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NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT
R. BRUCE ETHERIDGE, DIRECTOR

DIVISION OF MINERAL RESOURCES
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INFORMATION CIRCULAR 4

OCCURRENCES OF SILLIMANITE IN NORTH CAROLINA

By
Charles E. Hunter
and
William A. White

Prepared in cooperation with the Tennessee Valley Authority

Foreword

During recent years there has been a great advance in the industrial use of non-metallic minerals. This has been made possible in a large measure by basic geological investigations through which commercial reserves of many little known and used non-metallic minerals have been established. The Division of Mineral Resources of the North Carolina Department of Conservation and Development, in cooperation with other agencies, is actively engaged in supplying basic information on the non-metallic minerals of the State.

The accompanying report, "Occurrences of Sillimanite in North Carolina," by Charles E. Hunter and William A. White, has been prepared in cooperation with the Regional Products Research Division, Commerce Department of the Tennessee Valley Authority. It is a preliminary summary describing the principal features of the occurrences of sillimanite, an industrial mineral of considerable importance to the ceramic and refractory trade. Additional investigations are being continued, both on the geological occurrence and the technology of the sillimanite.

Jasper L. Stuckey
State Geologist

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OCCURRENCES OF SILLIMANITE IN NORTH CAROLINA

By Charles E. Hunter* and William A. White**

Contents

Introduction

The occurrence of sillimanite in North Carolina was known as early as 1873 when a specimen from Burke County was described by F. A. Genth 1/. Pratt and Lewis 2/ observed it in association with corundum in Macon County, and Keith 3/ identified it as a rock-forming mineral in the vicinity of Kings Mountain, Cleveland County. All these identifications were incidental to the microscopic examination of samples collected for the study of corundum and cassiterite.

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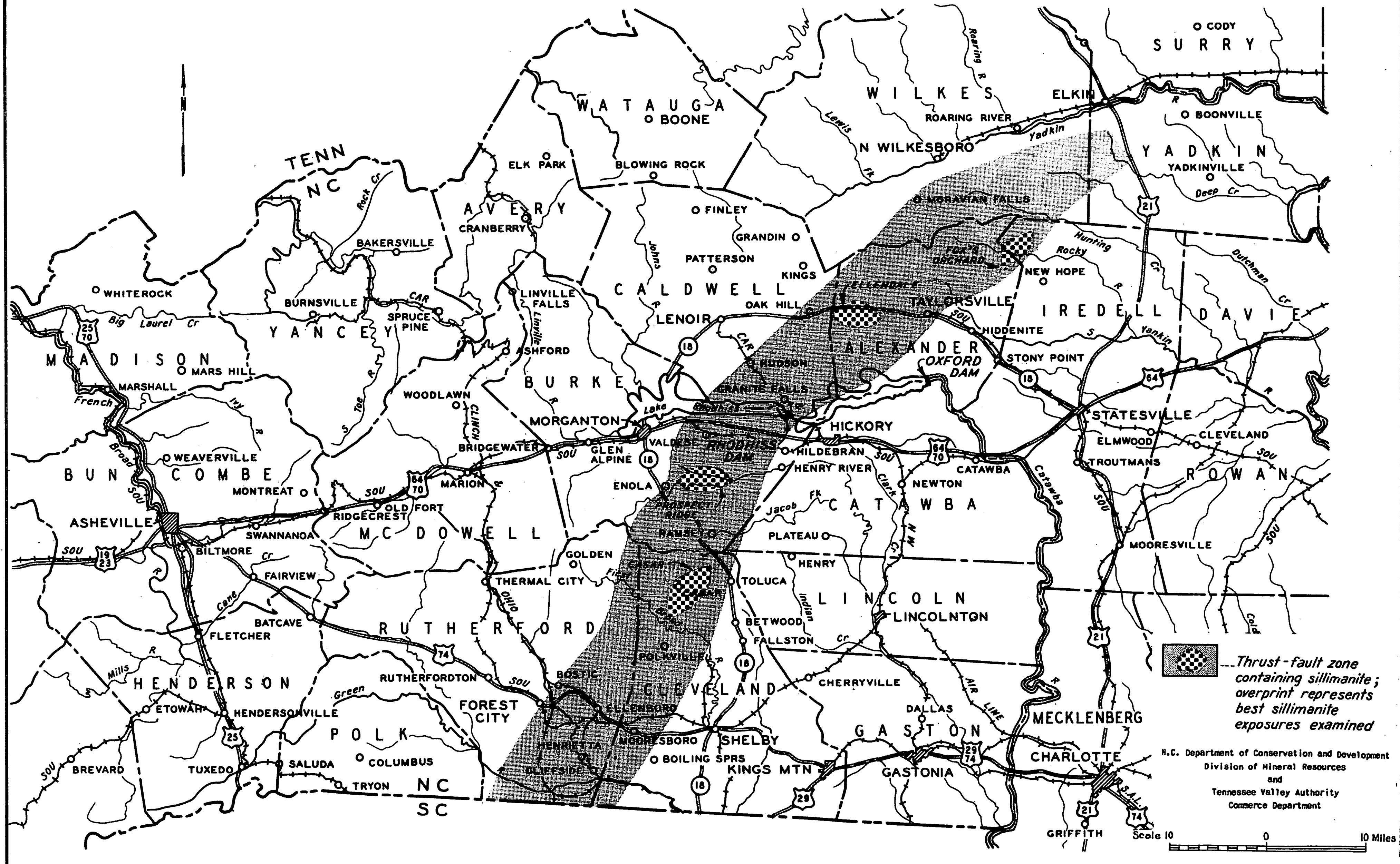
1/References are at end of circular.

In 1943 Charles E. Hunter, of T.V.A., discovered extensive sillimanite outcrops near the town of Valdese and in the South Mountains of Burke County. The first geological investigation of sillimanite in North Carolina was made in the summer of 1945 as a joint survey by the Division of Mineral Resources of the North Carolina Department of Conservation and Development and the Regional Products Research Division of the Commerce Department of T.V.A. This investigation, in a preliminary way, attempted to determine the areal extent, geologic relations, and economic potentialities of a large zone of sillimanite in the upper Piedmont area parallel to and some 20 miles east of the Blue Ridge escarpment. Examination during the summer of 1945 disclosed that these deposits occur in a thrust shear zone about 10 miles wide and 95 miles long. This zone enters the state from South Carolina, near Cliffside in Rutherford County, and extends northeastward to the Yadkin River near the Yadkin-Surry County line in the vicinity of Elkin. No sillimanite was observed north of the Yadkin River. The zone traverses Rutherford, Cleveland, Burke, Caldwell, Alexander, Wilkes, Iredell, and Yadkin Counties. Near its central part the zone passes a few miles east of Morganton, the county seat of Burke County.

The survey, because of the limited time available and the large area covered, was largely made from the secondary road system, and it is possible that some of the best mineralized areas yet remain undiscovered.

Markets and Economics of Sillimanite

In the past no large and dependable source of supply of sillimanite has been available to the ceramic industry. For this reason, the possible markets for sillimanite, as well as the quantity that could be utilized, cannot be predicted until work on concentrations and uses is completed.



OCCURRENCES OF SILLIMANITE IN CLIFFSIDE - ELKIN ZONE OF NORTH CAROLINA

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It is thought that if a dependable source were available the uses of sillimanite should be expected to parallel closely those of the other minerals of the same chemical composition ($Al_2O_3.SiO_2$), andalusite, kyanite, and closely allied dumortierite ($8 Al_2O_3.B_2O_3.6SiO_2.H_2O$). These minerals have a wide application in the ceramic and refractory industries.

All of the sillimanite group of minerals are converted upon heating into mullite ($3Al_2O_3.2SiO_2$) and vitreous silica. The conversion of kyanite into mullite takes place at about 1350°C, andalusite at about 1470°C, and sillimanite at about 1650°C.

McVay and Wilson[4/] report as follows: "Mullite ($3Al_2O_3.2SiO_2$) is the only stable high-temperature crystalline aluminum silicate formed when any of the aluminum silicate minerals, such as andalusite, kyanite, sillimanite, topaz, dumortierite, or kaolinite, are heated to a sufficiently high temperature."

The use of mullite adds certain desirable properties to ceramic ware and refractories. Porcelains and enamels produced from mullite have high melting points, high thermal-dielectrical resistance, low coefficient of expansion, and resistance to chemical attack. Refractories prepared from mullite-forming minerals have high melting points and thus a very high load-carrying capacity at high temperatures; they also have resistance to corrosion by certain fluxing agents and furnace gases. This group of minerals is also valuable in glass making, refractory cements, and kiln furniture[5/].

One apparent advantage that sillimanite possesses over domestic kyanite in the preparation of refractories is that it has a very slight or no change in volume when heated to the mullite conversion temperature. This permits the manufacture of a dense super-duty refractory.

If a low iron (0.10 to 0.25 per cent) sillimanite concentrate can be made, a large market should develop for glass manufacture because of the high alumina content of the sillimanite.

The annual consumption of minerals in the sillimanite group can only be roughly estimated as many of the producers of these minerals are also consumers and production figures are not available. However, it is believed that the preparation of a high quality concentrate would permit marketing of 15,000 to 20,000 tons per year of sillimanite at a price of $20 to $35 per ton.

Geology

The occurrence of sillimanite in North Carolina in sufficient concentration to be classed as a possible ore is restricted to four major zones. Listing these zones from west to east they are: Clay County, Asheville, Cliffside-Elkin, and Kings Mountain. However, the authors are aware of the existence of sillimanite outside of these major zones. For instance, it was observed at the Big Ridge mica mine in Haywood County and scattered localities as far east as Winston-Salem. None of these occurrences east of the Cliffside-Elkin zone are believed to be of any economic importance at the present time. For the most part, they are isolated small bodies of sillimanite schists along the smaller shear zones.

In the Clay County zone the sillimanite occurs in a graphite-mica schist. It extends from Tusquitee to the Georgia state line and has been described by Furcron and Teague[6/]. Occurrences within the Asheville zone are to be observed at Oteen, Recreation Park, and Skyland, Buncombe County. In these the sillimanite is associated with a mica schist and quartzite. No detailed work has been done in this zone and its areal extent is not known.

In the Kings Mountain zone the sillimanite is associated with the Battle Ground schist and tin bearing pegmatites. The zone extends southwestward for about 50 miles, from a point near Lincolnton through the town of Kings Mountain to the South Carolina line.

The Cliffside-Elkin zone is the most extensive and is the one with which this report is primarily concerned. The limits of the Cliffside-Elkin zone were outlined during the investigation as shown on the map (Plate 1). Four subsidiary areas within the zone were selected for detailed study because of their apparent greater sillimanite content, the larger size of sillimanite crystals, or availability of fresh rock faces. These four areas (Prospect Ridge, Fox's Orchard, Ellendale, and Casar) are described below in more detail. There may be other areas within the Cliffside-Elkin zone just as good as the ones selected, but the limited time did not permit more detailed work. It is recommended that any additional search for sillimanite be concentrated within this 95 mile zone, and especially within the four selected areas mentioned above.

A number of different rocks appear throughout the extent of the Cliffside-Elkin zone, but, in general, the country rock is granite, granite gneiss or quartz-biotite schist.

The Cliffside-Elkin zone is different from the others in that, with a few exceptions, the sillimanite is found in the shear zones of low-angle thrust faults which occur in the biotite-quartz schists. These shear zones are usually many hundreds of feet thick and are readily self-evident by their fragmental appearance. The rock is broken intimately and the shearing may be seen in many orders of magnitude which vary from minute intragranular shears, seen only with the microscope, to large and persistent fault planes which may be traced for considerable distances along the outcrop. However, the commonest evidence of shearing is found in the small, deformed fragments which have commonly been dragged into somewhat sigmoidal shapes. These sigmoidal fragments average from 1/2 to 3 inches in length and are thin lenses with the ends slightly bent into an elongated or stretched S shape. These fragments are found quite generally throughout the shear zones and provide a ready criterion for their recognition in the field.

The shear zones may themselves be folded, apparently by a later and less vigorous deformation. Where their contacts with adjacent rocks are exposed, they are usually tilted and frequently extensively warped. Such a contact may be seen to good advantage in the road cut at the intersection of State Highways 10 and 18, near Toluca in Cleveland County.

The outcrops of the shear zones are usually curved or irregular in shape because of the above-mentioned late warping. However, there seems to be a general tendency for their strikes to be unconformable with the regional strike of approximately N 60° E.

In marked contrast to the rather irregular general strikes of the outcrops, the individual component shear planes within the zones are usually quite uniform in having a strike of N 20° E, or at an angle of approximately 40° from the regional strike of N 60° E. The dips of the shears are possibly a little less uniform than the strike, but in general they average about 18° to 20° S.E.

Mineralogy

Megascopic observation in the field and microscope studies in the laboratory both suggest that there has been extensive mineralization in the shear zones.

One of the most characteristic inherent qualities of these zones is the presence of innumerable small pegmatites which connect throughout the component shears forming a fine lattice. They show no evidence of deformation and are obviously later than the shearing and are also dependent upon it for the openings they fill. In the writer's opinion the sillimanite, as well as other replaced and introduced minerals, had its origin in mobile solutions emanating from these small pegmatites. Usually the pegmatites themselves are, at least megascopically, free of sillimanite. However, they are almost universally present in intimate relation with the sillimanite-bearing schist and at one locality on

Gunpowder Creek in Caldwell County small needles of sillimanite were found within the undeformed pegmatite.

Under the microscope the sillimanite-bearing rock is seen to be a quartz-biotite schist with very minor amounts of a plagioclase which appears to be albite. The bulk of the rock is quartz, which, like the feldspar, seems to have been a component of the original rock. Both these minerals are allotriomorphic. Small euhedra of biotite are disseminated quite generally throughout the rock and locally garnets appear. Both these minerals probably represent original components of the rock also.

The above minerals are commonly replaced by muscovite which is believed to be the first mineral deposited from the impregnating pegmatite solutions. The muscovite appears as amall euhedra, disseminated or in clusters, or elongated, which are lineally arranged in groups with a common orientation. In some places these muscovite crystals have apparently formed in conjugate shears, lending a rhombohedral cleavage and pearly luster to a quartzose rock. (Plate 5 Figure W-1.)

The sillimanite appears in needle-like crystals which replace the quartz, biotite, muscovite, and garnet. The crystals occur singly or in groups which take on several distinct patterns of aggregation. Sometimes they are in subparallel growth but following a sinuous line apparently determined by the previous position of the linear aggregates of muscovite crystals which they tend to replace, largely with the longest direction of the sillimanite parallel to the cleavage of the muscovite. Again, the bundles of sillimanite needles may be heterogeneously oriented in felted aggregates, or thinly disseminated in random orientation throughout the quartz. Of most importance, however, is the tendency for them to form bundles in parallel or sheaf-like growth to the virtual exclusion of all other minerals. Such bundles are usually small and sparsely distributed through the rock, but in some of the more favorable localities such as Smith Cliff on Prospect Ridge in Burke County they are larger and form a significant fraction of the rock, offering one of the most promising potentialities for development.

Small amounts of pyrite are found scattered throughout the zone. This, the only sulfide observed, appears to be one of the late minerals. It seems to have replaced sillimanite and is apparently in turn replaced by sericite and chlorite, the last minerals deposited.

In connection with the presence of pyrite it is of interest to note that the city of Valdese in Burke County drilled a water well in the shear zone. An excellent flow was obtained, but the water was not suited for the city supply because of the sulphur compounds contained in it.

Sericite is a common mineral throughout the shear zone, usually appearing in curved veinlets which seem to follow small fractures. It is of interest to note that the quartz along the edge of these veinlets is frequently granulated and the earlier micas are sometimes deformed.

Chlorite is seen more rarely than sericite. Its position in the sequence of replacement is less clear than that of sericite but it also appears to have been a late mineral.

It is perhaps worthy of note that no secondary quartz was observed in any of the thin sections studied despite the strong evidence that many of the components of the rock were hydrothermal in origin. Locally quartz-tourmaline veins were observed to cut the sillimanite-bearing schists, but these appear to represent a later period of mineralization unconnected with the sillimanite-depositing solutions.

Important Areas

Prospect Ridge

The largest and the best exposures of sillimanite in the Cliffside-Elkin zone are located in the Prospect Ridge area, six miles southeast of Morganton, Burke

County. The best outcrops found in this area are in the cliffs along the valleys of Laurel Creek and Henry Fork River. These streams have exposed the sillimanite formation across the strike for about 4-1/2 miles. The greatest vertical section of sillimanite exposed is in Smith Cliff which rises precipitously from the north bank of Henry Fork. The main part of the cliff is about 1,500 feet long and about 450 feet high. The entire cliff is sillimanite-bearing rock except for a few small granite ledges; however, the upper 100 feet of the cliff contains the greatest concentration of coarse bundles of sillimanite crystals. Many of these bundles are almost pure sillimanite and attain a size of 2 by 4 inches. The upper 50 feet of the cliff is weathered but the sillimanite appears to be sound. Most of the completely weathered overburden on top of the cliff contains an accumulation of bundles of coarse crystals in concentrations up to approximately 10 to 20 per cent. Some of the richer zones of hard rock ledges in the cliff appear to contain 15 per cent sillimanite by weight.

In addition to Smith Cliff there are five known similar occurrences of coarse sillimanite in the Prospect Ridge Area.

Fox's Orchard

The Fox's Orchard Area is located in the northeast part of Alexander County and northwest part of Iredell County. This zone begins about 1/2 mile south of New Hope Post Office and extends for a distance of about 2 miles southwestward to a point 1 mile south of Rocky Creek. This area was not studied in detail as only exposures along the secondary road cuts were examined.

In Fox's Orchard Area the sillimanite is of two types: nodules 1 by 2 inches in quartz gneiss, and fine-grained material consisting of interlocking needles associated with large garnets. Many of these garnets are 1-1/2 inches in diameter and clearly have been replaced by sillimanite to a considerable degree. One of these garnet zones observed just north of Rocky Creek was about 50 feet wide and perhaps 300 feet long. Here the sillimanite appears to constitute from 20 to 60 per cent of the rock. However, it is doubtful if this rich concentration of sillimanite is of economic importance because the grain size is small and the sillimanite is iron stained. The nodular type of sillimanite is more pronounced in the area between Rocky Creek and New Hope. On weathered surfaces the nodules stand up and give the rock a knotty appearance. The bundles of sillimanite crystals contain visible amounts of sericite and thus the nodules are unlike those of other areas.

Ellendale Area

Two types of sillimanite occur in the vicinity of Ellendale school 6 miles west of Taylorsville, Alexander County. About 1/4 to 1/2 mile east of the school several zones of sillimanite schist outcrop in the road cut of State Highway No. 90. They range from a few to perhaps 100 feet in thickness. Here the sillimanite is of the fibrolite variety. The sillimanite occurs in a sericite schist which has been intimately impregnated with pegmatitic material which contains muscovite, feldspar, and kaolin. The sillimanite appears to comprise between 20 and 25 per cent of the rock and it, as well as the host rock, is white in color, thus suggesting a low iron content which is possibly the lowest in the entire Cliffside-Elkin zone.

In the vicinity of Ellendale school and especially to the south, sillimanite nodules are observed in a massive biotite gneiss which contains a small amount of chlorite. The sillimanite nodules here attain a size of 1 by 2 inches and have been partly replaced by sericite.

Casar Area

In the northern part of Cleveland County, east and northeast of Casar, there is a zone of sillimanite about 3 miles wide and 6 miles long. At several points in this zone sillimanite is more concentrated than throughout the zone as a whole. Two of these points are along the road, between Toluca and Casar. One is near the

Baptist Church at the eastern edge of the zone, and the other is about 2,000 feet southeast of Olive Grove. The sillimanite consists of felted or matted fibers in gray sericite schist. It is difficult to estimate the percentage of sillimanite in the rock but it appears to be greater than 10 per cent. However, it was noted that the outcrop specimens contained altered sillimanite. This altered material is white in color and can be scraped off with a knife.

In the deeply weathered parts of the Casar Area, especially in cultivated fields, there is an accumulation of sillimanite bundles which have been stained red by iron oxides of the associated soils. These nodules differ from those in the Prospect Ridge area in that they are smaller, and the sillimanite is fibrous rather than blady. Locally they comprise about 10 per cent of the total mass of the top soil. East of Casar several fields contain nodules averaging 1/2 inch in length and reaching a maximum of 2 inches.

Cliffside Area

In the extreme southern part of Rutherford County there is a zone of sillimanite schist about two miles long and about 1/2 mile wide. It is best exposed along U. S. Highway 221-A, just north of the spur track of the Carolina, Clinchfield, and Ohio Railroad leading to the Duke Power Company's plant on the Broad River near Cliffside. The sillimanite along the east bank of the highway appears to have replaced a fractured quartzite. The major concentration is along the fracture planes and the sillimanite is of the fibrous type. Even in the best exposures the sillimanite has been altered to a soft clay-like white mineral. The writers are of the opinion that this alteration is hydrothermal in nature and, therefore, will extend to depth.

Most of the other outcrops in the surrounding areas of the southern part of the Cliffside-Elkin zone also show signs of having been altered by hydrothermal solutions. This alteration generally produced sericite or clay-like minerals.

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PLATE 2

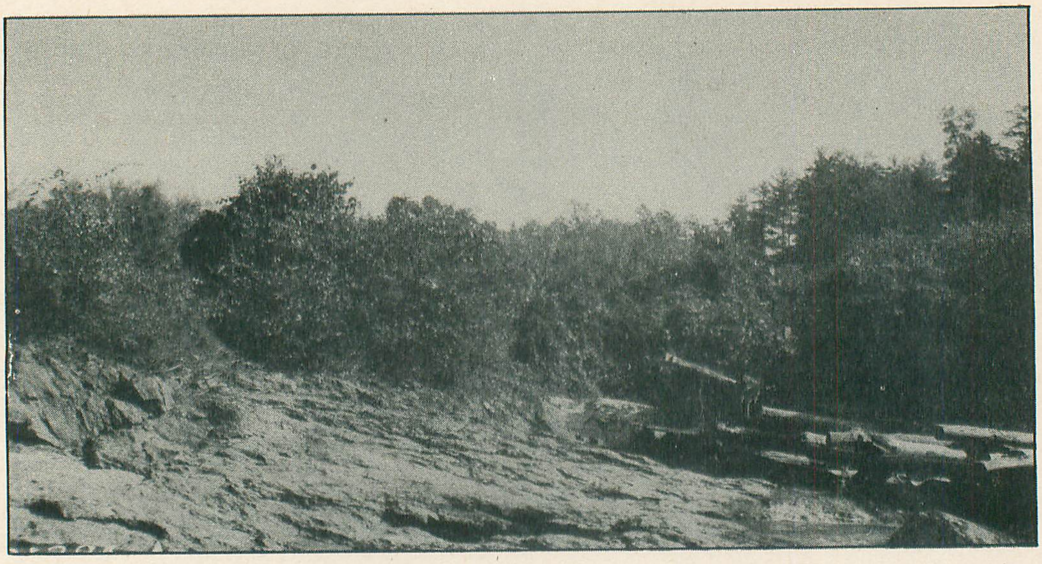

Figure A. Hard rock outcrop of sillimanite showing thrust faulting on Gunpowder Creek, Caldwell County, North Carolina.

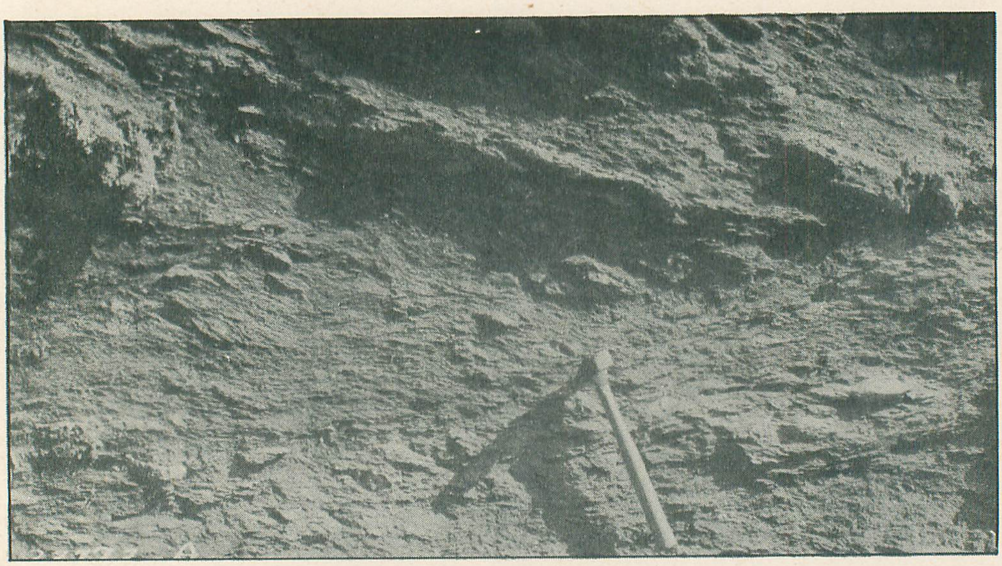

Figure B. Weathered outcrop of sillimanite showing thrust faulting on Laurel Creek, Burke County, North Carolina.

PLATE 3

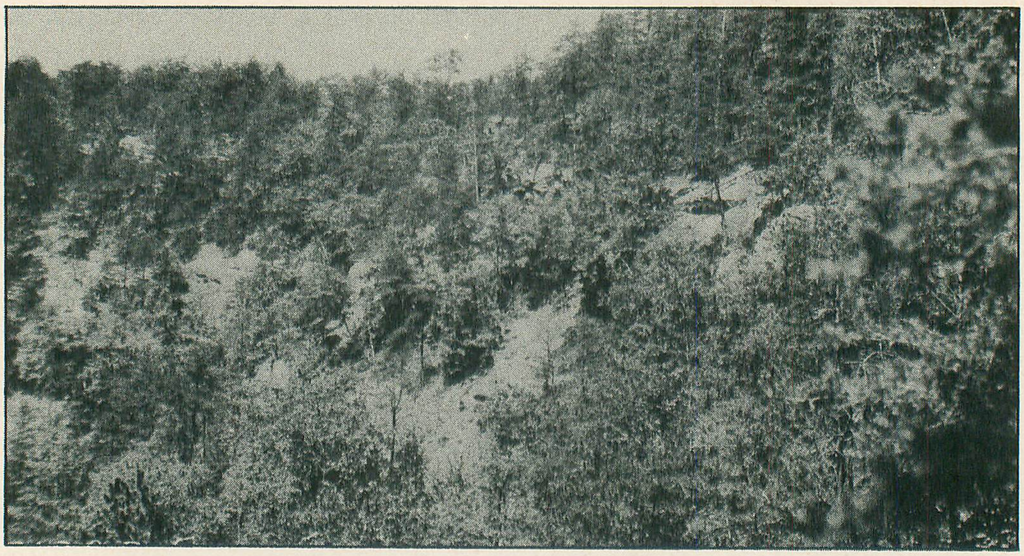

Figure A. Sillimanite outcrops in Smith Cliff on Prospect Ridge, Burke County, North Carolina.

Figure B. Bundles of sillimanite in schists on Prospect Ridge, Burke County, North Carolina.

PLATE 4

Figure A.

Bundles of sillimanite crystals weathered free from schist in Prospect Ridge Area of Burke County

Figure B.

Three inch bundle of crossed sillimanite crystals split and the top half fired

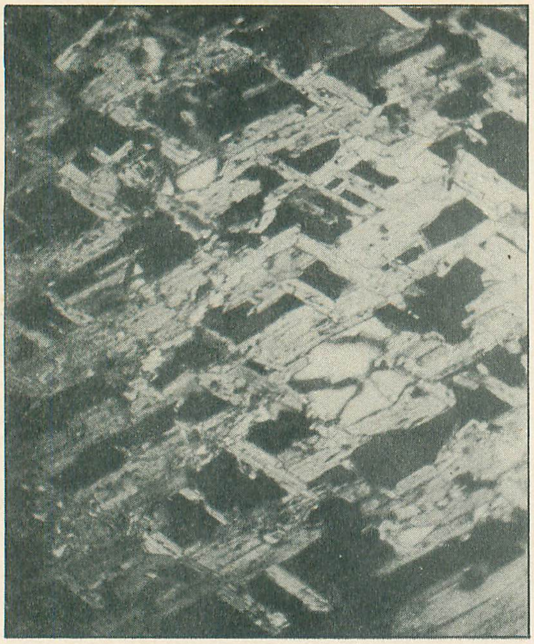

Figure W-1

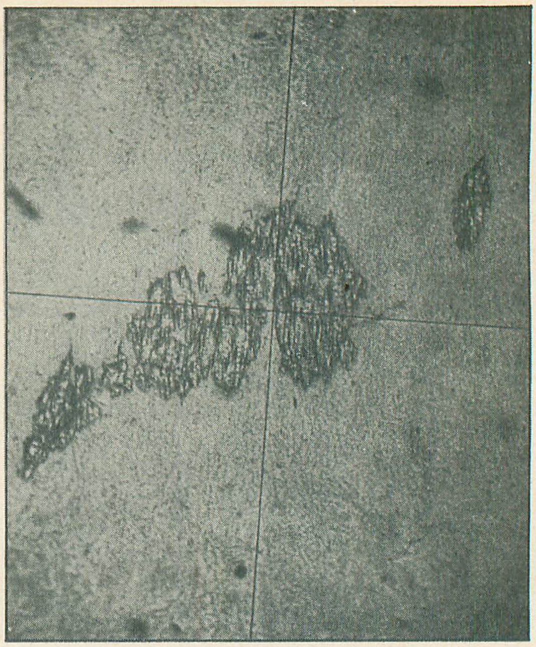

Figure W-2

Figure W-3

Figure W-4

Figure W-1. Muscovite (light) replacing quartz (dark) along conjugate shears, X 45, X nicols.

Figure W-2. Sericite (ground mass) replacing sillimanite (high relief), X 45.

Figure W-3. Sillimanite (small euhedra) replacing sericite (ground mass), X 45.

Figure W-4. Sericite (colorless wisps) replacing sillimanite (large colorless grains with pronounced cross fractures) and biotite (dark), X 45.