotite.	2	143	100	0	0
Do	do	do	Washer	do	1	11	100	0	0
Foster, W. L. C., prospect	do	Lincoln, N. C.	6, 7	Scattered wisps of biotite	1	75	100	0	0
Foster, W. T. (W. A. Thompson) mine group.	do	do	Washer	Scattered specks and spots of magnetite.	1	9	100	0	0
Fowler, Will, prospect	Outlying South Carolina.	Pickens, S. C.	5, 6	Scattered hematite spots and blotches.	1	22	100	0	0
Gaines, C. U., prospect	Hartwell	Elbert, Ga.	5, 6	Sparse magnetite specks	1	55	100	0	0
Greer and Merriman mines	Outlying Virginia	Henry, Va.	7	Sparse magnetite specks and spots.	1	116	100	0	0
Do	do	do	Washer	do	1	3	100	0	0
Griggs mine	Shelby-Hickory	Cleveland, N. C.	6	Sparse hematite specks	2	56	100	0	0
Hawkins (Joe Hawkins) mine	Ridgeway-Sandy Ridge.	Stokes, N. C.	Washer	Scattered specks and spots of hematite and magnetite; local pale-green mottling.	2	25	100	0	0
Herron mine	Thomaston-Barnesville.	Upsan, Ga.	do	Scattered magnetite and hematite spots; local green mottling.	1	21	100	0	0
Hogg mine (wall-zone mica)	Outlying Georgia	Troup, Ga.	5, 6, 7	Abundant shreds and plates of biotite; spots and lattices of hematite.	4	410	50	41	9
Horsehead mine	Hartwell	Hart, Ga.	6	Rare magnetite specks	1	18	100	0	0
Howell prospect	Outlying Virginia	Charlotte, Va.	6	Scattered hematite spots and biotite shreads.	1	87	100	0	0
Humphries, Joe E., mine	Shelby-Hickory	Cleveland, N. C.	6, 7	Rare magnetite specks and biotite wisps.	1	212	100	0	0
Huskins mine	do	Gaston, N. C.	5, 6, 7	Scattered magnetite specks and hematite specks and spots.	7	1, 245	100	0	0
Do	do	do	Washer	do	4	40	100	0	0
Isinglass Hill mine	Outlying North Carolina Piedmont.	Rutherford, N. C.	6, 7	Many specks, spots, and triangular lattices of hematite.	1	94	87	13	0
Jefferson No. 6 mine	Amelia	Amelia, Va.	6	Sparse specks and spots of hematite.	1	91	100	0	0
Do	do	do	Washer	do	1	100	100	0	0
Johnson mine	Thomaston-Barnesville.	Upson, Ga.	do	Rare biotite wisps and hematite specks.	1	8	100	0	0
Jones, Ruth, mine	Hartwell	Hart, Ga.	6, 7	Abundant biotite plates; rare iron oxide specks.	1	116	100	0	0

TABLE 8.—*Summary of Q-meter tests of stained muscovite from deposits in the southeastern Piedmont*—Continued

Mine or prospect	District	County and State	Type of material	Remarks	Electrical tests				
					Number of lots tested	Total number of pieces tested	Percent E-1	Percent E-2	Percent E-3
Kay mine	Outlying North Carolina Piedmont.	Rutherford, N. C	5, 6	Scattered hematite specks and wisps.	1	8	100	0	0
Kidd mine	Alabama	Tallapoosa, Ala	6, 7	Scattered large magnetite spots and hematite specks.	3	468	100	0	0
Do	do	do	Washer	do	3	35	100	0	0
Knight mine	Ridgeway-Sandy Ridge.	Rockingham, N. C	3, 4, 5, 5½, 6, 7	Sparse iron oxide spots; much pale-green mottling.	81	15,987	61	23	16
Do	do	do	Washer	do	3	21	100	0	0
Lail prospect	Shelby-Hickory	Cleveland, N. C	5	Specks, small spots, and laths of magnetite.	1	131	100	0	0
Martin, Ben, mine	Hartwell	Anderson, S. C	5, 6, 7	Hematite spots, specks, and lattices.	3	211	100	0	0
Mays mine	Amelia	Amelia, Va	6	Spots and blotches of hematite	1	32	100	0	0
Do	do	do	Washer	do	1	7	100	0	0
Merck (Old Hope) mine	Outlying Georgia	Hall, Ga	3, 5, 5½, 6, 7	Abundant spots and blotches of hematite in broad lattices.	7	1,044	100	0	0
Do	do	do	Washer	do	1	14	100	0	0
Mica Hill mine	Alabama	Tallapoosa, Ala	5, 5½, 6, 7	Abundant hematite specks and spots; minor biotite shreds.	6	894	94	6	0
Do	do	do	Washer	do	1	16	100	0	0
Mill Race mine	Shelby-Hickory	Cleveland, N. C	do	Magnetite laths, specks, and spots; rare hematite; biotite intergrowths.	2	35	100	0	0
Moose mine	do	Catawba, N. C	do	Hematite blotches and lattices	2	26	100	0	0
Morefield mine	Amelia	Amelia, Va	do	Sparse biotite, hematite specks and spots; some pale-green mottling.	3	29	100	0	0
Morrison, C. R. (Oak Level) mine.	Outlying Virginia	Henry, Va	6	Rare magnetite spots and specks	1	139	100	0	0
Do	do	do	Washer	do	1	11	100	0	0
New Bethel M. E. Church prospect.	Hartwell	Elbert, Ga	do	Rare hematite specks; sparse biotite shreds.	1	9	100	0	0
Niagara mine	Shelby-Hickory	Cleveland, N. C	5, 6, 7	Sparse biotite	2	220	100	0	0
Do	do	do	Washer	Magnetite specks, spots, and laths.	2	14	100	0	0
Norman, Archie, (W. H. Thompson) mines.	do	do	6	Rare hematite specks	1	52	100	0	0
Norman-Thompson (W. H. Thompson) mine (in Archie Norman group).	do	do	Washer	do	1	8	100	0	0
Price mine	Ridgeway-Sandy Ridge.	Henry, Va	5, 6	Abundant hematite specks, spots, and blotches; some lattices.	2	146	100	0	
Do	do	do	Washer	do	2	35	100	0	0
Rice mine	Shelby-Hickory	Cleveland, N. C	7	Sparse hematite specks and spots.	1	96	100	0	0
Do	do	do	Washer	do	1	9	100	0	0
Ruby King (J. C. Hawkins) mine.	Ridgeway-Sandy Ridge.	Stokes, N. C	6, 7	Scattered spots and specks of magnetite; some pale-green mottling.	3	288	100	0	0
Do	do	do	Washer	do	1	12	100	0	0
Scrap mine	Hartwell	Hart, Ga	6	Magnetite specks and spots; very pale green mottling.	1	38	100	0	0
Self, E. R. (Old Neale) mine	Shelby-Hickory	Gaston, N. C	Washer	Rare magnetite spots and hematite spots and specks; sparse light-brown mottling.	3	41	100	0	0
Shelby-Hickory district (localities unknown).	do	North Carolina	do	Sparse hematite specks and spots; specks of magnetite.	1	12	100	0	0
Shelton, G. R., mine	Ridgeway-Sandy Ridge.	Stokes, N. C	5, 6	Scattered magnetite spots and specks.	1	40	100	0	0
Skelton, J. M., prospect	Hartwell	Elbert, Ga	6, 7	Scattered magnetite specks and locally abundant biotite.	2	293	100	0	0
Do	do	do	Washer	do	1	15	100	0	0
Slaughter, J. G., prospect	Outlying North Carolina Piedmont.	Caswell, N. C	7	Widespread hematite spots and lattices.	1	112	100	0	0
Smith, Ernest, mine	Ridgeway-Sandy Ridge.	Rockingham, N. C	6, 7	Locally abundant hematite specks and spots; some magnetite spots.	1	175	94	6	0
Smith store, road cut 1/10 mile south of.	Outlying Georgia	Troup, Ga	6	Abundant spots, blotches, and lattices of hematite.	1	83	86	14	0
Do	do	do	Washer	do	1	7	0	100	0
Smith store prospect	do	do	6, 7	Heavily stained with hematite spots and blotches.	1	149	100	0	0
Do	do	do	Washer	do	1	15	100	0	0
Sycamore (Roach) mine	Outlying Virginia	Pittsylvania, Va	6	Abundant hematite spots, specks, blotches, and lattices.	1	29	100	0	0
Taylor, Nettie, mine	Amelia	Amelia, Va	Washer	Rare magnetite specks; pale-green mottling.	2	22	100	0	0
Turner prospect	Hartwell	Elbert, Ga	6	Rectangular lattices of curdy green to brown stain (hydrous iron oxides?).	2	123	100	0	0
Unknown mine	Outlying Virginia	Charlotte, Va	5, 6, 7	Hematite spots, specks, and lattices.	1	128	95	4	1
Unnamed prospect	Ridgeway-Sandy Ridge.	Stokes, N. C	6, 7	Scattered iron oxide specks	1	127	100	0	0
Vaughan mine	Amelia	Amelia, Va	Washer	Rare hematite and biotite specks	1	12	100	0	0
Vaughn, Early, mine	Thomaston-Barnesville.	Lemar, Ga	do	Sparse magnetite spots and specks; rare green mottling.	1	12	100	0	0
Warlick, Clyde, mine	Shelby-Hickory	Cleveland, N. C	do	Rare hematite specks and spots; scattered biotite wisps.	1	9	100	0	0
Webb mine	do	do	do	Magnetite specks, spots, and laths; scattered biotite plates and wisps.	1	15	100	0	0
Williamson mine	do	do	5, 6, 7	Sparse magnetite spots and laths; rare hematite specks and spots.	3	723	100	0	0
Do	do	do	Washer	do	1	15	0	100	0
Wright prospect	do	do	do	Rare hematite specks	1	7	100	0	0

TABLE 8.—*Summary of Q-meter tests of stained muscovite from deposits in the southeastern Piedmont*—Continued

Mine or prospect	District	County and State	Type of material	Remarks	Electrical tests: Number of lots tested	Total number of pieces tested	Percent E-1	Percent E-2	Percent E-3
Yarboro No. 1 (Old Milton) mine.	Outlying North Carolina Piedmont.	Caswell, N. C.	7	Hematite spots, blotches, and lattices.	1	86	100	0	0
Young mine	Outlying Virginia	Bedford, Va.	5, 6	Scattered biotite laths and wisps; some large magnetite spots.	1	27	100	0	0
Do	do	do	Washer	do	1	8	100	0	0
Total					264	28,434			

CONCLUSIONS

The results of the tests described are similar in many respects to those of several earlier testing programs (Horton, 1941, pp. 41–46, 54–55; Kesler and Olson, 1942, pp. 18–30; Townsend, 1944a, pp. 18–30), and the study of 68,351 pieces from 231 mines and prospects in the southeastern Piedmont gives them additional statistical value. The close correlation between power factor and physical appearance suggested by Kesler and Olson (1942, p. 18) holds in a general way, but evidently there are numerous exceptions. Nearly all these exceptions lie in one direction, however, in that the power factor of such mica is lower than that expected on the basis of visual appearance. Thus much weathered material tests E–1, and the power factor at a frequency of 1 megacycle is not greatly affected by most clay stains that do no transgress the laminae of the host mica. Such blemishes as biotite inclusions, green and brownish mottling, inorganic vegetable stain, and air stain also have little adverse effect. Appreciable increase in power factor due to air bubbles in mica, however, has been demonstrated by Hall (Olson, 1942, p. 382).

It should be recognized that power factor alone does not determine the applicability of a given piece of mica for condenser or other high-grade uses. The mica must also meet other physical requirements and hence must also be tested visually and with the spark-coil set. Tightly intergrown plates and wisps of biotite, for example, have little effect on the power factor of block muscovite, yet they may well interfere seriously with its filming properties or lead to the development of cracks and holes in finished films (Jahns and Lancaster, 1950).

Neither the color nor the depth of color in clear muscovite appears to have any definite relation to the power factor. This has been suggested by Hall (1944, p. 396) and others (A. S. T. M., 1945, p. 45), despite the frequently repeated assertions that green and dark-colored varieties have basically inferior electrical characteristics. The present tests fully confirm Hall's statement, as the clear brownish-olive micas and the clear green micas, both light and dark, were found to lie within essentially the same power-factor range as the pinkish-buff and light-brown (ruby) varieties. If, however, green and dark-brown muscovite is taken as a whole, without discrimination as to presence or absence of iron oxide stains, its power factor is distinctly higher than that of the other types, simply because damaging mineral stain is more common in such mica. This important point is summarized by the American Society for Testing Materials (1945, p. 57) as follows:

> Experience has shown that the Q value range of ruby and white types of block mica, regardless of source, is 80 to 95 percent E–1, whereas, the Q value range of light green, dark green, greenish brown, and rum-colored block mica is 45 to 90 percent E–1. It is important to bear in mind that it is permissible for all qualities of mica prescribed in A. S. T. M. Specifications D 748, to contain spots and stains, providing the mica meets all electrical and physical requirements, whereas, no spots or stains (other than air stains) are permitted in the visual quality groups in A. S. T. M. Methods D 351.

Some investigators have contended that mica must be free from stain of all types to be suitable for condenser use, but others have pointed out that much mica with inclusions and intergrowths of iron oxides has a low power factor (Townsend, 1944a, pp. 21–25, 1944b, pp. 1–8; Hall, 1944, p. 396; A. S. T. M., 1945, pp. 45, 54–57; Coutlee, 1945b, pp. 4–5). Most statements of the latter type have been based on actual tests and are further borne out by the results of the present investigations. The potential usefulness of mica hitherto considered unacceptable for certain high-grade electrical equipment is in part the basis for the new A. S. T. M. specifications (1945, p. 45), which do not "discriminate against the presence of spots and stains in even first quality electricically selected mica providing the mica conforms to specific electrical and physical requirements."

MICA IN WORLD WAR II

Heavy demands for sheet mica of superior quality are characteristic of modern wartime periods. Such mica has been used, for example, as splittings in the form of built-up mica commutator segments and coil insulation in motors and generators and in transformers, switchboards, blasting apparatus, and aircraft generators and spark plugs (Wayland, 1944, pp. 1–2). In addition, an unprecedented problem was caused during World War II by the demands and exacting requirements for condenser mica. Developments in the field of military radio and electronic equipment focused attention on mica condensers, owing to the constancy and excellence of their electrical properties under varying physical conditions (Wayland, 1944, p. 2).

"Strategic mica" was first defined during World War II in War Production Board Conservation Order M–101 as reasonably flat block and sheet mica of heavy-stained quality or better that is free from cracks and comparable imperfections. Excluded from this category were scrap mica, block mica that will trim to a size less than 1 by 1 in., splittings used in making built-up mica, and the so-called electric mica. The definition of the term "strategic mica," however, is by no means fixed, and its meaning varies with changes in military needs, anticipated future requirements, and conditions of supply. Most strategic mica is simply sheet material of superior quality. Gwinn (1943, p. 3) suggests the alternative term "mica of military grade," which would include all sizes and qualities of mica used in the manufacture of equipment for the armed forces. "Strategic mica" then would be the qualities or sizes in short supply at a particular time.

Some of the problems encountered in increasing the domestic supply of sheet mica already have been described and discussed (Wayland, 1944, pp. 1–8; Burgess, 1944; Lintner, 1944; Billings and Montague, 1944; War Production Board, 1942). To stimulate the production of strategic mica, the Metals Reserve Company, a subsidiary of the Reconstruction Finance Corporation, designated the Colonial Mica Corp. as its agent, with authority to purchase mica of certain types and to assist the operators of mines with equipment leases, development loans, and consulting services on problems of mica mining and preparation. A market for mica of superior quality was assured at favorable prices and for specified periods.

PRICES AND MARKETING

Prices for sheet mica not only fluctuate widely in response to variations in demand, but vary at any given time according to the size and quality of the material. The general ranges for clear and stained trimmed sheet mica in the Southeastern States during a 30-yr period are as follows:

Size in inches	Range in price per pound	
	Clear	Stained
1½ by 2	$0. 12–$0. 60	[1]
2 by 2	. 22– 1. 05	$0. 06–$0. 40
2 by 3	. 38– 1. 45	. 10– . 60
3 by 3	. 58– 2. 00	. 15– 1. 25
3 by 4	. 78– 2. 30	. 30– 1. 50
3 by 5	. 95– 2. 70	. 48– 1. 75
4 by 6	1. 75– 3. 65	. 70– 2. 25
6 by 8	2. 25– 7. 25	1. 25– 2. 50
8 by 10	3. 50–11. 50	2. 00– 3. 00

[1] Under ordinary conditions the smallest size of stained mica purchased as sheet material in the Southeastern States is 2 by 2 in.

The value of punch or untrimmed small-sheet mica ranged from 2½c to about 15c per pound during the same period. Trimmed electric (stained sheet) mica is sold according to a sliding-price scale, with values consistently lower than those for clear material of comparable size. Electric mica also is sold as thumb-trimmed block, generally at prices that vary according to the estimated proportion of waste. Many jobbers purchase selected mine-run material (either clear or stained), rift and trim it, and sell the prepared mica to manufacturers. Others purchase punch and washer stock from which they recover and trim sheet material, and still others have recovered sheet and punch mica from mine scrap.

Prices for most scrap mica range from $9 to $45 per ton, depending in part upon whether it is bought at the mine or at some more convenient distributing point. Bench scrap, which is reasonably free from quartz, feldspar, and other impurities, generally commands a higher price than mine scrap. The value of clear, light-colored mica that yields a very white product when ground also is relatively high. Buyers and grinders of mica are listed by Gwinn (1943, pp. 15–17).

During war periods, when the demand for sheet mica is greatly increased and the problems of supply often are complex, prices characteristically reach very high levels. The rising trend during the period December 1941–December 1944 and the subsequent sharp drop in prices are shown in table 9. Through parts of 1942 strategic-grade mica was purchased by private individuals and organizations and by the Colonial Mica Corp. as well, but during most of the wartime period purchases were made solely by the Colonial Mica Corp.

After January 1, 1945, private purchases of strategic-grade mica were again permitted, and during the following months the Colonial Mica Corp. continued to buy only sheet mica other than green. Purchases of full-trimmed mica in sizes smaller than 1½ by 2 in. were discontinued. With the end of hostilities and a trend toward peacetime economy, most of the remaining subsidies for mica production were removed, and the prices for sheet mica dropped sharply. The attendant closing of many mines and the general diminution of sheet-mica production curtailed the supply of punch, washer, and scrap material, so that prices for such mica actually remained at wartime levels or even rose. During 1945, for example, some lots of punch mica were sold at prices of 45c to 50c per pound.

FELDSPAR

Feldspar is used chiefly as a ground raw ingredient of glasses, pottery, and glazes, and additional quantities are processed for use in abrasives, building materials, poultry grit, soaps, artificial teeth, and various fillers. Potash feldspar is preferred for pottery manufacturing, soda spar (chiefly albite and oligoclase) is widely used

TABLE 9.—*Price schedules for domestic clear sheet mica, December 1941–February 1945*

[Adapted in part from Billings and Montague (1944, p. 94). See also Jahns and Lancaster (1950, p. 28)]

Size	Price per pound, in dollars and cents											
	Private purchasers		Colonial Mica Corp.									Private purchasers, February 1945 [6]
	December 1941	April-May 1942	June 1942 [1]	November 1942 [1]	May 1943 [2]	February 1944 [2]	August 1944 [3]	February 1945 [4]	February 1945 [5]			
									No. 1 quality	No. 2 quality	No. 2 inf. quality	
Punch	0.10–0.15	0.12–0.16	0.22	0.30					1.70–3.50	1.25–2.50	0.50–1.10	0.08–0.15
1½ by 2 in.	.45– .65	.50– .65	1.10	2.40					5.00	3.50	1.60	1.00
2 by 2 in.	.60– .85	.95–1.10	1.75	3.52								1.40
2 by 3 in.	1.30–1.50	1.50–1.85	2.75	4.64					7.80	5.50	2.60	2.00
3 by 3 in.	1.90–2.05	2.00–2.35	3.50	5.12	5.00	6.00	6.00	2.25	9.10	6.50	3.40	2.55
3 by 4 in.	2.15–2.25	2.25–2.60	4.25	6.08			and					3.00
3 by 5 in.	2.60–2.75	2.75–3.00	5.00	7.04			8.00		10.50	7.10	4.65	3.45
4 by 6 in.	3.60–3.70	3.75–4.00	6.25	8.00					13.30	8.30	6.20	4.30
6 by 8 in.	5.25–5.50	5.50–6.00	8.00	9.12					20.10	12.70	9.20	6.50

[1] Punch material required to yield 20 percent or more trimmed pieces 1 by 1 in. or larger; price scale for larger mica based on no. 1 quality and half trim, with maximum bonuses of 30 and 40 percent for ¾ trim and full trim, respectively.

[2] Uniform price per pound established regardless of size or quality within strategic range. Punch material required to be full-trimmed; sheet mica, ¾-trimmed.

[3] Premium price of $8 paid for full-trimmed sheet mica 2 by 2 in. in size and larger; $6 for full-trimmed punch material and full-trimmed sheet mica smaller than 1½ by 2 in. and for ¾-trimmed sheet in the larger sizes.

[4] Blanket price for full-trimmed sheet and punch mica regardless of size or quality within strategic range; drop in price reflects general subsidy-removing policy with respect to production of strategic mica.

[5] Alternative price schedule based on size and quality of ¾-trimmed mica.

[6] Price based on untrimmed punch and ¾-trimmed sheet mica.

in glazes and opalescent glasses, and both types of material are satisfactory for most glass making. Feldspar generally is graded on the basis of free silica or quartz content, and in nearly all grades the tolerance for iron is very low. The best grades contain less than 5 percent quartz, and the poorest acceptable material contains about 30 percent quartz.

Graphic granite, or "corduroy spar," in which 15 percent or more free quartz ordinarily is present, is marketable in some areas but commands a relatively low price. The chief iron-bearing impurities, biotite, garnet, and tourmaline, are objectionable because of the strong discoloration they give to glass, pottery, and other products. Quartz and muscovite, on the other hand, are diluents and affect the alumina content and fluxing properties of the ground spar.

Much crude feldspar is hand-cobbed at the mine, the degree of treatment depending upon the desired purity of the product. At most mines an effort is made to obtain perthite reasonably free from quartz and other feldspars, but in general the mine-run material is a mixture of potash and soda-lime feldspars with some quartz. After it is hauled from the mine, it is crushed and then ground, either in continuous or batch mills. In some plants a picking belt is used to reduce waste before grinding, and magnetic devices are used to separate iron-bearing impurities. Mica generally is removed by means of screens, air separators, or both. The purified and ground feldspar can be tested by fusing small sample blocks or cones, but most modern plants are based on chemical control, with correlation between composition and behavior of the product for various uses. Standardized screen tests are used to check the fineness of grinding.

Most domestic feldspar is produced and consumed east of the Mississippi River, and ordinarily the difference between the unit price and unit cost of production is so small that the cost of transportation from mine or grinding plant to place of demand is a serious factor. Prices for crude feldspar at or near the mine range from about $3.50 to $12 or more per long ton, with a general 25-yr average for all common grades of nearly $6. The average for feldspar containing 5 percent free quartz or less is distinctly higher. Prices for ground spar vary according to freight rates and general market conditions, as well as according to the potash content, freedom from iron and diluents, and fineness and uniformity of grinding. Chemically controlled blending to obtain material that will meet specifications set by the purchaser has become standard practice. Most pottery and glaze (high-potash) ground spar is sold at prices of $17 or more per ton. The prices for enamel spar are somewhat lower, and those for glass spar average about $12 per ton. Producers, grinders, and buyers of feldspar are listed by Metcalf (1941, pp. 7–13).

Most of the feldspar produced in the southeastern Piedmont is obtained from aplite and pegmatite in Virginia. The deposits are large, and nearly all the pegmatite bodies being mined are at least 24 ft thick. The principal pegmatite feldspar areas are in the Otter River-Moneta belt of Bedford County, chiefly in the vicinity of Moneta. Past production from this belt has amounted to at least 250,000 tons, and current production is maintained at a fairly steady level. Most of the output is processed at two grinding plants in Bedford.

The pegmatites contain recoverable spar of all grades, and in general the purest material, which is rich in potash, occurs as very coarse crystals in discontinuous quartz-rich cores. These cores are surrounded by pegmatite with many coarse, poorly formed perthite crystals, which form masses that commonly amount to many hundreds of tons. Some quartz is present as small pods, irregular veinlets, and interstitial masses, and locally the perthite is associated with plagioclase and minor muscovite. The bulk content of potash feldspar in such pegmatite units ranges from about 50 to 90 percent or more, and a fairly pure product can be obtained by careful cobbing.

The pegmatite between the perthite-rich units and the wall-rock contacts also is coarse-grained. It grades inward from granitoid aggregates of plagioclase, quartz, muscovite, and perthite to rock rich in blocky plagioclase and perthite with abundant graphic intergrowths of quartz. This very coarse rock, which merges inward into the richer parts of the pegmatites, is the principal source of the relatively low-grade glass spar. Some quartz generally is recovered as a byproduct in the mining operations, but the mica is so sparse in these pegmatites that it adds little to the value of the output. The proportion of feldspar recovered from the rock mined ranges from 5 percent to about 40 percent for lots of 25 tons or more. The average at most mines probably is between 15 and 20 percent of cobbed material. Where corduroy spar or similar quartz-rich rock is the only product, the average yield from the pegmatite mined may be as high as 35 or 40 percent.

Many smaller pegmatites in other areas are potential sources of high-quality potash feldspar, although few of these could be worked extensively. Crystals of perthitic microcline, many of them 2 ft or more in diameter, occur with massive quartz in the cores or intermediate zones of some pegmatites, and larger but less pure aggregates of coarse crystals are present in others. Such concentrations, however, may be lenticular, discontinuous, and difficult to mine efficiently. They have been worked on a small scale in several pegmatites in the Amelia and Ridgeway-Sandy Ridge districts and at scattered localities in Virginia, the Carolinas, and Georgia. Additional small to moderately large deposits of high-grade feldspar are known to be present in the Amelia, Ridgeway-Sandy Ridge, Shelby-Hickory, Hartwell, and Thomaston-Barnesville districts. Many of these lie close enough to mica shoots to be accessible from existing mine workings or to be mined in connection with operations for mica. In most of the upper parts of the deposits the potash content of the feldspar is exceptionally high, owing to the removal of plagioclase by weathering.

Numerous past operations have been sustained by a combined production of feldspar and mica or other minerals, whereas production of any single mineral would not have been feasible. Substantial quantities of feldspar were produced during World War II as a byproduct mill concentrate from spodumene-bearing pegmatites near Kings Mountain, N. C. Bulk mining of many thin pegmatite bodies would yield sheet and scrap mica, quartz, and a mixture of potash and soda-lime feldspars, and similar mixtures of feldspars could be obtained from numerous coarse-grained intermediate zones. Few of the plagioclase concentrations are sufficiently extensive or free from accessory minerals to sustain an operation for soda-lime feldspar alone.

KAOLIN

Kaolin, the chief constituent of residual clay, is used mainly in the manufacture of china, pottery, paper, rubber, crayons, paint products, and fabrics. Impure varieties of residual clay are used for brick, tile, and certain refractories. Raw kaolin, employed mainly as a filler, is graded on the basis of its whiteness, fineness, uniformity of texture, plasticity, and freedom from gritty impurities. Where the clay is fired, as in the manufacture of china, its strength when molded, its fusibility, and its hardness, shrinkage, porosity, color, and strength after firing are important. Individual specifications for given lots of raw clay generally are set by the consumer. Standard tests for determining specific properties have been recommended by Ries (1927), Parmelee (1935), the American Ceramic Society (1928, p. 442), and others.

The kaolin formed by the weathering of pegmatite and granite rarely is free from particles and irregular larger fragments of quartz, mica, and other minerals that are resistant to chemical attack; hence most of it must be purified by washing or by air separation. In general it is carried from mine to refining plant by water flowing in V- or U-shaped troughs. Most plants in the Southeastern States employ log washers, in which the kaolin is broken up, and small sand-settling tanks, which collect the coarser sand and thick fragments of mica. Finer sand and flake mica are subsequently removed by settling in long troughs, and the clay-bearing waters are then screened and run into final collecting tanks. The sludge taken from these tanks is filter-pressed and dried for shipment. Prices generally average about \$9 or \$10 per ton, with extremes as low as \$2.40 for crude material and as high as \$45 for special grades.

The best residual pegmatite clays are those that contain little or no limonite, hematite, garnet, biotite, or other iron-bearing minerals. These are easily freed of most other mechanical impurities and command relatively high prices. Reasonably well refined kaolin generally is valued at \$6 to \$8 per ton, the price depending upon market conditions and upon fineness, color, and other physical properties.

Kaolinized plagioclase is abundant in all parts of the southeastern Piedmont, but most individual deposits are too small to permit large-scale clay mining. Some of the deposits worked for feldspar, especially in Bedford County, Va., were opened as kaolin prospects and mines and were operated as such until unweathered pegmatite was encountered. Kaolin was obtained from the outer parts of other pegmatite bodies, whereas fresh or only partly weathered potash feldspar was mined from their inner parts. The rock that contains economically recoverable kaolin is approximately coextensive with the wall zones of most pegmatites and hence rarely exceeds widths of 20 ft. The average width through all districts probably is less than 8 ft, so that in hydraulicking, the least expensive method of mining, it commonly is difficult to avoid serious contamination of the pegmatite by iron-bearing wall rock.

The principal deposits of pegmatite kaolin are in the Otter River-Moneta area of Virginia and in outlying areas in Georgia. Very few of these are in current operation, and most of those that have been worked are now covered by slumped overburden. Other deposits occur in the Amelia, Shelby-Hickory, and Hartwell districts and in outlying parts of Virginia and North Carolina. Some of these may contain enough mica to support small-scale combined operations for that mineral and kaolin. Other groups of deposits with a favorable topographic situation might be hydraulicked and the crude product purified in a single centrally located plant. The outlook for the production of large quantities of pegmatite kaolin in the southeastern Piedmont, however, is very poor, although large bodies of thoroughly weathered granite possibly could yield kaolin free from undesirable impurities.

QUARTZ

Pegmatite quartz is used in ceramics; sandpaper, scouring compounds, and other abrasives; paints; roofing materials; gems; optical devices; and certain types of radio and telephone equipment. Most is roughly crushed and sold to grinders for ultimate use in the manufacture of ceramic products. Such material at the mines is valued at $2.50 to $6 per ton, whereas most ground products of reasonable purity are sold for $10 or more per ton.

Little quartz of radio grade occurs in the pegmatites of the Southeastern States, but some usable pieces have been recovered from thoroughly weathered rock in parts of the Virginia and North Carolina Piedmont. Many appear to have been derived from quartz veins, but the source of others is not clear. The quartz cores of numerous pegmatites have been mined for ceramic materials, but only in those pegmatites worked for feldspar. Most of the output is derived from the Otter River-Moneta area in Virginia. Such quartz is very pure and occurs in milky-white to slightly smoky masses as much as 20 ft in minimum dimension. Most, however, are less than 10 ft thick and 100 ft long. A little clear but smoky quartz from several deposits in the Amelia district has been sold as gem material.

BERYLLIUM MINERALS

Beryl is used directly as a gem material and in ceramics; in addition, it is the principal commercial source of beryllium metal and beryllium compounds. These are used in ceramics, in the preparation of X-ray tubes and fluorescent lamps and screens, in special processes of paint and textile manufacture, and in the optical systems of specialized electrical instruments. The metal is alloyed with aluminum for certain light-metal uses and is a constituent of some nickel and iron alloys. The chief demand, however, is for copper-base alloys, which are exceptionally resistant to fatigue and wear, responsive to hardening treatments after being worked soft, and harder and otherwise superior to copper in structural characteristics. Moreover, they are good electrical conductors and are nonmagnetic and nonsparking. Alloys of the beryllium-copper group are used, for example, in nonsparking tools and springs, contact plates, bushings, shims, and corrosion-resistant parts in motors, gages, and precision instruments and machines.

The BeO content of pure beryl varies with the proportion of certain alkalies present, notably sodium and cesium (Schaller, W. T., personal communication, April 1942), and in general ranges from less than 10 percent to a theoretical maximum of about 14 percent. Most of the beryl in the pegmatities of the southeastern Piedmont can be cobbed nearly free from mechanical impurities, but some crystals and irregular masses are cut by veinlets and more irregular aggregates of quartz, albite, mica, and other minerals. A few crystals comprise concentric shells of quartz and beryl. The proportion of pure beryl in such composite material can be estimated, but the proportion of BeO in pure beryl is not so simply determined. Nearly all the material in the southeastern Piedmont appears to be high-grade; that is, its BeO content is 12 percent or more, but chemical analyses are needed to confirm this for any given lot.

Beryl is a sparse pegmatite constituent in the Amelia, Shelby-Hickory, and Thomaston-Barnesville districts and is common in the tin-spodumene belt of the Carolinas, but it is rare in other parts of the southeastern Piedmont. A few exceptionally rich concentrations might be profitably mined on a small scale, but the reserves in such concentrations appear to be small. On the other hand, crystals and irregular masses large enough for hand cobbing are present in many deposits and ordinarily can be recovered with little added expense as a byproduct of operations for feldspar or mica. Production in past years has been very small, in part because very few pegmatites contain more than 0.3 percent beryl and in part because many mica-mine operators have made no effort to sort out and stockpile coarse beryl. A substantial aggregate tonnage of such material is scattered through many dumps. Even with full recovery of beryl from mined pegmatite, however, production would not be great from the mica and feldspar deposits, although much might be obtained as a byproduct of spodumene production.

Phenakite, which contains a theoretical maximum of about 45 percent BeO, is the only other beryllium mineral of potential commercial importance in the Southeastern States. It is locally abundant in the Morefield pegmatite, Amelia County, Va., where it is associated with quartz and topaz. A reserve of several tons of this mineral may well be present, but it occurs as such small masses that their separation could not be accomplished profitably by ordinary hand sorting.

SPODUMENE

Spodumene, one of the chief sources of lithium, is used directly in ceramics and is the raw material for lithium compounds used in pharmaceuticals, lubricants, storage batteries, fluxes, and flares and fireworks and in curing meat, smelting iron ore, and dehumidifying air in air-conditioning equipment. High-grade spodumene contains 7 to 8 percent Li_2O.

Some of the pegmatites in the Carolina Piedmont contain abundant spodumene, and they constitute by far the greatest domestic reserve of that mineral. Kesler (1942, pp. 268–269) estimates that a minimum of 650,000 tons of spodumene, or about 45,500 tons of lithia, is present in rock minable to depths of 100 ft in the Beaverdam Creek area and in an area southwest of Kings Mountain. Most of this is milling material. Byproduct minerals that might be obtained during mining and treatment of lithia ores from pegmatites in the tin-spodumene belt include beryl, cassiterite, columbium-tantalum minerals, muscovite, and both potash and soda feldspars. During World War II the Solvay Process Co. erected a mill near Kings Mountain, N. C., and large quantities of spodumene concentrates were produced before the plant was shut down in February 1945.

Small quantities of hiddenite and kunzite, clear but colored varieties of spodumene, have been mined intermittently from deposits in Alexander County, N. C., most recently by B. S. Colburn, of Asheville. Some of the material has been cut into gems, but the bulk of the output has been sold as mineral specimens.

CASSITERITE

Cassiterite is the most important source of tin, which is used chiefly in plate and bar forms and as a constituent of numerous alloys and chemicals. This mineral has been recovered commercially from pegmatites in Coosa County, Ala., and in the tin-spodumene belt of the Carolinas, chiefly during the years prior to World War I. At least half the total output probably was obtained from the Ross mine near Gaffney, S. C. Most of the lode deposits are small and irregular, and only a few large placer deposits have been formed from them. According to Kesler (1942, pp. 261–262), reserves of placer and the most readily recoverable lode cassiterite probably are not much greater than 300 tons.

A little cassiterite occurs in pegmatites of the Amelia district, Va., but its commercial recovery may not be feasible.

TANTALUM-COLUMBIUM (NIOBIUM) MINERALS

The metals tantalum and columbium are derived mainly from members of the tantalite-columbite series. Columbium is alloyed with nickel, copper, and aluminum. Columbium-bearing ferroalloys, with their favorable welding characteristics and high-temperature strength properties, are in demand for turbine and aircraft-engine parts. Tantalum metal is used in radio and neon tubes, where its gas absorption properties are important, and in instruments and equipment that are exposed to corrosive liquids and fumes. It is uniquely satisfactory as a surgical metal and is alloyed with columbium and tungsten to form dies and cutting tools. Tantalum-bearing glass is used in special camera lenses and other optical equipment.

The most desirable ores are low-tantalum columbite and low-columbium tantalite that contain little tin or titanium.

Manganotantalite, tantalite, and columbite are moderately abundant in parts of the Morefield, Rutherford, and Herbb No. 2 pegmatites in the Virginia Piedmont, and microlite occurs in the Morefield, Rutherford, and Champion pegmatites. Other tantalum minerals are rare. Few large masses of rock contain concentrations of tantalum minerals richer than 2 lb to the ton, but their separation as byproducts during operations for feldspar and mica might well be feasible under favorable market conditions. Tantalum-bearing placer and dump materials occur at the Morefield and Rutherford mines, and the total tantalum-columbium reserve in the district may amount to 40 tons or more.

Tantalite and columbite are reported to be rare constituents of several pegmatites in the Shelby-Hickory district and also are present in the tin-spodumene belt. A small but steady production might be obtained in the course of future large-scale spodumene mining and milling operations. A little tantalite-columbite has been produced from some of the pegmatites in Bedford County, Va., entirely by hand sorting.

MONAZITE

Compounds of the rare-earth elements, derived mainly from monazite, have a limited use in incandescent mantles, cores in carbon-arc electrodes, special refractories, abrasives, glasses, ceramic products, and dyeing and decay-proofing compounds for textiles and catalysts for industrial organic chemicals. Monazite also is the principal source of thorium.

Monazite is an accessory in several Virginia and South Carolina pegmatites; is widespread in a belt of residual and transported placer deposits that extends across parts of Cleveland, Rutherford, and Burke Counties, N. C., and southwestward into South Carolina. The belt is coextensive with the "western" type granite of the Shelby-Hickory district and related hybrid rocks. Much monazite remains in the placer deposits, once the chief domestic source of the mineral, and far more is present in the granitoid source rocks.

TOPAZ

Topaz is used as a gem and in the manufacture of steel and ceramics and has potential refractory uses as well. Virtually the entire domestic output during recent years has come from nonpegmatitic sources, chiefly the Brewer mine near Kershaw, S. C. At present the market appears to be limited.

The coarse topaz in the Morefield pegmatite, Amelia County, Va., constitutes a potential source of the mineral. Small quantities were recovered by hand sorting during past operations, and more substantial quantities might be produced if the pegmatite were worked by bulk methods with separation of feldspar, mica, tantalite-columbite, topaz, and other minerals by milling. The topaz would represent only a small proportion of all the rock thus handled.

VERMICULITE

Vermiculite, with its remarkable property of expanding and exfoliating to fluffy, porous masses when heated, is widely used as a refractory, heat insulator, and lightweight aggregate for concrete. It also is a constituent of some inks, paints, and decorative substances. The highest grades of prepared vermiculite weigh less than 8 lb per cu ft, but material as heavy as 15 lb per cu ft finds a limited market.

The high-grade vermiculite deposits in the Southeastern States generally are in or around masses of basic and ultrabasic rocks, but some are associated with pegmatite and granitic types, particularly in parts of South Carolina and Georgia. Most of the vermiculite appears to have been derived from biotite or chlorite by alteration. It occurs in the outer parts of pegmatite bodies and locally as coarse masses in their inner parts. Some concentrations also are present in the wall rock immediately adjacent to the pegmatite contacts. A few deposits are said to contain substantial tonnages of the mineral, but in most it is so intimately mixed with quartz, feldspar, and other impurities that some washing or other beneficiation would be required to obtain a marketable concentrate. Moreover, it is reported that the pegmatite vermiculite yields an appreciably heavier exfoliated product than vermiculite from deposits in basic rocks. The outlook for future production of such material from the Piedmont pegmatites appears to be only fair.

URANIUM MINERALS

Deposits of uraninite, samarskite, and other uranium-bearing minerals have been carefully scrutinized during recent years because of the use of uranium as a source of nuclear energy. Demands for this purpose have drawn attention away from the former chief uses of uranium compounds in the fields of ceramics, paints, alloys, and chemical manufacturing.

Uranium-bearing minerals are so rare in the Piedmont pegmatites that their potential commercial value is exceedingly small. Some have been sold as specimens, but these represent a negligible proportion of the total mineral output from the pegmatite deposits.

ZIRCON

Zircon, used chiefly in refractories, ceramic products, and special alloys, is widespread in the granites and pegmatites of the southeastern Piedmont. It is most abundant in parts of the Carolinas and Georgia, both in lode and in placer deposits. In the latter it is associated with ilmenite, rutile, monazite, and some sphene. Small quantities of concentrates have been produced from localities near Statesville and Morganton, N. C., and Spartanburg, S. C., but there have been no operations in this type of deposit during recent years. The bulk of current domestic production is obtained from beach placers in Florida, and placer deposits undoubtedly will continue as the predominant source of the mineral.

GEM AND SPECIMEN MATERIAL

Beryl, feldspar, garnet, quartz, and spodumene are the chief pegmatite sources of gem material in the southeastern Piedmont. Transparent blue or aquamarine beryl occurs in Burke and Alexander Counties, N. C., and in Amelia County, Va. The green or emerald variety is a rare accessory of several pegmatites in Alexander and Cleveland Counties, N. C., and some golden beryl ocurs in the South Mountains of Burke County. The outlook for appreciable production of such material under present economic conditions is poor. Hiddenite and very small quantities of kunzite, the gem varieties of spodumene, are present in some of the Alexander County deposits, but only the earliest operations for such material appear to have been profitable.

Amazon stone, the green to blue-green variety of perthitic microcline, is common in the Morefield, Rutherford No. 1, and Rutherford No. 2 pegmatites of Amelia County and the Herbb No. 2 pegmatite of Powhatan County, Va. It has constituted a large part of the production from the three Amelia pegmatites, so far as value is concerned, and some of the deepest-colored material of best quality has commanded high prices. Translucent and chatoyant plagioclase, or moonstone, also has been obtained from these pegmatites, though not on as large a scale. Some salmon to wine-red gem garnet was recovered during early operations at the Rutherford mine.

Several of the Amelia pegmatites yield material marketable as mineral specimens. Groups of white and bluish-white cleavelandite crystals from the Rutherford deposit are especially attractive, and some of them contain bertrandite, cassiterite, helvite, microlite, and other rare minerals. Cassiterite, manganotantalite, microlite, phenakite, topaz, and zinnwaldite also form desirable specimens, either as irregular masses, individual crystals, or parts of crystal groups.

The muscovite from several pegmatites in the Piedmont belt has found a limited specimen market, owing chiefly to its color, size, and flatness or to excellent crystal form. A lot sold in 1947 from the Mitchell Creek mine, Upson County, Ga., consisted of small, hard books with good crystal faces and abundant inclusions of apatite, pyrite, and other minerals.

Amethyst and rutilated quartz, used in jewelry, have been obtained in Alexander and Iredell Counties, N. C.

MINING

HISTORY

Mining operations for sheet mica in the southeastern Piedmont date back at least to the fourteenth century, and the remnants of ancient trenches, pits, and cuts have been recorded from the Rutherford (Fontaine, 1883), Stevens-Rock, Liberty (Curley), Great Southern No. 1, Miller, Indian, and several other pegmatite occurrences in the Amelia, Shelby-Hickory, Thomaston-Barnesville, and Alabama districts (Sterrett, 1923, pp. 28, 32, 34, 35, 308). Evidently these were mined by Indians, who probably used the mica for ornamental purposes and possibly also as a medium of exchange. Indians are said to have worked the Smith No. 1 deposit in Alabama for beryl, which they used for ornaments. Mining by the aborigines was confined to the soft, kaolinized parts of the deposits but in places was rather extensive. Open-cuts as much as 20 ft deep and 50 by 80 ft in plan are known, and even a little underground mining appears to have been attempted. All these ancient workings are caved or badly slumped, and large trees are growing on the dumps and waste-covered floors of the cuts.

Modern mining was started shortly after the Civil War, chiefly in the Saunders and Champion pegmatites of Virginia, the Jack Baxter, Tom Cabaniss, and others in the Shelby-Hickory district of North Carolina, and the Pinetucky No. 1 in Alabama. Many other mines were opened soon after 1870, particularly in the Amelia, Shelby-Hickory, and Alabama districts, and large quantities of stove mica were produced from 1875 to 1900. The Hawkins mine was first worked about 1890, but the Ridgeway and others in the Ridgeway-Sandy Ridge district were not opened until 1900 or later. Increasing use of sheet mica in the electrical industry gradually stimulated production from 1900 to 1915, especially after 1910, and in general counteracted the dwindling demand for stove material. Mining activity during this period centered in the Amelia, Shelby-Hickory, and Alabama districts, with a substantial total production from deposits scattered over the remainder of the Piedmont.

The high price schedules of World War I raised mining and prospecting activities to new levels, and in 1918 as many as 350 mines and prospects in all parts of the Piedmont were in simultaneous operation. In addition to activities elsewhere, systematic mining was begun in the Thomaston-Barnesville district, which soon became one of the important producers. A severe but brief postwar slump was followed by a 10-yr period of prosperity in the industry, during which the annual average production of sheet and punch mica from all the Southeastern States was about 760,000 lbs, and that from the Piedmont deposits about 200,000 lbs. Large-scale mining of feldspar was started in 1923 and 1924, mainly in Bedford County, Va. Production of all grades of spar quickly rose to record levels, reaching a general maximum during the period 1926–30.

The output of feldspar and mica fell off sharply in 1931 and 1932, and the greatly reduced price schedules of the early and middle thirties permitted successful operation of only the richest and most easily worked deposits. Mining activity in some districts ceased entirely for long periods. For example, most of the mica produced from the Amelia area of Virginia for several years was the result of operations for feldspar, gems, and specimen material at the Morefield and Rutherford mines, and production therefore dropped to almost nothing when those mines were abandoned. During the period of depression prices the output from several districts represented the efforts of individuals, chiefly local inhabitants who were unable to find employment elsewhere and so turned to mining by hand methods as a possible means of earning a living.

Pegmatite mining and prospecting increased markedly in response to gradually rising prices after 1935, but for several years the production was very irregular. Unprecedented wartime demands for sheet mica of superior quality began in 1940 and led to the most widespread pegmatite mining, development, and prospecting on record. Operations were extended to more than a thousand deposits in the southeastern Piedmont, and nearly 600 prospects, mines, and groups of mines or prospects yielded salable mica during the period 1942–45. The peak of activity was reached late in 1943 and early in 1944, after which a gradually increasing supply-demand ratio brought about the removal of subsidies, curtailing of purchasing programs, and a general reduction in price schedules. By June 1945 production had dwindled to prewar levels, and a year later activity had further decreased to the point where only a few mica mines were being worked in some districts and little or no mining was being done elsewhere.

METHODS

Methods of mining and types of mine workings developed in the pegmatite districts of the southeastern Piedmont have varied according to the size, shape, and attitude of the deposits, as well as the type of material handled and the mining equipment available at the time. Nearly all operations prior to World War I were confined to weathered parts of the pegmatites and hence were almost wholly above the water table. Trenches, shallow pits, and irregular cuts were excavated in the mica-bearing rock and were subsequently deepened or extended along the strike in those deposits rich enough to sustain mining operations.

Some of the cuts were excavated to the general level of ground water, so that nearly all the mica between that level and the surface could be recovered. On the other hand, such operations commonly required timbering or the removal of much overburden, especially in deposits with moderate or gentle dips, so that most miners sank shafts or inclines, either from the bottoms of existing cuts or from points on the surface nearby (fig. 45). Adits were driven to tap the lower parts of deposits with a favorable topographic situation, but the low relief in most Piedmont areas has restricted the number of such operations. Crosscuts, drifts, stopes, and other openings were developed from the adits and shafts as the mica concentrations were mined. Some of these shallow underground workings followed definite patterns, but most were formed by highly irregular and unsystematic mining operations known as "gophering" or "jayhawking."

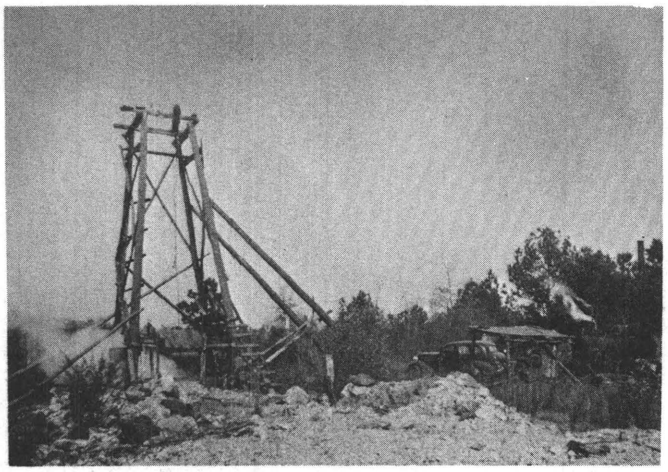

FIGURE 45.—Shaft at the Battles mine, Monroe County, Ga.

The soft, weathered pegmatite was easily handled with a pick and shovel in most places and was hauled from the workings in wheelbarrows, buckets, or small skips. Hand windlasses or simple derricks were used for lifting at most mines, and some open-cuts were excavated by horsedrawn scrapers or by drag pans powered directly or indirectly by automobiles, tractors, or steam engines. Owing to the general ease of handling and the simplicity of the necessary equipment, the miners preferred to work in soft rock, despite the constant danger of caving and the high proportion of clay-stained sheets in the recovered mica books of some deposits. A little drilling and blasting was required for the removal of "horses" of hard, unweathered rock, but this constituted a small proportion of the mining effort.

Timbering was avoided wherever possible, and many of the openings collapsed soon after they were opened. In several of the large mines, where work was carried beneath the water table, it became necessary to install pumps or to drive drainage tunnels wherever feasible. Heavy flows of ground water multiplied the problems of mine maintenance in soft ground, and where the rock was less weathered it became necessary to break it up by means of blasting. Drilling in all but a few mines was done by hand, and operating costs per pound of recoverable mica became greater with increasing depth.

Many deposits were worked for the first time during World War I. Activities in operating mines also were increased, and numerous abandoned mines and prospects were reopened. The general mining methods did not differ greatly from those previously used, although some attempts were made to improve haulage and hoisting. The proportion of hard-rock mines increased greatly, but hand drilling remained dominant over other types. Broad application of mechanized mining was deferred until World War II, when operators began to make widespread use of portable air compressors, mechanical drills, power hoists, motor-generator sets, high-capacity pumps, and other modern equipment. Much of this was supplied on a rental basis by the Colonial Mica Corp. and unquestionably was an important factor in increasing the domestic production of strategic grades of mica.

The opening of new deposits during the wartime period followed the usual pattern of trenching, test pitting, and sinking of open-cuts, and several important mines were developed in this way from surface showings of massive quartz or mica flakes. Among these are the Knight in Rockingham County, N. C., and the Mitchell Creek in Upson County, Ga. The reopening of old mines was more difficult than ever before. Some had been operated and abandoned five times or more during previous periods, and many of their workings were caved, slumped, backfilled, or flooded. Numerous old surface workings had been refilled to make land suitable for cultivation, and new operators were further handicapped by incomplete or inaccurate information concerning the extent and distribution of underground workings.

New shafts were sunk at many mines, chiefly in country rock at points some distance from any known earlier workings, and mica-bearing pegmatite was then reached through crosscuts or drifts. Old caved or muck-filled stopes were unexpectedly encountered at many places, and a few deposits were found to have been completely worked out during previous operations. In some hard-rock mines it was possible to rehabilitate the upper parts of shafts and inclines and thus use the old workings for access and haulage. The simplest and commonest kind of reopening, however, involved the workings of prospects and small mines. Existing pits and cuts were cleaned out and deepened or otherwise enlarged, and some of them were developed into narrow, slotlike openings (figs. 46 and 47). Others became large, broad cuts, excavated by shovels or scrapers in soft rock (fig. 48) or by ordinary quarrying methods in hard rock (fig. 49). Narrow, irregular drifts, stopes, and other underground workings were developed from many of these surface openings.

Stripping methods were widely used for the first time, both for removing overburden from gently dipping deposits and for eliminating dangerously steep or overhanging walls of cuts. Horse- or winch-drawn scrapers were used in many places, as at the Knight mine in Rockingham County, N. C., but highly mechanized techniques were tested by several operators. Dragline scrapers, bulldozers, and power shovels were in most common use (figs. 50 and 51) and proved very effective in removing the soft near-surface material at several deposits. The most spectacular operations, in the Big Bess mine, Gaston County, N. C., involved the stripping of large quantities of country rock from a gently dipping pegmatite body exceptionally rich in mica. More than 70 ft of overburden was removed from parts of this pegmatite.

A few deposits that had been previously honeycombed

FIGURE 46.—Open-cut work in decomposed pegmatite, White Peak No. 1 mine, Powhatan County, Va. View of the main cut, looking west. The left wall is country-rock schist, the right wall massive quartz.

FIGURE 47.—Large mica books in kaolinized wall-zone pegmatite at the White Peak No. 1, mine, Powhatan County, Va.

FIGURE 48—Irregular open-cut with waste-choked floor, Liberty mine, Randolph County, Ala.

with "gopherhole" workings were mined by bulk methods, chiefly with bulldozers or dragline scrapers, and mica that had been present in old pillars and other unmined masses of ground was thereby recovered. Such operations were attempted at the De Shazo mine in Henry County, Va., the Short Tom Smith mine in Rockingham County, N. C., the Brown mine in Upson County, Ga., and several others, but few were successful. The bulk of the near-surface mica was found to have been mined out prior to the stripping operations at most deposits, and the recovery of usable books was disappointingly low. The application of such methods of mining to newly discovered deposits therefore remains to be tested.

PRODUCTION

The yearly production of sheet and punch mica from North Carolina, from all the Southeastern States, and

FIGURE 49.—Abandoned open-cut in hard, unweathered rock, Mitchell Creek mine, Upson County, Ga.

FIGURE 50.—Dragline equipment at work, Colbert mine, Upson County, Ga.

from the entire United States during the period 1912–44 is shown in table 10. Nearly 97 percent of the mica produced in the Southeastern States has been derived from deposits in North Carolina, and this mica represents about 95 percent of the total value. Virtually all the remaining 3 percent has been obtained from the

TABLE 10.—*Production of sheet and punch mica, 1912–44, in North Carolina, the southeastern States, and the entire United States*

[Based on data from U. S. Geol. Survey and U. S. Bur. Mines, Mineral Resources U. S. and Minerals Yearbook, 1912–44. See also Jahns and Lancaster (1950, p. 30)]

Year	North Carolina		Southeastern States Va., N. C., S. C., Ga., and Ala.)		United States	
	Amount (pounds)	Value (dollars)	Amount (pounds)	Value (dollars)	Amount (pounds)	Value (dollars)
1912	489,599	219,874	(1)	(1)	845,483	282,823
1913	803,462	230,674	(1)	(1)	1,700,677	353,715
1914	274,121	171,370	308,121	175,704	556,933	278,540
1915	281,074	266,650	294,376	272,830	553,821	378,259
1916	546,553	380,700	616,700	406,000	865,863	524,485
1917	643,476	543,207	761,044	581,707	1,276,533	753,874
1918	941,200	460,450	1,239,700	587,100	1,644,200	731,810
1919	1,021,306	331,498	1,092,152	385,312	1,545,709	483,567
1920	1,084,946	405,654	1,395,838	461,936	1,683,480	546,972
1921	230,532	51,851	250,084	55,245	741,845	118,513
1922	544,495	119,767	598,321	130,601	1,077,968	194,301
1923	1,130,283	188,317	1,194,628	194,652	2,063,179	311,180
1924	597,385	108,656	682,961	116,475	1,460,897	212,035
1925	592,478	105,376	622,421	111,328	1,793,865	321,962
1926	700,313	150,362	742,345	157,576	2,172,159	400,184
1927	665,360	114,514	713,554	127,755	1,512,492	212,482
1928	777,395	129,706	804,457	133,492	1,681,777	230,956
1929	894,200	150,293	936,524	155,649	2,035,128	286,321
1930	749,074	112,451	776,075	117,573	1,465,485	177,307
1931	389,426	51,657	405,234	53,475	962,953	111,830
1932	127,696	18,322	139,863	19,554	338,997	45,882
1933	162,672	21,107	162,731	21,113	364,540	53,179
1934	293,381	38,671	295,994	38,788	583,528	90,268
1935	512,590	77,598	517,157	78,052	936,633	191,150
1936	730,446	119,653	783,768	124,115	1,319,233	203,879
1937	1,044,328	218,176	1,057,320	219,247	1,694,538	285,244
1938	632,646	87,879	655,866	89,706	939,507	139,333
1939	401,170	69,344	419,210	71,317	813,708	138,963
1940	1,002,646	218,154	1,046,535	223,817	1,625,437	291,685
1941 [2]	1,614,863	318,783	1,707,488	332,050	2,666,453	566,858
1942 [2]	1,654,895	505,634	1,783,646	555,475	2,761,844	725,030
1943 [2]	1,901,120	1,772,324	2,132,826	2,007,583	3,448,199	3,228,742
1944 [2]	814,874	1,530,625	891,465	1,715,046	1,523,313	3,262,711
Total	24,250,005	9,286,297	25,028,404	9,720,273	46,656,377	16,134,040

[1] No complete data available.
[2] Includes splittings.

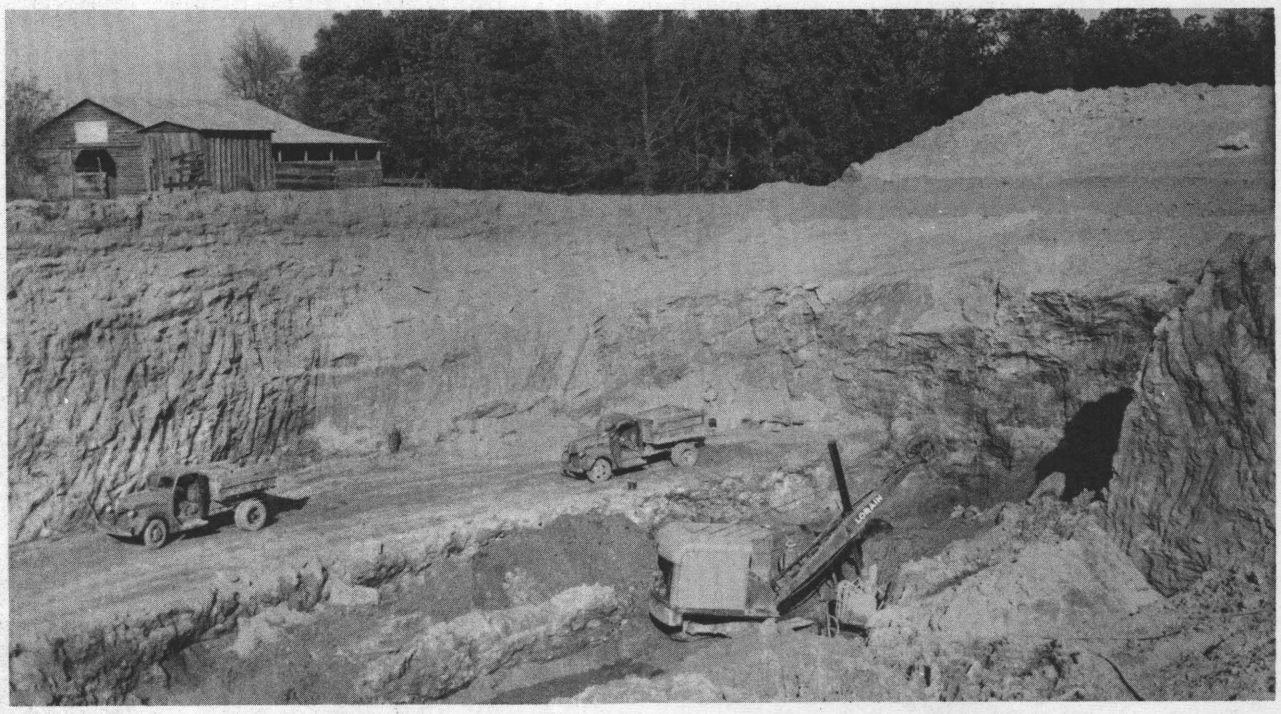

FIGURE 51.—Large-scale power-shovel operations, Big Bess mine, Gaston County, N. C. The pegmatite lies nearly flat at the level of the shovel, and all the material at higher levels is partly decomposed schist with thin pegmatite stringers.

Piedmont of Georgia, Virginia, and Alabama, and approximately one-ninth of the North Carolina output also is attributable to deposits in the Piedmont province. Through the same period the Southeastern States have accounted for 25,028,404 lb, or about 54 percent of the total United States output of sheet and punch mica, and its value of $9,720,273 has amounted to 62 percent of the total. In general these proportions have been rising slightly during recent years. The average value of the output from the Southeastern States has been about 39¢ per pound. In contrast, it was 50¢ per pound during the wartime period 1917–19 and 89¢ per pound during the period 1942–44.

The sheet and punch mica obtained from deposits in the southeastern Piedmont constituted about 13 percent of the total amount of such material produced in the Southeastern States during the period 1912–44. During World War II, however, the proportion rose sharply to nearly 24 percent, owing chiefly to greatly increased activities in parts of North Carolina and Georgia. Table 11 is a summary of wartime production by districts, with a breakdown of figures according to degree of preparation. The basic data were obtained from purchase records of the Colonial Mica Corp. and hence do not include punch, washer, and even some sheet mica sold on the open market. A total of 360,758 lbs of Piedmont mica valued at $1,207,208 was purchased by the Colonial Mica Corp. during its wartime existence, and nearly three-fourths of this output was obtained from the Ridgeway-Sandy Ridge, Shelby-Hickory, and Thomaston-Barnesville districts. Approximately 40 percent of the total was punch, and most of the remainder was three-quarter-trimmed sheet and full-trimmed punch (small-sheet) material.

TABLE 11.—*Production of mica from deposits in the southeastern Piedmont during World War II*

[Determined from purchase records of Colonial Mica Corp. Does not include punch, washer, and some sheet mica sold on open market]

District	Production (pounds)						Proportion of total production from southeastern Piedmont (to nearest 1 percent)	Value (dollars)
	Sheet mica			Small-sheet or trimmed punch mica (mainly full-trimmed)	Punch mica [1]	Total		
	Full-trimmed	Three quarter-trimmed	Half-trimmed					
Amelia	1, 380. 90	1, 909. 29	3. 56	3, 615. 01	247. 69	7, 156. 45	2	42, 583. 73
Ridgeway-Sandy Ridge	4, 395. 62	24, 815. 29	1, 013. 01	14, 511. 28	31, 975. 25	76, 710. 45	21	261, 294. 89
Outlying Virginia	340. 87	1, 899. 78	173. 98	3, 909. 08	2, 143. 00	8, 466. 71	2	37, 002. 72
Shelby-Hickory	6, 129. 41	24, 920. 17	245. 63	32, 185. 74	39, 264. 33	102, 745. 28	28	358, 034. 93
Outlying North Carolina	70. 55	1, 123. 32	49. 61	1, 570. 07	1, 105. 56	3, 919. 11	1	15, 307. 97
Outlying South Carolina	45. 06	95. 63	19. 25	401. 91	638. 00	1, 199. 85	1	3, 270. 22
Hartwell	1, 292. 85	559. 90	87. 50	3, 761. 97	6, 317. 03	12, 019. 25	3	36, 773. 84
Thomaston-Barnesville	4, 488. 34	22, 868. 34	506. 35	32, 998. 88	53, 303. 50	114, 165. 41	32	331, 062. 91
Outlying Georgia	2, 578. 94	2, 394. 61	190. 57	6, 755. 48	8, 269. 00	20, 289. 60	6	70, 597. 72
Alabama	800. 18	2, 889. 96	146. 00	5, 058. 23	5, 291. 61	14, 185. 98	4	51, 279. 01
Total	21, 522. 72	83, 476. 29	2, 435. 46	104, 768. 65	148, 554. 97	360, 758. 09		1, 207, 207. 94
Total for Southeastern States	81, 454. 18	354, 057. 91	40, 650. 75	502. 015. 34	550, 875. 24	1, 529, 053. 42		5, 297, 982. 55

[1] Includes some washer stock and skimmings.

The Thomaston-Barnesville district of Georgia was the leading producer of sheet and punch mica during World War II. The Shelby-Hickory district of North Carolina yielded almost as much mica, and its output included a higher proportion of sheet material. The other large producer, the Ridgeway-Sandy Ridge district, was followed by outlying Georgia deposits, the Alabama district, and the Hartwell district. The highest yield per producing deposit was obtained in the Ridgeway-Sandy Ridge district, where the output from only 34 mines, prospects, and small groups of mines or prospects amounted to 77,710 lbs, for an average of 2,255 lbs with a value of $7,685 per deposit (table 12). The yield also was high in the Thomaston-Barnesville district, but in the Shelby-Hickory district, where many small prospects were opened, it was only 410 lbs with a value of $1,430 per deposit. The lowest figures, 45 lbs valued at $120 per deposit, were recorded from outlying areas in South Carolina.

All lots of mica purchased by the Colonial Mica Corp. were carefully sampled in the Asheville, N. C., shop of that organization, and the samples—generally weighing about 5 lbs—were qualified according to the standard domestic classification of no. 1, no. 2, and no. 2 inferior. The grand average for all Piedmont mica was about 15 percent no. 1, 45 percent no. 2, and the remainder no. 2 inferior, and in general the mica from the Amelia, Shelby-Hickory, outlying South Carolina, and Alabama deposits was of somewhat higher quality (table 12). The poorest material was derived from the Ridgeway-Sandy Ridge district, where many slightly stained sheets were classed as no. 2 inferior. The Hartwell district and outlying areas in Georgia also yielded mica of less than average quality.

A list of prospects and mines from which sheet mica was obtained during the period of World War II follows. This list, which is based on purchase records of the Colonial Mica Corp., is divided into five groups on the basis of total production of sheet mica. The total production includes "equivalent sheet" (calculated from punch), which is taken as one-fifth the weight of standard untrimmed punch material. Fifteen mines and mine groups yielded more than 3,000 lbs of sheet mica and hence are classed as very large.

TABLE 12.—*Summary data on the total production of sheet mica from districts in the southeastern Piedmont during World War II*

[Based on purchase records of the Colonial Mica Corp. Does not include punch, washer, and some sheet mica sold on open market]

District	Total production (pounds)	Value (dollars)	Number of productive mines and prospects	Approximate average production per mine or prospect (pounds)	Approximate average value per mine or prospect (dollars)	Average quality of sheet mica (to nearest 5 percent)		
						No. 1	No. 2	No. 2 inferior
Amelia	7, 156. 45	42, 583. 73	13	550	3, 275	20	60	20
Ridgeway-Sandy Ridge	76, 710. 45	261, 294. 89	34	2, 255	7, 684	5	30	65
Outlying-Virginia	8, 466. 71	37, 002. 72	24	355	1, 540	15	55	30
Shelby-Hickory	102, 745. 28	358, 034. 93	250	410	1, 430	25	50	25
Outlying-North Carolina	3, 919. 11	15, 307. 97	37	105	415	10	70	20
Outlying-South Carolina	1, 199. 85	3, 270. 22	27	45	120	20	55	25
Hartwell	12, 019. 25	36, 773. 84	76	160	485	5	35	60
Thomaston-Barnesville	114, 165. 41	331, 062. 91	59	1, 905	5, 610	15	40	45
Outlying-Georgia	20, 289. 60	70, 597. 72	34	590	2, 075	5	45	50
Alabama	14, 185. 98	51, 279. 01	41	345	1, 250	20	55	50
Total or average	360, 758. 09	1, 207, 207. 94	595	605	2, 030	[1] 15	[1] 45	[1] 40

[1] Approximate; average is weighted according to relative production from each district.

Thirty others yielded 1,000 to 3,000 lbs (large), 8 yielded 600 to 1,000 lbs (moderately large), and the output from 32 others was more than 300 lbs (moderate). The production from each of the remaining mines, prospects, and groups of mines and prospects was classed as small. The total number of pegmatites and individual mica shoots from which some production was obtained was much greater than the sum of the above figures, in part because the workings of many mines are in more than one deposit and in part because other mines are so closely spaced that they are most easily treated as single groups.

Mines and prospects in the southeastern Piedmont that yielded sheet mica during World War II

[Based on records of the Colonial Mica Corporation. Does not include punch, washer, and some sheet mica sold on the open market]

	District	*County and State*
Mines with very large production:		
Adams mine	Thomaston-Barnesville.	Upson, Ga.
Amphlett (Franklin) mine.	Outlying Georgia	Cherokee, Ga.
Battles mine	Thomaston-Barnesville.	Monroe, Ga.
Big Bess (M. M. Carpenter) mine.	Shelby-Hickory	Gaston, N. C.
Brown (Parrish)	Thomaston-Barnesville.	Upson, Ga.
Champion (Jefferson No. 4, Bland) mine.	Amelia	Amelia, Va.
Foster, W. T., No. 1 (W. A. Thompson) mine.	Shelby-Hickory	Lincoln, N. C.
Hawkins (Joe Hawkins) mine.	Ridgeway-Sandy Ridge.	Stokes, N.C.
Knight mine	do	Rockingham, N. C.
M. and G. mine	Alabama	Clay, Ala.
Martin mine	Shelby-Hickory	Cleveland, N. C.
Merck (Old Hope) mine.	Outlying Gegrgia	Hall, Ga.
Mitchell Creek mine.	Thomaston-Barnesville.	Upson, Ga.
Sigmon mine	Shelby-Hickory	Catawba, N. C.
Vaughn, Early, mine.	Thomaston-Barnesville.	Lamar, Ga.

	District	*County and State*
Mines with large production:		
Abernathy Water mine.	Shelby Hickory	Catawba, N. C.
Archie mine	do	Cleveland, N. C.
Banister (Old Moss) mine.	Hartwell	Hart, Ga.
Baxter, Jack, (Tom Baxter) mine.	Shelby-Hickory	Lincoln, N. C.
Blanton, Cliff, mine.	do	Cleveland, N. C.
Blount No. 1 mine	Thomaston-Barnesville.	Upson, Ga.
Carter mine	do	Do.
Colbert (Castlen) mine.	do	Do.
Coleman No. 1 mine.	Ridgeway-Sandy Ridge.	Henry, Va.
De Shazo mine	do	Do.
Dickens mine	Outlying Georgia	Oconee, Ga.
Drum mine	Shelby-Hickory	Catawba, N. C.
Eanes mines	Ridgeway-Sandy Ridge.	Henry, Va.
Evans, Rosa, mine	do	Rockingham, N. C.
Franklin mine	Outlying Georgia	Cherokee, Ga.
Garner mine	Hartwell	Hart, Ga.
Gettys mines	Shelby-Hickory	Cleveland, N. C.
Hole (Jack Hole) mine.	Ridgeway-Sandy Ridge.	Stokes, N. C.
Hoyle, A. F., mine	Shelby-Hickory	Cleveland, N. C.
Huskins mine	do	Gaston, N. C.
McGee mine	Outlying North Carolina.	Caldwell, N. C.
Mauldin mine	Thomaston-Barnesville.	Upson, Ga.
Monteiro (Monteiro Tract) mine.	Outlying Virginia	Goochland, Va.
Morrison, C. R., (Oak Level) mine.	do	Henry, Va.
Reynolds mine	Thomaston-Barnesville.	Upson, Ga.
Ruby King (J. C. Hawkins) mine.	Ridgeway-Sandy Ridge.	Stokes, N. C.
Saunders No. 2 mine.	Outlying Virginia	Hanover, Va.
Self, E. R., (Old Neale) mine.	Shelby-Hickory	Gaston, N. C.

	District	*County and State*
Mines with large production—Continued		
Smith, Short Tom, (Ben Smith) mine.	Ridgeway-Sandy Ridge.	Rockingham, N. C.
White Peak No. 1 (Purcell, Miller) mine.	Outlying Virginia	Powhatan, Va.
Mines with moderately large production:		
Bailey mine	Hartwell	Hart, Ga.
Griggs mines	Shelby-Hickory	Cleveland, N. C.
Hanes mines	Alabama	Randolph, Ala.
King (Norman and Cecil) mine.	Shelby-Hickory	Lincoln, N. C.
Liberty (Curley) mine.	Alabama	Randolph, Ala.
Morefield mine	Amelia	Amelia, Va.
Patterson, Bun (Old Carroll) mine.	Shelby-Hickory	Cleveland, N. C.
Price No. 1 and No. 2 mines.	Ridgeway-Sandy Ridge.	Henry, Va.
Mines with moderate production:		
Abernathy Long Cut (Hickory) mine.	Shelby-Hickory	Catawba, N. C.
Big Fons mine	do	Lincoln, N. C.
Brittan, Floyd, mine.	do	Burke, N. C.
Brown mine	Ridgeway-Sandy Ridge.	Stokes, N. C.
Cabaniss mine	Shelby-Hickory	Cleveland, N. C.
Cagle (Dunsmore) mine.	Outlying Georgia	Pickens, Ga.
Chatfield mine	Thomaston-Barnesville.	Monroe, Ga.
Clay Cheek (Harrison W. Harp) mine.	do	Lamar, Ga.
Dougan mine	Shelby-Hickory	Cleveland, N. C.
Gaines, M. L., mine.	Hartwell	Elbert, Ga.
Gold, Mary, mine	Shelby-Hickory	Cleveland, N. C.
Harper and Pierman mine.	Hartwell	Hart, Ga.
Hefner mine	Shelby-Hickory	Catawba, N. C.
Holmes mine	Thomaston-Barnesville.	Monroe, Ga.
House mine	Outlying Georgia	Cherokee, Ga.
Houser, Plato, mine.	Shelby-Hickory	Lincoln, N. C.
Howell mine	Outlying Georgia	Pickens, Ga.
Hurst mine	Alabama	Clay, Ala.
Indiantown (Mull) mine.	Shelby-Hickory	Cleveland, N. C.
Johnson mine	Thomaston-Barnesville.	Upson, Ga.
Jones mine	Outlying Georgia	Cherokee, Ga.
Ligon mines	Amelia	Ameila, Va.
McSwain, G. B., mine.	Shelby-Hickory	Cleveland, N. C.
Mauney, S. S. (M. M. Mauney, Homestead) mine.	do	Do.
Moss mine	Hartwell	Hart, Ga.
Overstreet mine	Outlying Virginia	Bedford, Va.
Persons, Joe, mine	Thomaston-Barnesville.	Upson, Ga.

	District	*County and State*
Mines with moderate production—Continued		
Randall mine	Shelby-Hickory	Cleveland, N. C.
Rutherford mines	Amelia	Amelia, Va.
Smith No. 1 and No. 2 mines.	Alabama	Clay, Ala.
Terry mine	Shelby-Hickory	Catawba, N. C.
Waterhole mine	Hartwell	Hart, Ga.
Mines and prospects with small production:		
Adams mine	Hartwell	Hart, Ga.
Alexander prospect	Outlying Georgia	Jasper, Ga.
Amber Queen mine	Outlying Virginia	Goochland, Va.
Anderson mine	Hartwell	Elbert, Ga.
Andrews prospect	Outlying Georgia	Franklin, Ga.
Do	Hartwell	Hart, Ga.
Ankin prospect	do	Do.
Anthony prospects	Shelby-Hickory	Cleveland, N. C.
Arnott mine	Alabama	Randolph, Ala.
Atwater mine	Thomaston-Barnesville.	Upson, Ga.
Ayers, Pat, prospects.	Alabama	Randolph, Ala.
B. C. prospect	Outlying South Carolina.	Greenville, S. C.
Baker prospect	Shelby-Hickory	Burke, N. C.
Barfield mine	Alabama	Clay, Ala.
Barron (Bennie Barron, Walker Wakefield) mine.	Thomaston-Barnesville.	Upson, Ga.
Barron No. 2 prospect.	do	Do.
Baxter prospect	Shelby-Hickory	Cleveland, N. C.
Baxter, Carl, prospect.	do	Do.
Beam prospect	do	Lincoln, N. C.
Beam, Claude, prospect.	do	Gaston, N. C.
Beam, J. A., prospect.	do	Cleveland, N. C.
Beaver prospect	Outlying Georgia	Cherokee, Ga.
Benfield prospect	Shelby-Hickory	Cleveland, N. C.
Bennett mine	Outlying Georgia	Cherokee, Ga.
Berry mine	Amelia	Amelia, Va.
Bert Georgia prospect.	Hartwell	Hart or Elbert, Ga.
Biggerstaff (Deadman) mine.	Shelby-Hickory	Lincoln, N. C.
Billy prospect	do	Cleveland, N. C.
Bingham prospect.	do	Do.
Bishop prospect	Outlying Georgia	Georgia (county not known).
Blankenship prospect.	Shelby-Hickory	Alexander, N. C.
Blanton, C. Robert mine.	do	Cleveland, N. C.
Blevins prospect	Thomaston-Barnesville.	Upson, Ga.
Bobby mine	Shelby-Hickory	Cleveland, N. C.
Bobo mine	Hartwell	Hart, Ga.
Bonnet Split (Big Hill) mine.	Shelby-Hickory	Cleveland, N. C.
Borders mine	do	Do.
Bowen mine	do	Do.
Bowling prospect	Outlying South Carolina.	Greenville, S. C.
Boyt mine	Thomaston-Barnesville.	Upson, Ga.

Mines and prospects with small production—Continued	District	County and State
Bozeman (Jones) mine.	Outlying Georgia	Pickens, Ga.
Bridges, Pleaz, mine.	Shelby-Hickory	Cleveland, N. C.
Brooks prospect	do	Do.
Do	Outlying North Carolina.	Rutherford, N. C.
Brooks, L. M., prospect.	Thomaston-Barnesville.	Upson, Ga.
Brown prospect	Outlying Georgia	Cherokee, Ga.
Brown, J. R., prospect.	Hartwell	Hart, Ga.
Brown, J. W., prospect.	Thomaston-Barnesville.	Lamar, Ga.
Brown Cherry prospect.	Hartwell	Abbeville, S. C.
Browner prospect	do	Hart, Ga.
Bruce prospect	do	Anderson, S. C.
Buchanan prospect.	Outlying North Carolina.	Rutherford, N. C.
Buchanan, Carrol, prospect.	Shelby-Hickory	Cleveland, N. C.
Buchanan, Claude prospect.	do	Do.
Bunton prospect	do	Alexander, N. C.
Burgess (L. E. Hunter) mine.	Outlying South Carolina.	Anderson, S. C.
Burke Mountain prospect.	Outlying North Carolina.	Burke, N. C.
Burriss prospect	Outlying South Carolina.	Anderson, S. C.
Bush prospect	Thomaston-Barnesville.	Lamar, Ga.
Byrum prospect	Hartwell	Hart, Ga.
Cabaniss-Story (Cabaniss-Three Sisters) mine.	Shelby-Hickory	Cleveland, N. C.
Cabbie prospect	do	Do.
Cain prospect	Outlying Georgia	Cherokee, Ga.
Campbell mine	Shelby-Hickory	Cleveland, N. C.
Campbell, Mattie, prospect.	Hartwell	Elbert, Ga.
Canipe prospect	Shelby-Hickory	Catawba, N. C.
Carpenter mine	do	Cleveland, N. C.
Carpenter, Calvin, prospect.	do	Do.
Carpenter, Plato, prospect.	do	Do.
Carrol, J. A., prospect.	do	Do.
Carter prospect	Hartwell	Elbert, Ga.
Cely mine	Outlying South Carolina.	Anderson, S. C.
Chastine prospect	do	Oconee, S. C.
Cherokee prospect	Alabama	Tallapoosa, Ala.
Chestnut Ridge prospect.	Shelby-Hickory	Catawba, N. C.
Childers, Noah, prospect.	do	Alexander, N. C.
Chrysolite mine	do	Cleveland, N. C.
Clark, Will, mine	do	Do.
Cleveland prospect.	do	Do.
Cleveland, Will, prospect.	Outlying South Carolina.	Greenville, S. C.
Cline prospect	Shelby-Hickory	Alexander, N. C.

Mines and prospects with small production—Continued	District	County and State
Clingingpeel (Old Pittsburg, Old Mica Farm) mine.	Ridgeway-Sandy Ridge.	Henry, Va.
Clippard prospect.	Shelby-Hickory	Cleveland, N. C.
Cochran mine	Outlying Georgia	Cherokee, Ga.
Coffey prospect	Outlying North Carolina.	Caldwell, N. C.
Cole prospect	Hartwell	Hart, Ga.
Coleman No. 2 mine.	Ridgeway-Sandy Ridge.	Henry, Va.
Comer prospect	Outlying Georgia	Oconee, Ga.
Cooke mine	Shelby-Hickory	Cleveland, N. C.
Coosa prospect	Alabama	Tallapoosa, Ala.
Corley mine	Thomaston-Barnesville.	Upson, Ga.
Cornwall, Lee, mine.	Shelby-Hickory	Cleveland, N. C.
Costner mine	do	Do.
Cox prospect	Outlying South Carolina.	Greenville, S. C.
Cox, Abner, mine	Ridgeway-Sandy Ridge.	Henry, Va.
Craft, J. H., prospect.	Hartwell	Elbert, Ga.
Crawford-Daniel mine.	do	Do.
Crews mine	Alabama	Randolph, Ala.
Crews prospect	Outlying Virginia	Charlotte, Va.
Crowder prospect	Outlying North Carolina.	Rutherford, N. C.
Crump prospect	Hartwell	Hart, Ga.
Crystal Clear mine.	Alabama	Randolph, Ala.
Crystal Hill prospect.	Outlying Georgia	Oconee, Ga.
Cunningham prospect.	Thomaston-Barnesville.	Upson, Ga.
Dagenhart mine	Shelby-Hickory	Alexander, N. C.
Daniels, C. and A., prospect.	do	Do.
Davis, Bob, prospect.	do	Do.
Davis, Walter, mine	do	Cleveland, N. C.
Deal prospect	do	Burke, N. C.
Dellinger mine	do	Catawba, N. C.
Delta prospect	Alabama	Clay, Ala.
Denney prospect	Outlying North Carolina.	McDowell, N. C.
Denson mines	Outlying Georgia	Pickens, Ga.
Dixon, John, prospect.	Hartwell	Hart, Ga.
Doggett prospect	Shelby-Hickory	Cleveland, N. C.
Doggin prospect	do	Do.
Dolphin, Clinton, mine.	Outlying Virginia	Powhatan, Va.
Downs, Bessie, prospect.	Shelby-Hickory	Cleveland, N. C.
Duke mine	Thomaston-Barnesville.	Upson, Ga.
Dycus mine	Shelby-Hickory	Rutherford, N. C.
Edwards mine	Thomaston-Barnesville.	Upson, Ga.
Elizabeth mine	Shelby-Hickory	Cleveland, N. C.
Elliott, L. R., mine	do	Do.
Ellis prospect	do	Do.

	District	County and State
Mines and prospects with small production—Continued		
Ellis, C. H., prospect.	Outlying South Carolina.	Pickens, S. C.
Elmore prospect	Shelby-Hickory	Lincoln, N. C.
Elrod prospect	Outlying South Carolina.	Pickens, S. C.
Eskridge (A. Blanton) mine.	Shelby-Hickory	Cleveland, N. C.
Estes mine	Hartwell	Hart, Ga.
Fairview prospect	Outlying Georgia	Franklin, Ga.
Fleming prospect	Hartwell	Hart, Ga.
Flock, Joe, prospect.	Outlying North Carolina.	Rutherford, N. C.
Flynn, John, prospect.	Amelia	Amelia, Va.
Foster mine	Alabama	Randolph, Ala.
Foster prospect	Outlying North Carolina.	Polk, N. C.
Fowler mine	do	Warren, N. C.
Friendship mine	Alabama	Randolph, Ala.
Gailliard mine	Hartwell	Anderson, S. C.
Gantt mine	Shelby-Hickory	Cleveland, N. C.
Garrett prospect	Ridgeway-Sandy Ridge.	Henry, N. C.
Do	Outlying South Carolina.	Pickens, S. C.
Gibson mine	Alabama	Clay, Ala.
Gilly prospect	Hartwell	Hart, Ga.
Gladen prospect	Shelby-Hickory	Lincoln, N. C.
Gold, Ralph, mine.	do	Cleveland, N. C.
Goodman prospect.	do	Do.
Gopher mine	Alabama	Clay, Ala.
Goss prospect	Hartwell	Hart, Ga.
Grace prospect	Thomaston-Barnesville.	Upson, Ga.
Great Southern Mica Co. mines.	Alabama	Randolph, Ala.
Green mine	Shelby-Hickory	Cleveland, N. C.
Green Rose mine	Hartwell	Hart, Ga.
Greene prospect	Shelby-Hickory	Catawba, N. C.
Greenway prospect.	Outlying South Carolina.	Anderson, S. C.
Greenwood prospect.	do	Do.
Greer mine	Outlying Virginia	Henry, Va.
Grigg, Paul, prospect.	Shelby-Hickory	Cleveland, N. C.
Grill prospect	Outlying North Carolina.	Burke, N. C.
Grindstaff mine	Ridgeway-Sandy Ridge.	Henry, Va.
Gudger, Bud, prospects.	Shelby-Hickory	Alexander, N. C.
Gully mine	Outlying North Carolina.	Franklin, N. C.
Gwaltney prospects.	Shelby-Hickory	Alexander, N. C.
Hall mine	do	Cleveland, N. C.
Hall prospect	Outlying Virginia	Charlotte, Va.
Hallman mine	Shelby-Hickory	Lincoln, N. C.
Hammer prospects	do	Alexander, N. C.
Hammerick prospect.	do	Cleveland, N. C.
Harrell mine	do	Do.
Do	Thomaston-Barnesville.	Upson, Ga.
Mines and prospects with small production—Continued		
Harren prospect	Hartwell	Hart, Ga.
Harris prospect	do	Anderson, S. C.
Harris prospects	Outlying Virginia	Bedford, Va.
Hastings mine	Shelby-Hickory	Cleveland, N. C.
Hawkins mine	do	Do.
Haynes mine	Outlying Georgia	Hall, Ga.
Head prospect	Outlying South Carolina.	Pickens, S. C.
Heard mine	Hartwell	Elbert, Ga.
Heard, Doc, prospect.	Alabama	Tallapoosa, Ala.
Hendricks prospect.	Shelby-Hickory	Catawba, N. C.
Henesee prospect	do	Do.
Herbb No. 1 and No. 2 mines.	Outlying Virginia	Powhatan, Va.
Herndon mine	Shelby-Hickory	Cleveland, N. C.
Herron mine	Thomaston-Barnesville.	Upson, Ga.
Hess prospect	Shelby-Hickory	Cleveland, N. C.
High Peak prospect.	Outlying North Carolina.	Burke, N. C.
Hill prospect	Hartwell	Elbert, Ga.
Hillhouse, J. D., mines.	Outlying Georgia	Cherokee, Ga.
Hodge mine	Alabama	Randolph, Ala.
Holbrook prospect.	Thomaston-Barnesville.	Upson, Ga.
Holcomb mine	Hartwell	Hart, Ga.
Holland mine	Ridgeway-Sandy Ridge.	Rockingham, N. C.
Holler prospect	Shelby-Hickory	Cleveland, N. C.
Home prospect	do	Do.
Homer prospect	do	Lincoln, N. C.
Honeycutt prospect.	Hartwell	Hart, Ga.
Hopkins, Fred, prospect.	Outlying Virginia	Henry, Va.
Horsehead mine	Hartwell	Hart, Ga.
Howard mine	Thomaston-Barnesville.	Lamar, Ga.
Do	Alabama	Tallapoosa, Ala.
Hoyle, Haywood, prospect.	Shelby-Hickory	Lincoln, N. C.
Hudson prospect	Outlying North Carolina.	Burke, N. C.
Huffstettler mine	Shelby-Hickory	Cleveland, N. C.
Hull (Rock Cut) mine.	do	Lincoln, N. C.
Humphries, Joe E., mine.	do	Cleveland, N. C.
Hunnicutt prospect.	Outlying Georgia	Stephens, Ga.
Hunt mine	Shelby-Hickory	Cleveland, N. C.
Hunt prospect	Hartwell	Hart, Ga.
Idaho prospect	Outlying North Carolina.	Burke, N. C.
Indian prospect	Shelby-Hickory	Catawba, N. C.
J. and B. mine	Thomaston-Barnesville.	Upson, Ga.
Jackie prospect	Shelby-Hickory	Cleveland, N. C.
Jeff mine	do	Do.
Jefferson No. 1 mine.	Amelia	Amelia, Va.
Jimmy mine	Shelby-Hickory	Cleveland, N. C.
Johnson prospect	Outlying Georgia	Merriwether, Ga.

	District	County and State
Mines and prospects with small production—Continued		
Jolly prospect	Outlying South Carolina.	Spartanburg, S. C.
Jones mine	Shelby-Hickory	Cleveland, N. C.
Jones, No. 1 (Stockdale, Bell and Kilgore, C. H. Boyd No. 1) and No. 2 mines.	Alabama	Randolph, Ala.
Jones, Ruth, mine	Hartwell	Hart, Ga.
Kallam prospect	Outlying Virginia	Henry, Va.
Kay mine	Outlying North Carolina.	Rutherford, N. C.
Keller prospect	do	Caldwell, N. C.
Kelley prospect	Thomaston-Barnesville.	Upson, Ga.
Keown mine	Hartwell	Anderson, S. C.
Kidd mine	Alabama	Tallapoosa, Ala.
King mine	Outlying Georgia	Cherokee, Ga.
Kirby prospect	Outlying North Carolina.	Wilkes, N. C.
Kitchen prospect	Alabama	Randolph, Ala.
Lackey prospect	Shelby-Hickory	Lincoln, N. C.
Lail prospect	do	Cleveland, N. C.
Landrum prospect	Outlying South Carolina.	Spartanburg, S. C.
Lands prospect	Outlying North Carolina.	Caldwell, N. C.
Lattimore mine	Shelby-Hickory	Cleveland, N. C.
Leatherman mine	do	Lincoln, N. C.
Ledford, J. B., mine.	Outlying Georgia	Cherokee, Ga.
Ledford mine	Shelby-Hickory	Cleveland, N. C.
Lee mine	do	Do.
Lee, Bob, mines	Alabama	Clay, Ala.
Lindsey mine	Thomaston-Barnesville.	Upson, Ga.
Lonestar prospect	Alabama	Clay, Ala.
Long prospect	Outlying North Carolina.	Caldwell, N. C.
Lookadoo prospect	Shelby-Hickory	Cleveland, N. C.
Love prospect	do	Lincoln, N. C.
Lovelace (John Doyle) mine.	Ridgeway-Sandy Ridge.	Henry, Va.
Lovelace prospect	Shelby-Hickory	Cleveland, N. C.
Lovelace No. 1 and No. 2 mines.	do	Do.
Lovelace No. 3 mine.	do	Do.
Lovelace, Doc, prospect.	do	Rutherford, N. C.
Lovelace, Pink, mine.	do	Cleveland, N. C.
Lovelace Heirs mine.	do	Do.
Lucas prospect	do	Catawba, N. C.
Lutz prospect	Outlying North Carolina.	Caldwell, N. C.
Lutz, Otis, prospect.	Shelby-Hickory	Catawba, N. C.
Lytle prospect	Outlying North Carolina.	Burke, N. C.
McAbe mine	Outlying South Carolina.	Cherokee, S. C.
McArthur prospect	Shelby-Hickory	Cleveland, N. C.
McBee prospect	Outlying South Carolina.	Spartanburg, S. C.
McClain prospect	Shelby-Hickory	Cleveland, N. C.

	District	County and State
Mines and prospects with small production—Continued		
McCraddock prospect.	Outlying Virginia	Henry, Va.
McCrary prospect	Hartwell	Hart, Ga.
McCraw and McCraw No. 3 (Old Pinchbeck) mines.	Amelia	Ameilia, Va.
McCurry prospect	Outlying North Carolina.	Rutherford, N. C.
McFarland prospect.	do	Do.
McGinnis, F. A., mine.	Shelby-Hickory	Cleveland, N. C.
McKenzie mine	Thomaston-Barnesville.	Upson, Ga.
McKinney prospect.	Outlying North Carolina.	Rutherford, N. C.
McMullen prospect.	Hartwell	Hart, Ga.
McNeely prospect	Outlying South Carolina.	Anderson, S. C.
McNeilly, John, prospect.	Shelby-Hickory	Cleveland, N. C.
McSwain, Bill, prospect.	do	Do.
Mace mine	Outlying North Carolina.	Wilkes, N. C.
Mack prospect	do	Burke, N. C.
Magness prospect	Shelby-Hickory	Cleveland, N. C.
Marie prospect	do	Do.
Marlowe prospect.	do	Iredell, N. C.
Martin mine	Outlying Virginia	Henry, Va.
Martin, Ben, mine	Hartwell	Anderson, S. C.
Martin, J. J., prospect.	do	Hart, Ga.
Mathews prospect	Thomaston-Barnesville.	Upson, Ga.
Mauney, Bailey, mine.	Shelby-Hickory	Cleveland, N. C.
Mauney, P., mine	do	Do.
Maurice mine	do	Rutherford, N. C.
Meade prospect	do	Cleveland, N. C.
Meade, Andy, prospect.	do	Do.
Meadows prospect.	do	Do.
Means, J. T., mine.	Thomaston-Barnesville.	Lamar, Ga.
Metcalf mine	Shelby-Hickory	Cleveland, N. C.
Mewburn, Frank, prospect.	Hartwell	Elbert, Ga.
Mica Hill mine	Alabama	Tallapoosa, Ala.
Mica House prospect.	Thomaston-Barnesville.	Lamar, Ga.
Mica Mine Farm prospect.	Outlying Virginia	Hanover, Va.
Middle Brook mine.	Thomaston-Barnesville.	Upson, Ga.
Mill Race mine	Shelby-Hickory	Cleveland, N. C.
Miller prospect	do	Caldwell, N. C.
Miller, Douglas, mine.	do	Do.
Mitchell prospect	do	Cleveland, N. C.
Mitchell, J. F., prospect.	Outlying North Carolina.	Franklin, N. C.
Mitchell, Walter, prospect.	do	Do.

Mines and prospects with small production—Continued

	District	County and State
Mooney prospect	Shelby-Hickory	Cleveland, N. C.
Moore prospect	----do	Catawba, N. C.
Do	Outlying Virginia	Charlotte, Va.
Moore, J. H., mine.	Hartwell	Elbert, Ga.
Moore Head prospect.	----do	Hart, Ga.
Mooresboro prospect.	Outlying North Carolina.	Rutherford, N. C.
Moose mine	Shelby-Hickory	Catawba, N. C.
Morgan prospect	Outlying South Carolina.	Pickens, S. C.
Morgan, Leslie, prospect.	----do	Do.
Morris prospect	Hartwell	Hart, Ga.
Moses prospect	Shelby-Hickory	Catawba, N. C.
Mull, Ivey, prospect.	----do	Cleveland, N. C.
Murray prospect	Hartwell	Hart, Ga.
N. C. prospect	Shelby-Hickory	Cleveland, N. C.
Nebo prospect	----do	Do.
New, J. J., mines	Alabama	Randolph, Ala.
Newton prospect	Outlying North Carolina.	Burke, N. C.
Do	Shelby-Hickory	Cleveland, N. C.
Do	Hartwell	Hart, Ga.
Do	Outlying South Carolina.	Pickens, S. C.
Niagara mine	Shelby-Hickory	Cleveland, N. C.
Nigger prospect	----do	Do.
Norman, Archie, prospects.	----do	Do.
Norman, Bob, prospect.	----do	Do.
Norman-Thompson (W. H. Thompson) mine.	----do	Do.
North Star mine	Outlying North Carolina.	Polk, N. C.
O. and H. prospect.	Outlying Virginia	Henry, Va.
Old Franklin prospect.	Shelby-Hickory	Burke, N. C.
Old Putnam mine	----do	Cleveland, N. C.
Old Simmons prospect.	Ridgeway-Sandy Ridge.	Stokes, N. C.
Oliver, Paul, prospect.	Shelby-Hickory	Caldwell, N. C.
Orchard prospect	----do	Cleveland, N. C.
Pace mine	Ridgeway-Sandy Ridge.	Henry, Va.
Parker prospect	Shelby-Hickory	Lincoln, N. C.
Parson prospect	Thomaston-Barnesville.	Monroe, Ga.
Patterson mine	Outlying Virginia	Bedford, Va.
Patterson No. 2 mine.	Amelia	Amelia, Va.
Patterson, O. F., mine.	Shelby-Hickory	Alexander, N. C.
Patton mine	Outlying South Carolina.	Anderson, S. C.
Payne prospect	Shelby-Hickory	Alexander, N. C.
Do	Thomaston-Barnesville.	Upson, Ga.
Payne, Charlie, mine.	Shelby-Hickory	Alexander, N. C.

Mines and prospects with small production—Continued

	District	County and State
Peeler mines	----do	Cleveland, N. C.
Penn prospect	Ridgeway-Sandy Ridge.	Rockingham, N. C.
Pennyman mine	Thomaston-Barnesville.	Upson, Ga.
Perdue prospect	----do	Lamar, Ga.
Persons, Rev. Thaddeus, mine.	----do	Monroe, Ga.
Pharr, Wade, prospect.	Shelby-Hickory	Iredell, N. C.
Philbeck mine	----do	Cleveland, N. C.
Phillips mine	Hartwell	Hart, Ga.
Pinchbeck prospects.	Amelia	Amelia, Va.
Pine Mountain prospect.	Thomaston-Barnesville.	Upson, Ga.
Pinetucky mines	Alabama	Randolph, Ala.
Pitts No. 1 (Weathers) and No. 2 mines.	----do	Clay, Ala.
Plonk mine	Shelby-Hickory	Gaston, N. C.
Polk County prospect.	Outlying North Carolina.	Polk, N. C.
Pond mine	Alabama	Coosa, Ala.
Poteat No. 1 mine	Outlying Virginia	Hanover, Va.
Powell (Sugar Barrel) mine.	Shelby-Hickory	Cleveland, N. C.
Presnell, D. W., prospect.	----do	Caldwell, N. C.
Pretty prospect	Ridgeway-Sandy Ridge.	Stokes, N. C.
Price prospect	Shelby-Hickory	Rutherford, N. C.
Price, George, mine.	Ridgeway-Sandy Ridge.	Henry, Va.
Putnam mines	Shelby-Hickory	Cleveland, N. C.
Ralph prospect	Hartwell	Hart, Ga.
Ray prospect	Shelby-Hickory	Rutherford, N. C.
Reed prospect	Outlying North Carolina.	Burke, N. C.
Do	Hartwell	Hart, Ga.
Reed, Monroe, prospect.	Outlying North Carolina.	Burke, N. C.
Reid prospect	----do	Caldwell, N. C.
Rhoades prospect	Hartwell	Hart, Ga.
Rice mine	Shelby-Hickory	Cleveland, N. C.
Rice, Jake, mine	Alabama	Randolph, Ala.
Rich prospect	Shelby-Hickory	Cleveland, N. C.
Rich Knob prospect.	----do	Rutherford, N. C.
Richardson, John, prospect.	----do	Gaston, N. C.
Ridgeway mine	Ridgeway-Sandy Ridge.	Henry, Va.
Roberts prospect	Outlying Georgia	Cherokee, Ga.
Robinittes prospect.	Shelby-Hickory	Alexander, N. C.
Robinson prospect	Ridgeway-Sandy Ridge.	Henry, Va.
Rocky River prospect.	Outlying South Carolina.	Anderson, S. C.
Roland prospect	Hartwell	Hart, Ga.
Rough Cove mine	Alabama	Clay, Ala.
Rowland mine	Hartwell	Hart, Ga.
Rubin prospect	----do	Do.
Rudasill prospect	Shelby-Hickory	Cleveland, N. C.
Rusk prospect	Thomaston-Barnesville.	Lamar, Ga.

	District	County and State
Mines and prospects with small production—Continued		
Russell prospect	Shelby-Hickory	Polk, N. C.
Sadler prospect	Hartwell	Hart, Ga.
Sanders prospect	do	Do.
Sayer prospect	do	Do.
Schmitt mine	Shelby-Hickory	Cleveland, N. C.
Scism prospect	do	Do.
Scoggins prospect	do	Burke, N. C.
Scott mine	Hartwell	Hart, Ga.
Scott prospect	Thomaston-Barnesville.	Monroe, Ga.
Self No. 2 prospect.	Shelby-Hickory ville.	Gaston, N. C.
Shaddix prospect	Alabama	Clay, Ala.
Sharr prospect	do	Do.
Shelton, G. R., mine.	Ridgeway-Sandy Ridge.	Stokes, N. C.
Sheriff mine	Hartwell	Hart, Ga.
Sherry prospect	Alabama	Clay, Ala.
Shiflett prospect	Hartwell	Hart, Ga.
Shiflett, Luke, prospect.	do	Do.
Shorty prospect	Shelby-Hickory	Cleveland, N. C.
Shuford prospect	do	Do.
Sipe prospect	do	Catawba, N. C.
Sloan, Wade, prospect.	do	Iredell, N. C.
Smith mine	Thomaston-Barnesville.	Monroe, Ga.
Smith prospect	Shelby-Hickory	Caldwell, N. C.
Smith, Ernest, mine.	Ridgeway-Sandy Ridge.	Rockingham, N. C.
Smith, Fletcher, prospect.	Alabama	Clay, Ala.
Smith, J. H., prospect.	Thomaston-Barnesville.	Upson, Ga.
Smith, Jack, prospect.	Ridgeway-Sandy Ridge.	Rockingham, N. C.
Smith, Long Tom, (W. T. Smith) mine.	do	Do.
Smith, Naith, prospect.	Shelby-Hickory	Cleveland, N. C.
Smith, Walter, prospect.	do	Do.
Snow prospect	Hartwell	Hart, Ga.
Snow, Cliff, prospect.	do	Do.
Sorrels prospect	Outlying Georgia	Franklin, Ga.
Spake prospect	Shelby-Hickory	Burke, N. C.
Spangler, T. N. (Reuben Spangler) prospects.	do	Cleveland, N. C.
Speagle prospect	do	Catawba, N. C.
Sprayberry prospect.	Alabama	Clay, Ala.
Springle mine	Shelby-Hickory	Cleveland, N. C.
Squeair prospect	do	Do.
Stamey prospect	do	Lincoln, N. C.
Steele mine	Ridgeway-Sandy Ridge.	Stokes, N. C.
Stevens Rock (Marshman, Sullivan, McKinney) mine.	Thomaston-Barnesville.	Upson, Ga.
Stewart prospect	do	Do.
Stoneville prospect.	Ridgeway-Sandy Ridge.	Rockingham, N. C.

	District	County and State
Mines and prospects with small production—Continued		
Stovall prospect	Outlying Georgia	White, Ga.
Stowers prospect	Hartwell	Hart, Ga.
St. Paul prospect	Shelby-Hickory	Cleveland, N. C.
Stroud, Lax, mine	do	Rutherford, N. C.
Stroud, T. C., prospects.	do	Cleveland, N. C.
Summie prospect	do	Do.
Sweezy mine	do	Do.
Taylor, Nettie, mine.	Amelia	Amelia, Va.
Temple prospect	Hartwell	Hart, Ga.
Terry prospect	Shelby-Hickory	Gaston, N. C.
Thompson prospect.	do	Cleveland, N. C.
Thorn prospect	Hartwell	Hart, Ga.
Thornton, Sidney, prospect.	do	Do.
Thurman mine	Thomaston-Barnesville.	Monroe, Ga.
Thurman, S. T., mine.	Outlying Virginia	Prince Edward, Va.
Tillman mine	Shelby-Hickory	Cleveland, N. C.
Timber, Clyde, prospect.	Outlying Georgia	Spaulding, Ga.
Tolbert, P. L., mine.	Shelby-Hickory	Caldwell, N. C.
Tony mine	do	Cleveland, N. C.
Tooley prospect	Hartwell	Elbert, Ga.
Trammel prospect	Alabama	Randolph, Ala.
Treadwell prospect.	Hartwell	Hart, Ga.
Trice prospect	Thomaston-Barnesville.	Upson, Ga.
Triune Mills prospects.	do	Do.
Van Horn prospect.	Outlying North Carolina.	Burke, N. C.
Vandiver prospect	Hartwell	Hart, Ga.
Vasser, J. L., mine.	Outlying Virginia	Charlotte, Va.
Vaughn No. 2 prospect.	Amelia	Amelia, Va.
Vermillion prospect.	Shelby-Hickory	Cleveland, N. C.
Vickers mines	Alabama	Randolph, Ala.
Walker mine	Outlying Georgia	Pickens, Ga.
Walker prospect	Shelby-Hickory	Caldwell, N. C.
Do	do	Cleveland, N. C.
Wallace mines	Alabama	Randolph, Ala.
Walton prospect	Outlying Virginia	Bedford, Va.
Warlick, Clyde, mine.	Shelby-Hickory	Cleveland, N. C.
Warner prospect	do	Catawba, N. C.
Washburn, Maynard, mine.	do	Cleveland, N. C.
Waste prospect	do	Do.
Watkins mine	Ridgeway-Sandy Ridge.	Rockingham, N. C.
Watkins prospect	Shelby-Hickory	Cleveland, N. C.
Watson mine	Thomaston-Barnesville.	Upson, Ga.
Waycaster prospect.	Outlying Georgia	Cherokee, Ga.
Weathers mine	Shelby-Hickory	Cleveland, N. C.
Webb mine	do	Do.
Webb prospect	do	Lincoln, N. C.

	District	County and State
Mines and prospects with small production—Continued		
Webb, Cliff, prospect.	Outlying South Carolina.	Anderson, S. C.
Wehunt prospect	Shelby-Hickory	Lincoln, N. C.
Welch prospect	do	Caldwell, N. C.
Weldon mine	Outlying Georgia	Franklin, Ga.
Weldon prospect	Shelby-Hickory	Cleveland, N. C.
Wellman, Luther, prospect.	do	Do.
Wellman, W. H., prospects.	do	Do.
Wheeless mine	Thomaston-Barnesville.	Upson, Ga.
Whisnant prospect.	Shelby-Hickory	Cleveland, N. C.
White prospect	do	Gaston, N. C.
Do	do	Cleveland, N. C.
Wike prospect	do	Alexander, N. C.
Wilkins prospect	Ridgeway-Sandy Ridge.	Stokes, N. C.
Williams mine	Shelby-Hickory	Catawba, N. C.
Do	do	Cleveland, N. C.
Williamson mine	do	Do.
Willingham prospect.	Thomaston-Barnesville.	Monroe, Ga.
Willis mine	Shelby-Hickory	Lincoln, N. C.
Willis prospect	do	Cleveland, N. C.
Willum (Willimon) mine.	Outlying South Carolina.	Greenville, S. C.
Wilma prospect	do	South Carolina (county unknown).
Wilson mine	Thomaston-Barnesville.	Upson, Ga.
Wilson prospect	Shelby-Hickory	Gaston, N. C.
Do	do	Catawba, N. C.
Do	do	Cleveland, N. C.
Wingo mine	Amelia	Amelia, Va.
Wite prospect	Shelby-Hickory	Alexander, N. C.
Wood (Gully, Lon Allen) mine.	Hartwell	Hart, Ga.
Woodrow prospects.	Shelby-Hickory	Cleveland, N. C.
Woodson mine	Hartwell	Anderson, S. C.
Wright prospect	Shelby-Hickory	Cleveland, N. C.
Wyant, A. S., prospect.	do	Catawba, N. C.
Young prospect	do	Lincoln, N. C.
Young, Henry, prospect.	do	Burke, N. C.
Young, Noah, mine.	do	Do.
Young, Ralph, prospect.	do	Catawba, N. C.
Yount mine	do	Lincoln, N. C.

The amount of half-, three-quarter-, and full-trimmed material sold as strategic mica during World War II represents only a fraction of the amount of sheet and punch mica that could have been recovered and sold from an equivalent amount of mine-run books at times when a superior degree of preparation was not required. However, high wartime price schedules more than compensated for the loss of bulk, particularly as no penalty was assessed for material of no. 2 or no. 2 inferior quality during most of the Colonial Mica Corporation buying period. In fact, the value of mine-run mica from nearly all deposits in the southeastern Piedmont was considerably increased, with a probable wartime average of about $450 per ton.

Scrap mica is an important byproduct of sheet mica. Most is obtained at or near the mine portals, and much additional material of higher quality is produced as waste from rifting, trimming, and punching operations. Some pegmatites are worked wholly for scrap, and many others for punch, washer stock, and scrap. Other substantial fractions of the total production are obtained from schists and as byproducts from kaolin-washing plants. The increasing importance of scrap mica is indicated in table 13, which shows the annual production from Georgia, North Carolina, and the entire United States. The steady rise in output by no means reflects the production trends for sheet and punch mica, although the relative quantities produced from different districts generally are proportional to the relative amounts of sheet mica obtained from those districts. During the period 1941–45 the average annual production of scrap mica from the Southeastern States was approximately 30,000 short tons, nearly a fifth of which was derived from Piedmont deposits. Prices during the same period ranged from about $10 to as much as $40 per ton, with considerable variations for different grades of material.

TABLE 13.—*Production of scrap mica from Georgia, North Carolina, and the entire United States, 1912–44*

[Based on data from U. S. Geol. Survey and U. S. Bur. Mines, Mineral Resources U. S. and Minerals Yearbook, 1912–44]

Year	Georgia		North Carolina		United States	
	Amount (short tons)	Value (dollars)	Amount (short tons)	Value (dollars)	Amount (short tons)	Value (dollars)
1912	(1)	(1)	2,492	36,675	3,226	49,073
1913	(1)	(1)	2,729	37,239	5,322	82,543
1914	(1)	(1)	1,789	23,900	3,730	51,416
1915	(1)	(1)	2,840	33,943	3,959	50,510
1916	(1)	(1)	2,755	41,880	4,433	91,756
1917	26	1,400	2,180	34,134	3,429	52,908
1918	40	2,750	1,046	12,930	2,292	33,130
1919	51	778	1,639	32,338	3,258	58,084
1920	101	3,015	2,823	91,653	5,723	167,017
1921	75	1,700	1,353	30,496	2,577	94,111
1922	[2] 224	(1)	[2] 4,205	65,923	[2] 7,554	137,202
1923	(1)	(1)	[2] 5,005	95,128	[2] 9,559	195,179
1924	(1)	(1)	3,212	115,774	4,709	143,396
1925	(1)	(1)	5,095	124,818	9,695	238,081
1926	(1)	(1)	2,880	124,048	7,043	206,643
1927	(1)	(1)	2,995	93,670	6,280	168,478
1928	(1)	(1)	[3] 4,419	132,119	[3] 7,760	212,867
1929	(1)	(1)	[3] 3,245	153,722	[3] 6,253	252,090
1930	(1)	(1)	[3] 4,744	98,400	[3] 6,732	155,131
1931	(1)	(1)	[3] 5,312	84,818	[3] 6,621	122,137
1932	(1)	(1)	[3] 4,837	71,842	[3] 7,040	122,157
1933	(1)	(1)	[3] 6,918	102,830	[3] 8,751	159,439
1934	(1)	(1)	[3] 4,757	101,985	[3] 7,719	166,622
1935	(1)	(1)	[4] 11,831	153,553	[4] 18,852	243,951
1936	(1)	(1)	[4] 10,840	131,138	[4] 20,955	260,594
1937	(1)	(1)	[4] 12,988	209,212	[4] 25,196	354,737
1938	(1)	(1)	[4] 11,959	161,598	[4] 20,257	256,382
1939	(1)	(1)	[4] 13,913	184,377	[4] 24,672	311,895
1940	(1)	(1)	[4] 11,595	173,327	[4] 22,386	314,565
1941	(1)	(1)	[4] 18,234	268,596	[4] 32,500	442,789
1942	(1)	(1)	[4] 24,145	485,560	[4] 43,262	671,165
1943	[4] 6,251	39,336	[4] 25,295	516,367	[4] 46,138	738,025
1944	[4] 5,305	107,135	[4] 29,774	750,285	[4] 51,727	1,089,072
Total			249,844	4,774,278	439,610	7,693,145

[1] Not listed separately.
[2] Includes mica recovered from schists.
[3] Includes mica recovered from kaolin.
[4] Includes mica recovered from kaolin and schists.

Production of crude feldspar from North Carolina, Virginia, and the entire United States for the period 1912–14 is shown in table 14. Most of the North Carolina output is obtained from pegmatites in the Blue Ridge province, but all of that recorded for Virginia is from Piedmont deposits, especially pegmatites in Bedford County. The annual Virginia production generally is about a fifth of that from North Carolina, and in recent years has been about 7 percent of that from the entire United States. Its average per-ton value of about $5.50 compares favorably with the $5.48 average value for the total United States production. Large quantities of ground feldspar for the glass trade also are obtained from aplitic rocks near Piney River, Va., and additional but much smaller quantities of crude pegmatite feldspar are produced elsewhere in the southeastern Piedmont from time to time, in part as a byproduct from mica- and spodumene-bearing pegmatites.

TABLE 14.—*Production of crude feldspar from North Carolina, Virginia, and the entire United States, 1912–44*

[Based on date from U. S. Geological Survey and U. S. Bureau of Mines, Mineral Resources of the United States, and Minerals Yearbook, 1912–44]

Year	Virginia		North Carolina		United States	
	Amount (long tons)	Value (dollars)	Amount (long tons)	Value (dollars)	Amount (long tons)	Value (dollars)
1912	(1)	(1)	[2] [3] 7, 011	18, 659	[2] 26, 462	89, 001
1913	(1)	(1)	[2] [3] 12, 166	30. 931	[2] 45, 391	148, 549
1914	(1)	(1)	[2] 15, 420	43, 153	[2] 85, 905	263, 476
1915	(1)	(1)	20, 635	55, 991	93, 853	188, 443
1916	(1)	(1)	30, 955	77, 446	118, 465	404, 689
1917	(1)	(1)	42, 463	131, 442	126, 715	474, 767
1918	(1)	(1)	35, 732	160, 275	88, 498	429, 989
1919	(1)	(1)	22, 495	116, 826	63, 441	347, 992
1920	(1)	(1)	36, 521	259, 603	135, 551	851, 123
1921	(1)	(1)	40, 712	187, 136	91, 865	617, 652
1922	(1)	(1)	56, 043	333, 745	117, 127	844, 568
1923	(1)	(1)	57, 622	360, 636	145, 004	1, 057, 595
1924	(1)	(1)	97, 075	640, 403	204, 772	1, 509, 339
1925	(1)	(1)	76, 806	496, 563	185, 706	1, 315, 654
1926	(1)	(1)	91, 433	602, 020	209, 989	1, 607, 101
1927	(1)	(1)	100. 756	612, 214	202, 497	1, 424, 755
1928	(1)	(1)	105, 560	630, 042	210, 811	1, 418, 975
1929	6, 677	38, 628	103. 273	598, 938	197, 699	1, 276, 640
1930	6, 760	38, 048	103. 163	593, 552	171, 788	1, 066, 636
1931	9, 331	48, 545	86, 429	505, 525	147, 119	861, 059
1932	6, 759	31, 990	58, 465	300, 877	104, 715	539, 641
1933	13, 459	52, 758	85, 962	471, 312	150, 633	778, 826
1934	12. 140	64, 529	79, 844	465, 214	154, 188	853, 136
1935	14, 810	81, 474	82, 499	482, 729	189, 550	1, 005, 021
1936	20, 459	114, 807	102, 393	591, 053	244, 726	1, 303, 090
1937	22, 175	125, 396	94, 595	538, 567	268, 532	1, 383, 249
1938	9, 766	52, 037	56, 795	295, 800	196, 119	895, 081
1939	18, 544	100, 299	76, 738	397, 631	253, 466	1, 112, 857
1940	21, 705	116, 531	79, 312	426, 784	290, 763	1, 271, 995
1941	(1)	(1)	100, 016	552, 386	338, 860	1, 519, 456
1942	24, 298	140, 304	93, 644	533, 448	316, 166	1, 546, 702
1943	20, 550	122, 957	112, 144	656, 182	308, 180	1, 646, 277
1944	24, 010	147, 106	122, 857	778, 007	327, 408	1, 813, 937
Total	---------	---------	2, 287, 534	12, 945, 090	5, 811, 964	31, 867, 271

[1] Not listed separately.
[2] Short tons.
[3] Includes production from other States.

Production of pegmatite quartz is virtually restricted to active feldspar mines, from which it generally is sold as a low-value byproduct. The annual output is small. Some of the quartz crystals of radio grade that were obtained from the thoroughly weathered mantle in parts of North Carolina and Virginia during World War II may have been derived from pegmatite bodies.

Residual kaolin has been mined from pegmatites in all districts, but few extensive operations have been carried on during recent years. Most of the substantial Piedmont production of kaolin is derived from deposits of transported material in Georgia and South Carolina.

Little spodumene was mined in the Southeastern States until 1942, when some of the pegmatites in the tin-spodumene belt of the Carolinas were owned on a moderate to large scale. A mill near Kings Mountain, N. C., was completed and put into operation by the Solvay Process Co. in May 1943, and before it was shut down in February 1945 it had become the chief commercial source of spodumene. Domestic production of lithium minerals during 1944 was 13,319 short tons containing 848 tons of Li_2O valued at $552,977 (Gwinn, 1946), and a large part of this was spodumene concentrates from the Kings Mountain area.

Cassiterite has been mined from many pegmatites in the tin-spodumene belt of the Carolinas, mainly during the years prior to World War I. The total recorded production of metallic tin is not more than 125 short tons, at least half of which probably was obtained from the Ross mine near Gaffney, S. C.

Tantalum-columbium minerals have been produced on a very small scale from pegmatites in Amelia and Bedford Counties, Va., and in parts of the North Carolina Piedmont. Most of the material has been marketed as mineral specimens.

Beryl has been recovered as a byproduct from several Piedmont pegmatites during recent years, but the total output has been small. Gem and specimen material valued at several thousand dollars was obtained from a few small deposits in North Carolina and Virginia prior to 1920, but little recent production has been recorded. Moonstone, amazon stone, garnet, spodumene, and other gems also have been mined in North Carolina and Virginia, and their total value may have been as much as $100,000. The value of gem and specimen feldspar recovered from pegmatites in Amelia County, Va., is said to have been at least $25,000. Other mineral specimens have found a market from time to time, but their combined value is not known.

Vermiculite has been obtained from pegmatites during recent years, especially in South Carolina, but the production has not been large. Small yields of monazite and zircon also have been reported from pegmatite mining chiefly prior to 1905, but there has been little recent commercial recovery of such minerals.

FUTURE POSSIBILITIES

Pegmatite deposits in the southeastern Piedmont, as in many other places, have been explored by the trial-and-error method. Pits and shafts were sunk at random in any exposed pegmatite, and sites were selected for convenience as much as for any other reason. As is inevitable under such conditions, the pegmatite deposits were considered to be completely erratic and impossible of evaluation before being completely mined out and the mineral content determined directly. The studies made during World War II, as pointed out in an earlier part of this report, have shown that the deposits are not nearly as erratic as had been thought and, in fact, may well be more predictable than many metal deposits.

The zoning and sequence of mineral assemblages, already discussed, can be very effectively used in directing exploratory efforts. Best-quality mica occurs in medium- to coarse-grained plagioclase-quartz pegmatite, which is found most commonly in unzoned or poorly zoned deposits and in the wall zones of the zoned deposits. In some districts lower-quality mica forms fringes around quartz cores. The first phase of prospecting for mica in zoned deposits should naturally be directed toward the wall zones. If they are found to be barren of mica, the edges of the quartz core, if any is present, and any intermediate zones should be explored. Very few mica-bearing zones are uniform in grade. The mica commonly is concentrated in a fourth to a sixth of the exposed length of long pegmatite dikes. There are several favored positions for the mica shoots, as stated, and these may be determined in the field by the study of the mines in each district. The thickness and continuity of the mica-bearing zones can be determined on the outcrop, and, with a knowledge of the mica content of the zone, an estimate can be made of the mica reserves of the deposit.

Coarse-grained microcline feldspar occurs mainly in the cores and intermediate zones of pegmatites. Few unzoned or poorly zoned deposits are coarse enough or contain enough microcline to yield feldspar by hand cobbing. Preliminary surface exploration for microcline ought therefore to be restricted to cores and intermediate zones of well-zoned pegmatites. Microcline is not as likely to be sharply restricted in shoots as mica. Along the sides of quartz cores it commonly is present with a smaller amount of admixed rock than in other parts of pegmatite bodies.

Diamond-drill exploration has not been used extensively in pegmatite-mining districts in the Piedmont. This is because of the legendary erratic distribution of minerals in pegmatite and the idea that, if the drill core is to yield valuable information, mica or some other valuable mineral must actually be recovered in it. After the zoning of a deposit and the position of the mica shoot are recognized, it no longer is necessary to obtain mica in the drill core. The character of the pegmatite can be determined from the drill core, as can the thickness and attitude of the pegmatite body. In most deposits a persistent mica shoot is not interrupted unless the mica-containing rock changes in character or the pegmatite body itself is interrupted or changed in shape. The diamond drill is also very useful in determining the size and position of old mine workings and the continuity of pegmatite beneath them.

Methods of exploring pegmatite deposits can be discussed much more easily than the possibilities of future production can be evaluated. Few mines were mapped before World War II, and an operator who plans to reopen a mine therefore has little to assure him that the deposit has not been exhausted. All the available information that was considered reliable has been assembled for several hundred mines, and together with many recent mine maps, is being published by the Geological Survey in the present series. Several moderately large blocks of favorable pegmatites are known to remain in partly mined deposits. The rate of discovery of new mica deposits has been quite low in recent years, as all the easily found deposits were found many years ago. Nevertheless, several new pegmatites were found during the 1940–46 period and many probably remain in wooded land and pastures. These might be found by careful search and will be uncovered as the woods are cleared and the land plowed.

The Piedmont has not been as thoroughly prospected for feldspar as it has for mica. Large dikes in the Carolinas and Georgia contain intermediate zones rich in microcline and might become commercial sources of feldspar, even though some are unpromising mica prospects. The recent opening of a feldspar mill in Jasper County, Ga., indicates that there are minable feldspar deposits in that area.

Few pegmatite bodies in the Piedmont outside the tin-spodumene belt are minable for any mineral other than feldspar or mica. The amount of mining and the production of the mines will therefor depend almost entirely upon the prices for those minerals. The microcline in the weathered pegmatites of the Piedmont has been freed from intergrown plagioclase and contains an exceptionally low soda content. The Piedmont feldspar, therefore, might average somewhat higher in value than the feldspar from the Blue Ridge. No reason is known why, with satisfactory prices, a significant, steady production of mica and feldspar could not be obtained from Piedmont mines for several decades.

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