STUDIES RELATED TO WILDERNESS

MINERAL RESOURCES OF THE CRAGGY MOUNTAIN WILDERNESS STUDY AREA AND EXTENSION, BUNCOMBE COUNTY, NORTH CAROLINA

GEOLOGICAL SURVEY BULLETIN 1515

Mineral Resources of the Craggy Mountain Wilderness Study Area and Extension, Buncombe County, North Carolina

By F. G. LESURE *and* A. E. GROSZ, U.S. GEOLOGICAL SURVEY,
and by B. B. WILLIAMS *and* G. C. GAZDIK, U.S. BUREAU OF MINES

STUDIES RELATED TO WILDERNESS—WILDERNESS AREAS

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An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, and as specifically designated by PL 93-622, January 3, 1975, the U.S. Geological Survey and U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are presently being studied. The Act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This report discusses the results of a mineral survey of national forest land in the Craggy Mountain Wilderness Study Area and Extension, North Carolina, that is being considered for wilderness designation (Public Law 93-622, January 3, 1975). The area studied is in the Pisgah National Forest in Buncombe County.

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MINERAL RESOURCES OF THE CRAGGY MOUNTAIN WILDERNESS STUDY AREA AND EXTENSION, BUNCOMBE COUNTY, NORTH CAROLINA

By F. G. LESURE and A. E. GROSZ, U.S. Geological Survey,
and
B. B. WILLIAMS and G. C. GAZDIK, U.S. Bureau of Mines

SUMMARY

The Craggy Mountain Wilderness Study Area includes about 550 hectares of steep forested ridges in the Blue Ridge Mountains of western North Carolina. An adjoining 518 hectares called the Craggy Mountain Extension has been added along the west side of the original area. The combined areas include the upper drainage basin of Carter Creek above the mouth of Peach Orchard Creek and the east half of the Mineral Creek drainage basin on the steep western slope of the Great Craggy Mountains in the Pisgah National Forest in Buncombe County. Bedrock is mostly mica-garnet schist, much of which contains kyanite, interlayered with quartz-biotite gneiss; a few layers of amphibolite and a few dikes of trondhjemite and granitic pegmatite are poorly exposed near the study area.

No metallic mineral resources have been identified in or near the study area. Reconnaissance geochemical surveys, including analyses of stream sediments, soil, rock samples, and panned concentrates, show no obvious anomalous values for 30 elements.

Kyanite and garnet in the mica schist are considered hypothetical submarginal resources, the kyanite for refractory use and the byproduct garnet for abrasive use.

Most of the rock types are suitable for use as crushed stone or rough building stone; however, adequate resources of stone are available in the general area in more favorable locations.

Natural gas may possibly be present at great depth.

INTRODUCTION

The Craggy Mountain Wilderness Study Area includes about 550 ha (hectares) of the Pisgah National Forest in the Blue Ridge Mountains of western North Carolina (fig. 1). The Craggy Mountain Extension, 518 ha, adjoins the Wilderness Study Area on the west. This area was added in 1978 during the U.S. Forest Service's second Roadless Area Review and Evaluation, known as RARE II. The combined areas are 21 km (kilometers) northeast of Asheville, Buncombe County, N.C.,

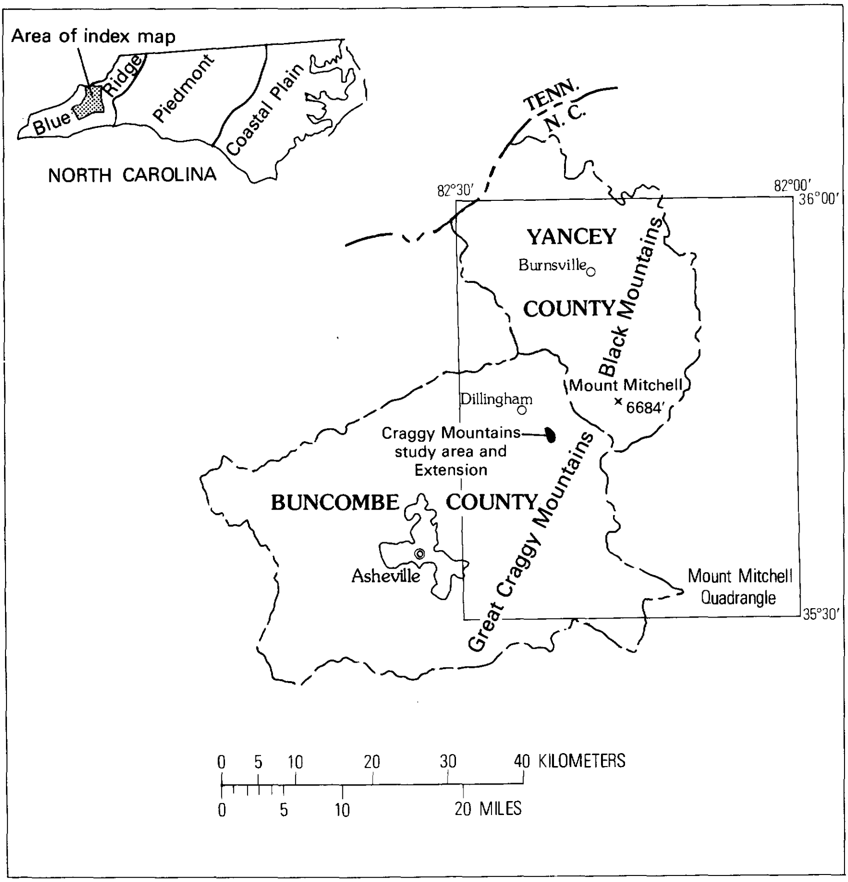

FIGURE 1.–Index map showing location of the Craggy Mountain Wilderness Study Area and Extension and the old Mount Mitchell 30-minute Quadrangle, North Carolina (Keith, 1905).

and 11 km southwest of Mount Mitchell, the highest point in eastern North America. The study area is bounded on the southeast by the Blue Ridge Parkway, on the northeast by Bullhead Ridge, and on the southwest and west by the road along Mineral Creek (pl. 1*B*). The wilderness study area includes all of the Craggy Mountain Scenic Area established by the Forest Service in 1961 and some additional land west of Bearwallow Branch and along the middle part of Carter Creek for a short distance beyond the mouth of Peach Orchard Creek.

The study area is on the northwest slope of the Great Craggy Mountains, a south-trending extension of the Black Mountains, of which Mount Mitchell is a part (fig. 2). The hillsides are steep and wooded. Altitudes range from a low of 768 m (meters) above sea level on Carter

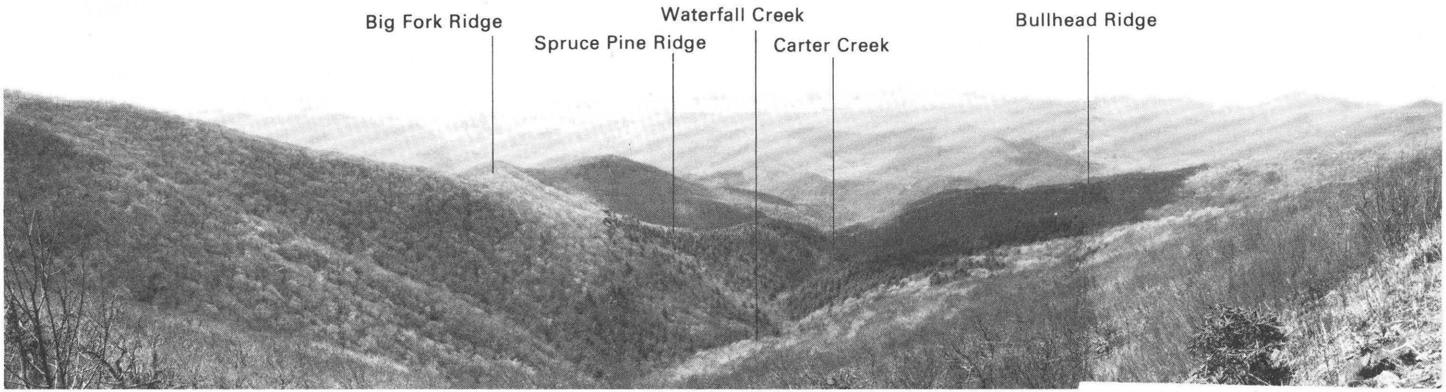

FIGURE 2.–Panorama of the Craggy Mountain study area, taken from the Blue Ridge Parkway, looking northwest.

FIGURE 3. – Upper falls of Waterfall Creek, Craggy Mountain study area. Above the falls, the stream flows along a foliation surface in interlayered mica schist and gneiss.

Creek to 1,796 m above sea level on Craggy Pinnacle. The average vertical rise is about 190 m per kilometer, a slope of 11°. Many of the slopes, however, are between 30° and 40°. The waterfalls on Waterfall Creek are the most notable physical features. The upper falls (fig. 3) drop free for more than 20 m; the lower falls are equally spectacular, being flanked by tens of meters of nearly vertically walled gorge.

Access to the study area is by foot from the Blue Ridge Parkway on the southeast, from the Big Ivy or Walker Ridge Road (U.S. Forest Service Road, FSR 74) on the northeast, from an unnamed road along Carter Creek at the north end, and from the road up Mineral Creek on the west. A trail is blazed from the visitor center at Craggy Gardens on the Blue Ridge Parkway across the steep head of the Carter Creek drainage to the upper waterfall on Waterfall Creek and from there to the parking lot at the end of FSR 74. Most of the area has no trails, but the woods are generally open enough for easy hiking, except in a few areas of dense rhododendron. Parts of Waterfall Creek, however, are steep and dangerous.

PREVIOUS WORK

Arthur Keith made the earliest study of the geology of the area while mapping the Mount Mitchell Quadrangle (Keith, 1905). He mapped the rocks as part of his Carolina Gneiss. Hadley and Nelson (1971) made a reconnaissance study of the area during the mapping of the Knoxville 2-degree Quadrangle and included the rocks in their Great Smoky Group, undivided (pl. 1*A*).

PRESENT WORK

Williams and Gazdik conducted field investigations for the U.S. Bureau of Mines in May 1976. During this time, rock samples and panned concentrates were collected for analyses, and several nearby mines and prospects outside the study area were examined. Gazdik and V. P. Girol spent several days looking at the Craggy Mountain Extension in spring 1979 and collected eight additional rock samples and one panned concentrate. The samples were analyzed by the U.S. Bureau of Mines, Reno Metallurgy Research Center, Reno, Nev.

During 5 days in October 1976, Lesure and Grosz mapped the geology and collected stream-sediment and rock samples for trace-element analyses. They spent an additional 3 days field checking the area in April 1977 and 5 days more studying the extension in March 1979. All their samples were analyzed in the U.S. Geological Survey laboratories in Denver, Colo. A few additional analyses were made at U.S. Geological Survey laboratories in Reston, Va.

SURFACE AND MINERAL OWNERSHIP

All surface and mineral rights are held by the U.S. Forest Service. Although prospecting and mining development permits are granted in Pisgah National Forest, no outstanding permits exist within the study area, nor is there any record of permits having been granted in the past.

ACKNOWLEDGMENTS

We wish to thank Leonard Wiener and Carl Merschat, North Carolina Division of Land Resources, Department of Natural Resources and Community Development, for helpful discussions of the geology of the general area. Cooperation of the U.S. Forest Service and the National Park Service in providing information and assistance is gratefully acknowledged.

GEOLOGY

The Craggy Mountain Wilderness Study Area and Extension contains high-grade regionally metamorphosed sedimentary rocks, possibly equivalent to the Great Smoky Group of Proterozoic age. Mica-garnet schist, locally containing abundant kyanite and sillimanite, is interlayered with biotite-quartz-garnet gneiss and scarce layers of amphibolite. A few small feldspar-quartz-mica pegmatite dikes and sills and quartz pods and veins intrude the schist and gneiss. A small trondhjemite dike cuts the gneiss on the Walker Ridge Road (FSR 74) on Bullhead Ridge, and similar dikes may be expected in the study area.

MICA-GARNET SCHIST

Mica-garnet schist, generally containing kyanite, is the most common rock type in the study area. The schist is a gray roughly equigranular well-foliated rock that contains conspicuous light pink crystals of garnet. Other minerals in decreasing order of abundance are quartz, feldspar, sillimanite, ilmenite, and graphite; some layers also contain iron sulfides.

Biotite is the more abundant of the two micas, biotite and muscovite, commonly present (table 1). The biotite content is 10–45 percent; muscovite, 5–30 percent. The average mica flake is about 1–3 mm across. Parallel orientation of the mica flakes produces the well-defined foliation and layering.

The garnet content of the schist ranges from a trace to 28 percent. The pale-pink garnet is a mixture of about 66–73 percent almandine ($Fe_3Al_2Si_3O_{12}$), 17–27 percent pyrope ($Mg_3Al_2Si_3O_{12}$), and smaller amounts of spessartine, grossular, and andradite (table 7). The crystals, 1–5 mm in diameter, are commonly well formed, but most contain inclusions of other minerals, such as quartz, mica, and graphite. Locally, garnet crystals form layers several centimeters thick in gneiss or schist, but most of the garnets are disseminated throughout the rock.

Kyanite, partly altered to sillimanite, forms a trace to as much as 25 percent of the schist. Many layers of schist several meters thick may be 10–15 percent kyanite. The kyanite crystals, which are 1–10 mm long, are irregular and poorly formed. Many contain inclusions of other minerals.

Quartz and feldspar form thin layers of irregular ragged grains that are generally finer than much of the micas, garnet, or kyanite. Quartz is probably more abundant than feldspar. The feldspar is mostly plagioclase.

Sillimanite partly replaces kyanite and is intergrown with micas and other minerals. Sillimanite is more abundant in the rocks towards the southeast part of the study area but is everywhere less abundant than

TABLE 1.—*Mineral composition of kyanite-bearing schist from the Craggy Mountain area, Buncombe County, N.C., compared with the composition of kyanite-rich gneiss from the Celo kyanite mine, Yancey County, N.C.*

[Composition was determined by heavy-liquid and magnetic-mineral-separation methods. Samples were crushed and sieved to pass 18 mesh (1 mm) and rest on 200 mesh (0.074 mm). Locations for Craggy Mountain samples shown on pl. 1*C*. Celo Mine location shown on pl. 1*A*]

Sample No	NCC 015	NCC 027	NCC 030	NCC 041	NCC 052	NCC 057	NCC 060
Sample weight (in grams)	90	57	22	88	150	50	120
			Weight percent				
Kyanite	21	21	4	9	19	18	8
Sillimanite	3	----	.5	5	.5	--	tr (?)
Garnet	28	19	8	9	10	5	13
Biotite	13	28	43	36	40	36	27
Muscovite	5	18	30	14	12	3	8
Quartz and feldspar	28	14	14	24	17	38	44
Graphite	1	----	----	1.5	.5	----	----
Iron sulfides	1	----	----	1	1	----	----
Opaque minerals	----	tr	.5	tr	tr	tr	tr
Specific gravity	3.23	2.97	2.95	2.85	3.07	2.93	3.02
Al_2O_3[1]	34	24	28	28	----	----	----

[1]In percent, determined by X-ray methods by A. E. Hubert, U.S. Geological Survey.

Sample descriptions

NCC 015–1-m chip sample, garnet-kyanite-mica schist.
NCC 027–1-m chip sample, biotite-kyanite-garnet schist.
NCC 030–2-m chip sample, mica-garnet schist.
NCC 041–3-m chip sample, biotite-garnet schist.
NCC 052–1-m chip sample, biotite-kyanite-garnet schist.
NCC 057–2-m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey County, N.C.; sample from area of channel sample D23 of Chute (1944).
NCC 060–2-m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey County, N.C.; sample from area of channel sample A2 of Chute (1944).

kyanite. The needlelike crystals of sillimanite generally form mats or bundles and are the form of the mineral commonly termed fibrolite. Individual crystals are a millimeter or less long, but crystal bundles may be as long as a centimeter.

Accessory minerals include graphite, which forms bright platelike crystals; zircon, which forms small rounded crystals; and ilmenite and other opaque minerals. Iron sulfides, which are found in about half the schist samples, are present from a trace to as much as 1 percent of the rock. Schist in the eastern and southern part of the area contains more iron sulfide than that in the northern and western part (pl. 1*C*).

Layers of schist range in thickness from 0.3 to several meters. Outcrops are not continuous enough for good estimates to be made of the strike length of individual schist layers.

QUARTZ-BIOTITE GNEISS

Thick massive layers of quartz-biotite gneiss, or metasandstone, are interlayered with mica-garnet schist, much of which contains kyanite, throughout the Craggy Mountain area. Gneiss is probably as abundant as schist but is not as well exposed, except along roadcuts. The gneiss is medium to light gray and fine grained. It is composed mostly of quartz, plagioclase feldspar, and biotite. Accessory minerals include muscovite, garnet, ilmenite, graphite, and possibly sillimanite. Grain size is generally 1 mm or less. Layers of gneiss are commonly 0.3–2 m thick. Locally, gneiss units 3–15 m thick are interlayered with thinner units of schist.

The gneiss and schist are undoubtedly a metamorphosed sedimentary-rock sequence of interlayered fine-grained feldspathic sandstones and clay-rich shales or mudstones (table 2).

AMPHIBOLITE

The mica schist and gneiss sequence contains rare lenses and thin layers of hornblende-feldspar gneiss or amphibolite. Amphibolite is poorly exposed in a narrow belt north of Big Fork Knob and along the west slope of Sawmill Branch, as mapped by Keith (1905). Some smaller masses of amphibolite are poorly exposed along Carter Creek about 300 m below the junction with Peach Orchard Creek. A layer of amphibolite about 2–3 m thick is exposed in the streambed in the upper reaches of Waterfall Creek just west of Bullhead Gap.

The amphibolite is composed mostly of hornblende and plagioclase in about equal amounts and contains a few percent garnet, quartz, and opaque minerals. Minor accessory minerals are biotite, zircon, and sphene. The rock is the metamorphosed equivalent of a basalt sill or flow.

PEGMATITE

A few medium-grained dikes of quartz-feldspar-biotite and quartz-feldspar-muscovite pegmatite are exposed in roadcuts along the Blue Ridge Parkway (fig. 4), and several large masses of finer grained quartz-feldspar pegmatite are poorly exposed along the Mineral Creek road and the road up Walker Creek (FSR 74). Most of the dikes are 0.3–2 m thick and probably less than 100 m long. Pegmatite appears to be more common along the Blue Ridge Parkway and to the east and less common within the study area; this apparent difference may be due merely to better exposures in the roadcuts along the parkway.

Within the study area no outcrops of pegmatite were seen, but fine-grained quartz-feldspar-muscovite pegmatite float was noted in several places. The approximate locations of pegmatite float and outcrop are

TABLE 2.—*Chemical composition, in percent, of typical schist and gneiss from the Craggy Mountain area, Buncombe County, N.C., compared with schist and gneiss from the Celo kyanite mine, Yancey County, N.C., and an average pelite (shale) from the Great Smoky Group and an average graywacke (sandstone)*

[Analyses made by single solution methods (U.S. Geological Survey Bulletin 1401) in U.S. Geological Survey laboratories, Reston, Va., by Z. A. Hamlin, Hezekiah Smith, and F. W. Brown. Locations for Craggy Mountain samples are shown on plate 1*C*; Celo mine location is shown on plate 1*A*]

Laboratory No. / Field No	W-195712 NCC 015	W-195713 NCC 041	W-195715 NCC 056	W-195716 NCC 057	W-195717 NCC 058	W-195719 NCC 060	Average pelite, Great Smoky Group[1]	W-195714 NCC 055	W-195718 NCC 059	Average Graywacke[2]
SiO_2	43.5	50.6	52.5	54.5	54.3	57.9	53.96	70.4	78.4	66.7
Al_2O_3	29.9	24.2	25.0	24.6	24.0	21.0	24.23	12.8	10.9	13.5
Fe_2O_3	6.6	3.1	1.7	1.8	1.7	1.4	1.73	1.2	1.0	1.6
FeO	5.8	7.4	7.7	7.6	7.6	7.2	3.65	4.9	2.2	3.5
MgO	3.9	3.6	3.0	2.9	2.9	2.8	1.93	2.2	.83	2.1
CaO	3.0	1.6	1.7	1.5	1.7	1.8	.39	1.9	2.2	2.5
Na_2O	2.4	1.3	2.1	1.8	2.0	2.2	1.33	2.1	2.3	2.9
K_2O	1.1	3.8	3.7	3.5	3.3	2.8	6.11	2.5	.83	2.0
H_2O^+	1.3	1.8	1.2	1.1	1.5	1.2	3.61	.94	.31	2.4
H_2O^-	.50	.61	.34	.34	.37	.31	--	.36	.27	.6
TiO_2	1.3	1.3	1.0	.98	1.0	.96	.87	1.2	.66	.6
P_2O_5	.24	.22	.32	.29	.32	.33	.19	.18	.12	.2
MnO	.24	.17	.11	.12	.13	.12	.32	.05	.06	.1
CO_2	.02	.00	.01	.00	.01	.01	----	.01	00	1.2
SO_3	----	----	----	----	----	----	----	----	----	.3
S	1.0	.94	.34	.22	.25	.20	.73	.02	.02	.1
C	----	----	----	----	----	----	.95	----	----	.1
Total	101	101	101	101	101	100	100.00	101	100	100.4

[1]Hadley and Goldsmith (1963, table 9, p. B45).
[2]Pettijohn (1963, table 12, p. S15).

Sample descriptions

NCC 015—1-m chip sample, garnet-kyanite-mica schist from study area (pl. 1*C*).
NCC 041—3-m chip sample, biotite-garnet schist from study area (pl. 1*C*).
NCC 056—1-m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey County, N.C.; sample from area of channel sample E24 of Chute (1944).
NCC 057—2-m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey County, N.C.; sample from area of channel sample D23 of Chute (1944).
NCC 058—1-m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey County, N.C.
NCC 060—2-m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey County, N.C.; sample from area of channel sample A2 of Chute (1944).
NCC 055—2-m chip sample, biotite-quartz gneiss (pl. 1*C*).
NCC 059—1-m chip sample, feldspathic quartzite, Celo kyanite mine, Yancey County, N.C.

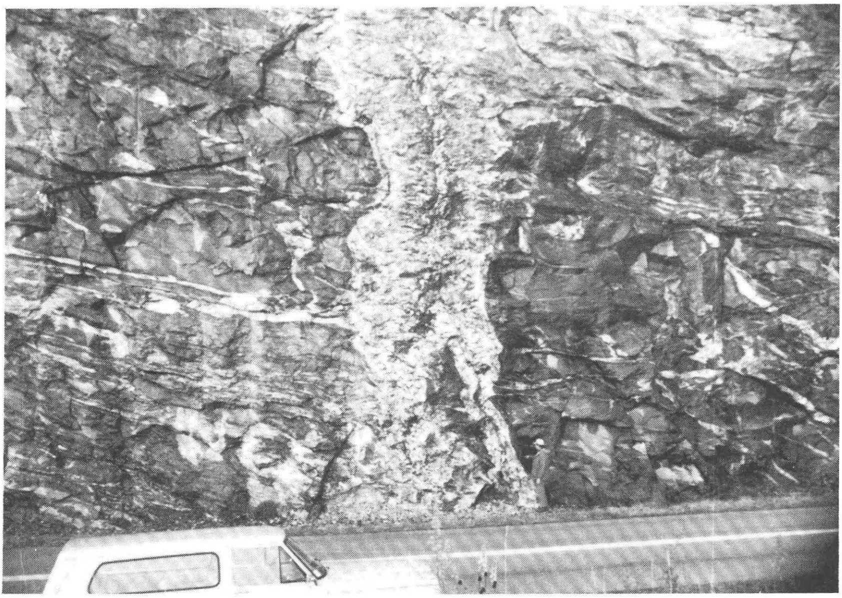

FIGURE 4. – Irregular granitic pegmatite dike cutting mica gneiss in a roadcut on the Blue Ridge Parkway, 0.5 km south of Pinnacle Gap, N.C.

indicated on plate 1*B* by letter symbol. Some of the float in the study area contains muscovite crystals 2–5 cm across. The mica is generally cracked, bent, and mineral stained; it is of scrap quality only.

QUARTZ VEINS

Numerous small boulders and a few scattered outcrops of massive quartz pods and veins in schist and gneiss were seen throughout the study area. The quartz is generally white to light gray and contains minor amounts of feldspar or mica. No metallic minerals were seen in quartz veins or float. The quartz was probably derived from the country rock during metamorphism.

TRONDHJEMITE

A small dike of light-colored trondhjemite or quartz diorite is exposed along the road up Walker Branch (FSR 74), just outside the study area on the slope of Bullhead Ridge. The dike is about 0.3 m thick and at least 32 m long. It is light gray and fine grained. Abundant zoned crystals of plagioclase 0.5–2.5 mm across are enclosed in a fine-grained (0.1–0.2 mm) matrix of plagioclase, quartz, muscovite, and biotite. The dike cuts the layering in a biotite schist that contains contorted plagioclase-quartz-biotite pegmatite. No similar dike was seen in the study area, but Hadley and Nelson (1971) showed many trondhjemite dikes just west of the study area. Similar dikes are also common in the eastern Great Smoky Mountains (Hadley and Goldsmith, 1963, p. 71–72).

STRUCTURE

Foliation and layering are conspicuous features in most outcrops in the area. In general, foliation is parallel to layering. Locally, foliation has been folded into low-plunging chevron folds (fig. 5). Throughout much of the area, foliation and layering strike north or northeast and dip west. Near Craggy Pinnacle, the dip is east, suggesting a minor fold plunging northeast. Major faults or shear zones are not obvious. The lack of distinctive stratigraphic units prevents a more detailed structural analysis.

METAMORPHISM

The rocks of the Craggy Mountain study area were originally interbedded sandstone and clay-rich shale, intruded by a few basalt sills or dikes. These rocks were metamorphosed under conditions of high temperature and pressure during a period of regional metamorphism in the Paleozoic Era. They occur within the sillimanite isograd, so that rocks having the appropriate alumina-rich composition contain sillimanite. The kyanite, which is metastable or which may be coexisting with sillimanite along a two-phase boundary, probably formed

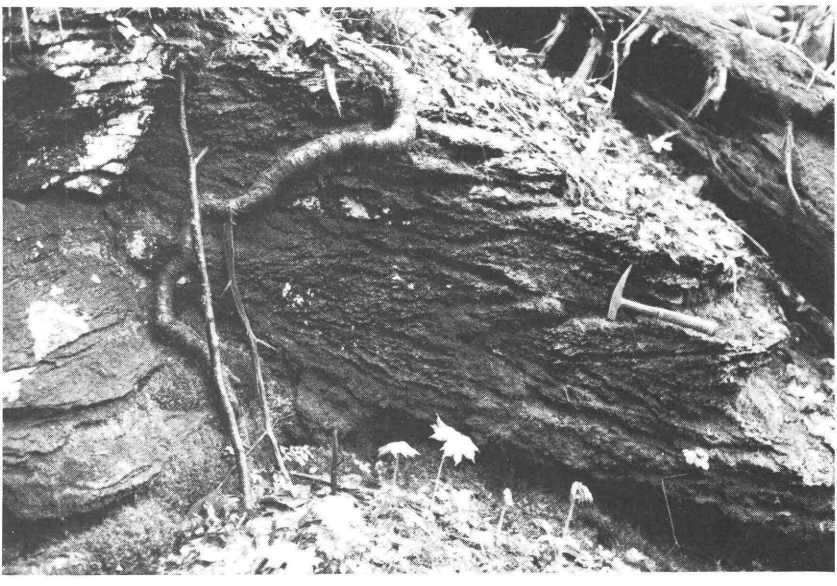

FIGURE 5.–Chevron folds in mica-garnet schist near the upper falls on Waterfall Creek.

during the course of metamorphism before the conditions for sillimanite were reached.

GEOCHEMICAL SURVEY

SAMPLING AND ANALYTICAL TECHNIQUES

Reconnaissance geochemical sampling of the Craggy Mountain study area was done to find indistinct or unexposed mineral deposits that might be recognized by their geochemical halos. No metallic deposits are reported to be in the study area, and none were found during the reconnaissance geologic mapping. The geochemical samples consisted of 30 bulk samples of stream sediments, 18 panned concentrates, 20 soil samples, and 65 rock samples, all collected by the U.S. Geological Survey (pl. 1*C*). In addition, the U.S. Bureau of Mines collected 25 rock samples and three panned concentrates (pl. 1*C*).

We sampled small drainage basins within the study area by collecting a few handfuls of the finest sediment possible. In addition, Grosz panned a concentrate of the heavier minerals in the sand-size fraction at 18 of the bulk stream-sediment sample sites. The bulk sediment samples were dried and sieved in the laboratory, and the analysts used the minus 80-mesh (0.177 mm) fractions. The 18 panned concentrates were studied microscopically to determine mineral content. Ten of the panned concentrates were further separated by heavy liquids, and the magnetic and nonmagnetic heavy fractions were analyzed.

The rock samples are representative of the major rock types exposed in the area. None are obviously mineralized, although most of the schist samples are rich in alumina. Almost half the mica schist samples contain iron sulfides in amounts ranging from a trace to several percent.

All rock, soil, and bulk stream-sediment samples were analyzed by semiquantitative emission spectrographic methods for 30 elements and chemically for gold and zinc in the U.S. Geological Survey laboratories, Denver, Colo. Magnetic and nonmagnetic fractions of the 10 selected panned concentrates were analyzed spectrographically for 30 elements. Table 3 summarizes the results; for complete analytical data, see Motooka and others (1978) and Motooka and others (1980).

Bureau of Mines samples were analysed at the Reno Metallurgy Research Center, Reno, Nev. Testing included semiquantitative spectrographic analyses for 42 elements on 26 samples, fire assay for gold and silver on 15 samples (table 4), and petrographic determination of kyanite and garnet on 6 samples (table 6).

RESULTS

Only normal background values of the elements tested for were found in the rock, soil, and stream-sediment samples (table 3). No

TABLE 3.—*Range and median values for 24 elements in rock, soil, and stream sediment samples from the Craggy Mountain Wilderness Study Area and Extension, Buncombe County, N.C.*

[All analyses by semiquantitative spectrographic methods by J. M. Motooka and J. A. Domenico, U.S. Geological Survey, except gold and zinc, which are by atomic absorption by J. D. Sharkey and A. L. Meier, U.S. Geological Survey. Spectrographic analyses are reported as six steps per order of magnitude (1, 0.7, 0.5, 0.3, 0.2, 0.15, or multiples of 10 of these numbers) and are approximate midpoints of the concentration ranges. The precision is shown to be within one adjoining reporting interval on each side of reported values 83 percent of the time and within two adjoining intervals on each side of the reported value 96 percent of the time (Motooka and Grimes, 1976). Letter symbols: L, detected but below limit of determination (value shown in parenthesis after element symbol); N, not detected; >, greater than. Elements looked for spectrographically but not found and their limits of determination, in parts per million (in parentheses): As (200), Au (20), Bi (10), Cd (20), Sb (100), Sn (10), and W (50)]

Elements	Rocks						
	Schist						Shale
	18 samples without sulfides			15 samples with sulfides			Average [1]
	Low	High	Median	Low	High	Median	
	Percent						
Ca (0.05)	0.07	1.5	0.5	0.07	1.5	0.5	2.2
Fe (0.05)	5	15	7	3	15	10	4.7
Mg (0.02)	1.5	2	1.5	1	2	1.5	1.5
Ti (0.002)	.3	1	.5	.3	1	.7	.46
	Parts per million						
Ag (0.5)	N	N	N	N	L	N	0.07
Au (0.5)	N	L	N	N	L	N	[3].00X
B (10)	L	20	L	L	20	L	100
Ba (20)	300	1,500	700	300	1,000	700	580
Be (1)	N	3	1.5	N	3	1	3
Co (5)	7	50	20	15	70	20	19
Cr (10)	50	150	70	50	150	70	90
Cu (5)	5	70	30	15	150	50	45
La (20)	50	200	100	50	150	100	92
Mn (10)	1,000	>5,000	1,500	700	5,000	1,500	850
Mo (5)	N	N	N	N	5	N	2.6
Nb (20)	L	20	L	N	20	L	11
Ni (5)	10	50	30	15	70	30	68
Pb (10)	L	30	20	L	30	15	20
Sc (5)	15	30	20	10	30	20	13
Sr (100)	N	500	150	N	700	150	300
V (10)	70	200	150	70	200	150	130
Y (10)	50	100	70	30	100	70	26
Zn (5)	30	120	90	10	130	80	95
Zr (10)	100	300	150	100	300	150	160

See footnotes at end of table.

metallic-mineral deposits of economic importance are known in rocks of this type within a radius of several tens of kilometers of the study area. Traces of gold in 26 rock, 10 soil, and 13 stream-sediment samples from the study area and traces of silver in 12 rock samples and 2 stream-sediment samples (table 4; pl. 1*D*), are not considered significant. No other unusual concentration of metallic elements was found in the samples analyzed.

TABLE 3.—*Range and median values for 24 elements in rock, soil, and stream sediment samples from the Craggy Mountain Wilderness Study Area and Extension, Buncombe County, N.C.*—Continued

[All analyses by semiquantitative spectrographic methods by J. M. Motooka and J. A. Domenico, U.S. Geological Survey, except gold and zinc, which are by atomic absorption by J. D. Sharkey and A. L. Meier, U.S. Geological Survey. Spectrographic analyses are reported as six steps per order of magnitude (1, 0.7, 0.5, 0.3, 0.2, 0.15, or multiples of 10 of these numbers) and are approximate midpoints of the concentration ranges. The precision is shown to be within one adjoining reporting interval on each side of reported values 83 percent of the time and within two adjoining intervals on each side of the reported value 96 percent of the time (Motooka and Grimes, 1976). Letter symbols: L, detected but below limit of determination (value shown in parenthesis after element symbol); N, not detected; >, greater than. Elements looked for spectrographically but not found and their limits of determination, in parts per million (in parentheses): As (200), Au (20), Bi (10), Cd (20), Sb (100), Sn (10), and W (50)]

Elements	Rocks						
	Gneiss			Sandstone	Quartz		
	16 samples			Average[1,2]	8 samples		
	Low	High	Median		Low	High	Median
Ca (0.05)	0.3	2.0	0.7	3.9	L	2	0.2
Fe (0.05)	2	7	2.5	0.98	.07	2	.5
Mg (0.02)	.5	1.5	.7	.7	.02	.3	.05
Ti (0.002)	.2	.7	.5	.15	.003	.3	.018
			Parts per million				
Ag (0.5)	N	N	N	[3]0.0X	N	0.7	N
Au (0.05)	N	N	N	[3].00X	N	L	N
B (10)	L	20	L	20–30	N	L	N
Ba (20)	300	1,000	500	300	20	1,500	100
Be (1)	L	3	1	2	N	1	L
Co (5)	7	30	10	.3	N	L	N
Cr (10)	20	70	30	10–20	L	30	10
Cu (5)	N	30	10	10–20	N	30	10
La (20)	N	150	30	30	N	50	N
Mn (10)	500	5,000	700	500	20	500	125
Mo (5)	N	5	N	.2	N	N	N
Nb (20)	L	L	L	[3].X	N	N	N
Ni (5)	5	50	15	2	N	30	L
Pb (10)	N	50	13	9	N	200	L
Sc (5)	7	15	10	1	N	7	L
Sr (100)	100	1,000	180	20	N	300	N
V (10)	50	150	70	10–20	N	30	L
Y (10)	15	50	30	40	N	30	N
Zn (5)	30	80	40	16	N	20	5
Zr (10)	100	500	200	200–250	N	100	L

See footnotes at end of table.

RADIOMETRIC SURVEY

In addition to the geochemical survey, we collected data by means of a four-channel gamma-ray spectrometer at 0.1-mile intervals along the road paralleling Mineral Creek from Beetree Gap due north to Stony Creek (fig. 6). The spectrometer traverse crosses the strike of geologic contacts and characterizes lithologic types as a function of their spectral radiometric response. Although no unusual radioelement concentrations are in the area traversed (table 5), the concentration of thorium and, more significantly, the Th/K and Th/U ratios are characteristically larger in schist.

TABLE 3.—*Range and median values for 24 elements in rock, soil, and stream sediment samples from the Craggy Mountain Wilderness Study Area and Extension, Buncombe County, N.C.*—Continued

[All analyses by semiquantitative spectrographic methods by J. M. Motooka and J. A. Domenico, U.S. Geological Survey, except gold and zinc, which are by atomic absorption by J. D. Sharkey and A. L. Meier, U.S. Geological Survey. Spectrographic analyses are reported as six steps per order of magnitude (1, 0.7, 0.5, 0.3, 0.2, 0.15, or multiples of 10 of these numbers) and are approximate midpoints of the concentration ranges. The precision is shown to be within one adjoining reporting interval on each side of reported values 83 percent of the time and within two adjoining intervals on each side of the reported value 96 percent of the time (Motooka and Grimes, 1976). Letter symbols: L, detected but below limit of determination (value shown in parenthesis after element symbol); N, not detected; >, greater than. Elements looked for spectrographically but not found and their limits of determination, in parts per million (in parentheses): As (200), Au (20), Bi (10), Cd (20), Sb (100), Sn (10), and W (50)]

Elements	Streams sediments					
	Bulk			Panned concentrates		
	30 samples			Magnetic 10 samples		
	Low	High	Median	Low	High	Median
	Percent					
Ca (0.05)	0.3	1.0	0.6	0.7	1	1
Fe (0.05)	1.5	7	5	15	20	20
Mg (0.02)	.2	1.0	.5	1.5	1.5	1.5
Ti (0.002)	.3	>1	.7	.5	>1	1
	Parts per million					
Ag (0.5)	N	L	N	N	N	N
Au (0.05)	N	L	N	[4]N	[4]N	[4]N
B (10)	L	30	10	L	L	L
Ba (20)	300	1,000	500	50	100	70
Be (1)	L	3	1.5	N	L	L
Co (5)	7	50	20	20	50	30
Cr (10)	20	100	50	100	150	150
Cu (5)	5	70	20	L	15	8.5
La (20)	50	300	150	N	70	70
Mn (10)	1,000	3,000	2,000	>5,000	>5,000	>5,000
Mo (5)	N	N	N	N	N	N
Nb (20)	N	30	L	20	100	30
Ni (5)	10	50	20	L	20	10
Pb (10)	15	70	30	N	N	N
Sc (5)	7	15	15	70	100	100
Sr (100)	100	500	200	N	N	N
V (10)	30	200	100	150	150	100
Y (10)	30	100	70	300	500	300
Zn (5)	40	150	70	[4]N	[4]N	[4]N
Zr (10)	150	1,000	300	70	150	100

See footnotes at end of table.

TABLE 3.—*Range and median values for 24 elements in rock, soil, and stream sediment samples from the Craggy Mountain Wilderness Study Area and Extension, Buncombe County, N.C.* —Continued

[All analyses by semiquantitative spectrographic methods by J. M. Motooka and J. A. Domenico, U.S. Geological Survey, except gold and zinc, which are by atomic absorption by J. D. Sharkey and A. L. Meier, U.S. Geological Survey. Spectrographic analyses are reported as six steps per order of magnitude (1, 0.7, 0.5, 0.3, 0.2, 0.15, or multiples of 10 of these numbers) and are approximate midpoints of the concentration ranges. The precision is shown to be within one adjoining reporting interval on each side of reported values 83 percent of the time and within two adjoining intervals on each side of the reported value 96 percent of the time (Motooka and Grimes, 1976). Letter symbols: L, detected but below limit of determination (value shown in parenthesis after element symbol);, N, not detected; >, greater than. Elements looked for spectrographically but not found and their limits of determination, in parts per million (in parentheses): As (200), Au (20), Bi (10), Cd (20), Sb (100), Sn (10), and W (50)]

Elements	Stream sediments			Soil		
	Panned concentrates – Continued			20 samples		
	Nonmagnetic 10 samples					
	Low	High	Median	Low	High	Median
			Percent			
Ca (0.05)	0.05	0.15	0.07	L	0.7	0.08
Fe (0.05)	1.5	2	2	2	3	3
Mg (0.02)	.5	.7	.5	.2	1	.5
Ti (0.002)	.7	>1	>1	.3	1	.7
			Parts per million			
Ag (0.5)	N	N	N	N	N	N
Au (0.05)	[4]N	[4]N	[4]N	[5]N	[5]0.016	[5]L
B (10)	L	50	20	10	50	18
Ba (20)	70	200	125	150	700	700
Be (1)	L	10	L	L	3	3
Co (5)	5	10	7	L	30	18
Cr (10)	150	200	200	15	150	70
Cu (5)	L	15	7	15	70	50
La (20)	200	700	400	20	200	125
Mn (10)	200	500	300	200	3,000	500
Mo (5)	N	N	N	N	N	N
Nb (20)	20	70	25	N	30	L
Ni (5)	L	15	10	10	50	40
Pb (10)	L	10	L	20	70	50
Sc (5)	L	15	5	5	20	15
Sr (100)	N	N	N	N	500	L
V (10)	200	300	200	50	150	150
Y (10)	30	100	50	20	150	70
Zn (5)	[4]N	[4]500	[4]N	20	180	100
Zr (10)	200	>1,000	600	150	500	300

[1] Turekian and Wedepohl (1961).
[2] Pettijohn (1963, p. S11)
[3] Order of magnitude estimated by Turekian and Wedepohl (1961).
[4] Spectrographic analyses only, limit of determination: Au (20), Zn (200 ppm).
[5] Limit of determination, 0.002 ppm.

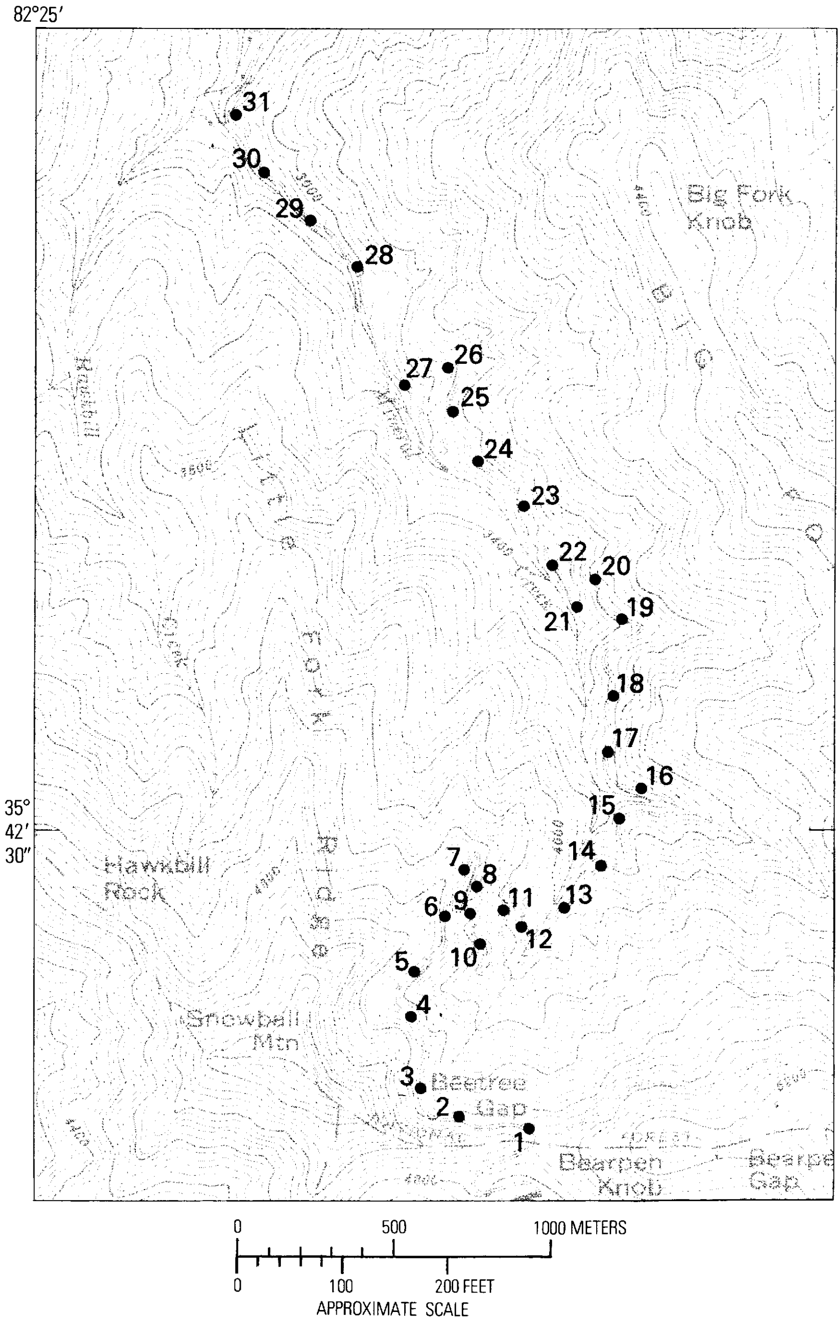

FIGURE 6.—Map of Mineral Creek Road, showing radiometric-survey localities. (For description of localities, see table 5.)

TABLE 4.—*Distribution of gold and silver in stream sediments, soil, and rock samples from the Craggy Mountain Wilderness Study Area and vicinity, Buncombe County, N.C.*

[Gold analyses by atomic absorption methods by J. D. Sharkey and A. L. Meier, U.S. Geological Survey; silver by semi-quantitative spectrographic analyses by J. M. Motooka and J. A. Domenico, U.S. Geological Survey, except sample NCC 015, for which silver is by computerized emission-spectrographic methods by L. Mei, U.S. Geological Survey, and samples NCC 314, 316, 827, 828, and 829, for which gold and silver are by fire-assay methods by U.S. Bureau of Mines, Reno Metallurgy Research Center, Reno, Nev. Three samples of quartz boulders, NCC 311, 315, and 318; four samples of quartz veins, NCC 306, 308, 310, and 319; and two panned concentrates, 301 and 302, were also tested by fire assay by the U.S. Bureau of Mines but contained no gold or silver. For sample locations see pl. 1*D*. Letter symbols: L, detected but below the limit of determination in parentheses; N, not detected at limit of detection. Limit of determination, in parts per million (ppm; in parentheses), varies with method used]

Sample	Gold (ppm)	Silver (ppm)	Sample descriptions
NCC 023	L (0.05)	N (0.5)	Bulk stream sediment
NCC 024	L (0.05)	N (0.5)	Do.
NCC 025	L (0.05)	N (0.5)	Do.
NCC 036	L (0.05)	N (0.5)	Do.
NCC 065	.002	N (0.5)	Do.
NCC 066	.01	N (0.5)	Do.
NCC 082	.006	N (0.5)	Do.
NCC 083	.002	N (0.5)	Do.
NCC 089	.004	N (0.5)	Do.
NCC 202	L (0.05)	N (0.5)	Do.
NCC 204	L (0.05)	N (0.5)	Do.
NCC 215	L (0.05)	N (0.5)	Do.
NCC 216	L (0.05)	N (0.5)	Do.
NCC 219	N (0.05)	L (0.5)	Do.
NCC 829	L (0.17)	6.9	Panned concentrate.
NCC 071	.002	N (0.5)	Soil.
NCC 077	.016	N (0.5)	Do.
NCC 078	.006	N (0.5)	Do.
NCC 080	.002	N (0.5)	Do.
NCC 088	L (0.002)	N (0.5)	Do.
NCC 103	L (0.002)	N (0.5)	Do.
NCC 107	.002	N (0.5)	Do.
NCC 108	.002	N (0.5)	Do.
NCC 112	.004	N (0.5)	Do.
NCC 114	L (0.002)	N (0.5)	Do.
NCC 004	L (0.05)	N (0.5)	1-m chip sample pegmatite.
NCC 008	N (0.05)	L (0.5)	1-m chip sample biotite-garnet schist containing iron sulfides.
NCC 009	L (0.05)	N (0.5)	Composite of several thin garnet-rich layers in schist.
NCC 011	N (0.05)	L (0.5)	1.5-m chip sample biotite-garnet schist containing iron sulfides.
NCC 012	L (0.05)	N (0.5)	1-m chip sample quartz-biotite gneiss.
NCC 015	N (0.05)	.18	1-m chip sample biotite-garnet schist containing iron sulfides.
NCC 041	N (0.05)	L (0.5)	3-m chip sample biotite-garnet schist containing iron sulfides.
NCC 042	N (0.05)	L (0.5)	2-m chip sample biotite-garnet schist containing iron sulfides.
NCC 047	L (0.05)	N (0.5)	1-m chip sample biotite-garnet schist.
NCC 052	L (0.05)	N (0.5)	1-m chip sample biotite-garnet schist containing iron sulfides.
NCC 053	L (0.05)	N (0.5)	2-m chip sample amphibolite.

TABLE 4.—*Distribution of gold and silver in stream sediments, soil, and rock samples from the Craggy Mountain Wilderness Study Area and vicinity, Buncombe County, N.C.*—Continued

[Gold analyses by atomic absorption methods by J. D. Sharkey and A. L. Meier, U.S. Geological Survey; silver by semi-quantitative spectrographic analyses by J. M. Motooka and J. A. Domenico, U.S. Geological Survey, except sample NCC 015, for which silver is by computerized emission-spectrographic methods by L. Mei, U.S. Geological Survey, and samples NCC 314, 316, 827, 828, and 829, for which gold and silver are by fire-assay methods by U.S. Bureau of Mines, Reno Metallurgy Research Center, Reno, Nev. Three samples of quartz boulders, NCC 311, 315, and 318; four samples of quartz veins, NCC 306, 308, 310, and 319; and two panned concentrates, 301 and 302, were also tested by fire assay by the U.S. Bureau of Mines but contained no gold or silver. For sample locations see pl. 1*D*. Letter symbols: L, detected but below the limit of determination in parentheses; N, not detected at limit of detection. Limit of determination, in parts per million (ppm; in parentheses), varies with method used]

Sample	Gold (ppm)	Silver (ppm)	Sample descriptions
NCC 062	.008	N (0.5)	1-m chip sample garnet-mica-kyanite schist, minor sulfides.
NCC 063	.006	N (0.5)	1-m chip sample biotite-garnet schist.
NCC 064	.002	N (0.5)	0.6-m chip sample mica-garnet schist.
NCC 067	L (0.002)	N (0.5)	0.6-m chip sample quartz vein.
NCC 068	L (0.002)	N (0.5)	1-m chip sample mica-garnet schist.
NCC 069	.01	N (0.5)	2-m chip sample quartz-biotite gneiss.
NCC 072	.002	N (0.5)	1-m chip sample quartz-biotite gneiss.
NCC 073	.012	N (0.5)	1-m chip sample mica-garnet schist.
NCC 074	L (0.002)	N (0.5)	2-m chip sample quartz-biotite gneiss.
NCC 075	.002	N (0.5)	Composite of chips from several boulders of amphibolite.
NCC 076	.004	N (0.5)	Do.
NCC 090	.002	N (0.5)	0.3-m chip sample quartz vein.
NCC 091	L (0.002)	N (0.5)	Do.
NCC 092	L (0.002)	N (0.5)	6-m chip sample mica-kyanite-garnet schist, minor sulfides.
NCC 101	.004	N (0.5)	1-m chip sample quartz-biotite gneiss.
NCC 105	L (0.002)	N (0.5)	1.5-m chip sample quartz-biotite gneiss.
NCC 109	L (0.002)	N (0.5)	Composite of chips from several boulders of amphibolite.
NCC 111	L (0.002)	N (0.5)	1-m chip sample quartz-biotite gneiss.
NCC 314	N (0.17)	3	Quartz boulder.
NCC 316	N (0.17)	L (0.7)	Composite of chips from several quartz boulders.
NCC 303	-----	1	15-m chip sample schist.
NCC 306	-----	L (0.5)	0.3-m chip sample quartz vein.
NCC 313	-----	.7	.6-m chip sample quartz boulder.
NCC 827	L (0.17)	3	Quartz.
NCC 828	L (0.17)	3	Do.

MINERAL-RESOURCE POTENTIAL

Kyanite, garnet, and building stone are the only mineral resources having known potential in the Craggy Mountain Wilderness Study Area and Extension; none is important economically at this time. A possibility exists for the presence of natural gas at great depth. Other minerals and rocks have been mined or prospected nearby but have no potential in the study area.

Sheet mica has been mined or prospected at 20 places within an 8-km radius of the study area (Lesure, 1968; Sterrett, 1923, p. 184–188). The New Balsam Gap and Rock Stand mica mines (pl. 1*B*, nos. 1a and 1b)

TABLE 5.—*Spectral radiometric measurements along Mineral Creek*

[Total count, 0.5-3.0 million electron volts (MeV), given in counts per second (c/s); concentration of potassium (K) in percent, based on K^{40} at 1.46 MeV peak; concentration of equivalent uranium (eU), based on Bi^{214} at 1.76 MeV peak; and equivalent thorium (eTh), based on Tl^{208} at 2.62 MeV peak, in parts per million (ppm) as calculated using 3π geometry; reading time at each station not more than 2 minutes. Precision of the measurements is estimated to be ±10 percent and absolute accuracy ±20 percent, both expressed at the 1σ confidence level. Localities are shown in fig. 6]

Locality	Rock type	Total count (c/s)	K percent	eU (ppm)	eTh (ppm)	eTh/ percent K	eTh/eU	eU/ percent K
1	Schist(?)[1]	319	0.8	2.0	9.3	11.6	4.7	2.5
2	Do	326	.9	1.7	10.1	11.2	5.9	1.9
3	Gneiss(?)	269	.7	1.7	7.3	10.4	4.3	2.4
4	Do	255	.7	1.3	7.0	10.0	5.4	1.9
5	Schist	319	.7	1.9	10.7	15.3	5.6	2.7
6	Gneiss	274	.8	1.6	7.8	9.8	4.9	2.0
7	Schist	306	.8	1.7	9.3	11.6	5.5	2.1
8	Pegmatite	271	.8	1.3	7.1	8.9	5.5	1.6
9	Schist	354	.9	1.9	11.5	12.8	6.1	2.1
10	Interlayered schist and gneiss	398	1.3	2.3	11.0	8.5	4.8	1.8
11	Schist float	206	.4	1.3	5.6	14.0	4.3	3.3
12	Schist	398	1.1	2.2	11.8	10.7	5.4	2.0
13	Gneiss	446	1.1	2.9	13.8	12.5	4.8	2.6
14	Interlayered schist and gneiss	371	1.1	2.2	10.3	9.4	4.7	2.0
15	Schist(?)	333	.7	1.8	10.3	14.7	5.7	2.6
16	Gneiss(?)	394	1.2	2.3	11.2	9.3	4.9	1.9
17	Interlayered schist and gneiss	443	1.4	2.8	12.1	8.6	4.3	2.0
18	Schist	425	1.1	2.6	13.2	12.0	5.1	2.4
19	Gneiss(?)	342	1.0	2.1	9.6	9.6	4.6	2.1
20	Schist talus	321	.8	1.9	9.3	11.6	4.9	2.4
21	Do	313	.8	1.9	9.2	11.5	4.8	2.4
22	Do	377	1.0	2.1	11.2	11.2	5.3	2.1
23	Gneiss	372	1.0	2.3	10.4	10.4	4.5	2.3
24	Schist	374	1.0	2.3	10.3	10.3	4.5	2.3
25	Do	475	1.5	2.6	12.9	8.6	5.0	1.7
26	Schist talus	382	1.0	2.5	10.7	10.7	4.3	2.5
27	Gneiss(?)	355	1.0	2.1	9.8	9.8	4.7	2.1
28	Do	402	1.3	2.8	8.3	6.4	3.0	2.2
29	Do	446	1.4	2.8	11.5	8.2	4.1	2.0
30	Do	375	1.0	2.6	9.6	9.6	3.7	2.6
31	Schist talus	376	1.0	2.3	11.1	11.1	4.8	2.3
Average of 31 measurements		355	1.0	2.1	10.1	10.7	4.8	2.2
Average of 16 schist measurements		350	.9	2.0	10.4	11.8	5.1	2.3
Average of 11 gneiss measurements		357	1.0	2.2	9.7	9.6	4.5	2.2
Average of 3 interlayered gneiss and schist measurements		404	1.3	2.4	11.1	8.8	4.6	1.9

[1] Query indicates no outcrop.

are about 3 km northeast of the Craggy Mountain area, near a cascade on Glassmine Branch, which is visible from the Blue Ridge Parkway. These mines were operated before World War I and again during World War II. Small amounts of rather small, average-quality sheet and punch mica were produced from small opencuts and some underground workings (Sterrett, 1923, p. 184–186; Lesure, 1968, p. 92). The Corner Rock mica mine (pl. 1*A*, no. 5) is about 4 km north of the study area on the north side of the Walker Ridge road (FSR 74). Moderate amounts of small average-quality sheet and punch mica were produced from a large opencut and some underground workings during

World War II (Lesure, 1968, p. 90). No other mine or prospect is within 3 km of the area (pl. 1), and no body of pegmatite large enough to prospect has been found in the study area. Clay, feldspar, and flake mica have been produced from several large pegmatite bodies near Democrat, 11 km west of the area (Hunter and Hash, 1949, p. 20-23; Lesure, 1968, p. 90; Merschat, 1977, p. 2–7) and near Swannanoa, 11 km south of the area (Lesure, 1968, p. 92).

Partly altered masses of dunite, peridotite, or pyroxenite near Democrat and Swannanoa have been prospected for chromite, corundum, nickel, olivine, soapstone, and vermiculite (Hunter, 1941, p. 58–63; Hunter and others, 1942, p. 5–7; Murdock and Hunter, 1946, p. 17; Pratt and Lewis, 1905, p. 48–51, Worthington, 1964; Merschat, 1977, p. 8–10). Small productions of some of these materials have been reported. No evidence of dunite, peridotite, or pyroxenite was found in the study area, and no reason exists to expect economic concentrations there of any of the materials normally associated with these rock types.

Gold has been found in quartz veins in Buncombe County near Cane Creek and Flat Creek south of Swannanoa, 18 km or more south of the study area (Butler, 1972, p. 6; Bryson, 1936, p. 145). The gold content is low, and no production has been reported. The Kirstein prospect is in rocks not found in the study area (pl. 1*A*, no. 7); the location of other prospects is not known. Rocks in the study area contain only traces of gold and silver (table 4).

KYANITE

In the study area, the most common mineral that might have future economic importance is kyanite, an aluminum silicate (Al_2SiO_5) used primarily as a high-quality refractory material (Espenshade, 1973, p. 307–311). Kyanite and the related mineral sillimanite are abundant in some alumina-rich layers of mica schist throughout the region. A few pegmatite dikes and quartz veins also contain coarse crystals of kyanite. Locally, kyanite is partly altered to sillimanite, much of which appears to be intergrown with mica and other minerals. The kyanite content of the schist ranges from a trace to as much as 21 percent (tables 1, 6); the sillimanite content is probably much less but may be as much as 10–15 percent in some areas, especially towards the southeast. The kyanite crystals range in length from a fraction of a millimeter to several millimeters. The needlelike or fibrous sillimanite crystals are smaller and generally form clusters or bundles. The kyanite grains commonly contain inclusions of biotite, quartz, garnet, iron sulfides, or graphite, making a clean separation of the various minerals difficult to achieve except after fine grinding. The sillimanite is so fine grained and also so intimately mixed with mica or other minerals that even finer grinding is necessary to obtain a clean concentrate. For this reason, sillimanite here is less desirable than kyanite for economic use.

The schists containing the kyanite and sillimanite in the study area are part of a large belt of alumina-rich rock, 10–13 km wide and at least 48 km long, that has been traced along the line of the Great Craggy and Black Mountains from Asheville in Buncombe County to Bandana in Mitchell County (Keith, 1905, p. 2; Stuckey, 1937, p. 63; Hash and Van Horn, 1951, p. 36). Much of this belt has not been mapped in detail, but it corresponds in a general way to the central part of the area mapped as Great Smoky Group, undivided, in the Knoxville Quadrangle (pl. 1*A*). In the alumina-rich belt, the kyanite and sillimanite are concentrated in lens-shaped layers of schist or gneiss that range in thickness from less than 30 cm to 76 m or more and in length from 30 m to as much as 750 m. The kyanite-sillimanite schist layers alternate with essentially barren layers of gneiss.

The only place where kyanite has been mined from rocks of this belt is at the Celo kyanite mine, 4 km southeast of Burnsville, Yancey County, N.C. (pl. 1*A*). The mine was in operation from 1934 to 1944 (Espenshade and Potter, 1960, p. 60), producing kyanite and byproduct garnet from coarse-grained biotite-kyanite-garnet gneiss and schist, which are interlayered with quartz-biotite gneiss and kyanite-poor mica schist. Layers of schist several meters thick have kyanite contents ranging from less than 1 to 18 percent (Espenshade and Potter, 1960, p. 62). Five zones of rock 3 m thick and averaging 12 percent kyanite were mapped and sampled by Chute (1944). Two of these zones were resampled (tables 1 and 2, samples NCC 057 and 060) for comparison with samples from Craggy Mountain. Chemical analyses indicate similar aluminum contents for schist from the study area and from the Celo kyanite mine. The Celo samples contain more silica and less ferric iron; other elements are present in similar amounts.

In 1971, the U.S. Bureau of Land Management issued a prospecting permit for kyanite on a locality on Brush Fence Ridge, about 0.8 km

TABLE 6.—*Petrographic determinations of kyanite and garnet percentages in schist samples from the Craggy Mountain Wilderness Study Area*

[Analyses by U.S. Bureau of Mines, Reno Metallurgy Research Center, Reno, Nev. Determinations made by visual estimate from 2-cm by 4-cm thin sections. Localities are shown on pl. 1*C*]

Sample	Kyanite (percent)	Garnet (percent)	Sample interval[1] (meters)
NCC 303	5	1– 2	5
NCC 304 [2]	none	5–10	3
NCC 304 [2]	5– 7	none	
NCC 307	none	7–10	2.5
NCC 309	none	1– 2	5
NCC 312	15–20	3– 5	4
NCC 317	5– 7	5– 7	3

[1] Samples are random chips taken every 5-15 cm throughout the interval noted.
[2] Hand sample had two distinct zones.

north of Balsam Gap (pl. 1*A*, no. 3). The prospecting permit expired in 1973; no discovery was recorded. During field investigation we found a small, badly slumped trench on the permit area but no other workings. Float in many places on this hillside is a kyanite-rich mica schist. Analyses of float samples from the prospected area show 5–7 percent kyanite and 2–3 percent sillimanite.

Brobst (1962, p. A23–A24) estimated a kyanite resource of 40 million tons in rock averaging 15 percent kyanite over an area about 3 km wide and 16 km long centered on the Celo mine. In the study area, hypothetical submarginal resources[1] may amount to several million tons of kyanite disseminated in schist that averages 15 percent kyanite and occurs in layers 1–3 m thick and 100–1,000 m long. A coarser grained rock was mined at the Celo Mine; recovery problems that might be involved in the use of finer grained kyanite-bearing rock of the study area are unknown. Much of the kyanite contains mineral inclusions that may preclude obtaining a clean concentrate. The average kyanite content of the schist in the study area is probably less than half that of quartzite currently being mined for kyanite in Georgia and Virginia.

In addition to its occurrence as disseminated deposits, kyanite is found locally in pegmatite and quartz veins in the Swannanoa-Burnsville belt. These deposits are small and discontinuous but in places can be traced intermittently along strike for several kilometers (Stuckey, 1937, p. 68). Although they are locally richer in kyanite than are the disseminated deposits, they are too small and intermittent to permit large-scale mining.

A pegmatite containing large, sapphire-blue kyanite crystals as much as 4 cm wide and 7.5 cm long is 90 m west of the Blue Ridge Parkway about 1 km south of Balsam Gap and 3.2 km north of the study area (pl. 1*B*, no. 2). The prospect consists of a badly slumped trench 1–3 m deep, 1.5–3 m wide, and 11 m long. The pegmatite is poorly exposed, but pieces on the dump are medium-grained quartz-feldspar-biotite-garnet pegmatite that contains kyanite and tourmaline. Books of biotite 10 cm^2 by 0.6 cm thick are common. The country rock is a dark amphibolite unlike any seen in the study area. The original rock was probably a peridotite.

More than 50 m north of this pegmatite and 15 m down the hillside is an old adit. Mining has removed most of the pegmatitic material, and only a thin band, which extends for about 6 m along the roof, is visible.

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[1]**Hypothetical resources.** Undiscovered resources that may reasonably be expected to exist in a known mining district under known geologic conditions. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as a reserve or identified-subeconomic resource. Submarginal resources require a substantially higher price (more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology to be minable (U.S. Bureau Mines and U.S. Geological Survey, 1976, p. A4; 1980, p. 3).

No mineral of economic value was seen, but because of the mine's proximity to the kyanite-bearing pegmatite discussed, we assume that kyanite or a related mineral was sought. Analyses of samples taken from this site show 1–2 percent kyanite and 5–6 percent sillimanite.

In summary, the Craggy Mountain Wilderness Study Area and Extension contains hypothetical submarginal resources of kyanite in deposits that are probably too lean to be mined at present. The area is not unique in its kyanite-rich rock but is a small part of the larger kyanite belt that extends from Swannanoa to Burnsville.

GARNET

Garnet, of both industrial-abrasive and gem quality, commonly occurs as an accessory mineral in gneiss and schist throughout the region. The only extensive commercial production has been at the Celo kyanite mine, where abrasive garnet was recovered as a byproduct from milling kyanite ore. According to local residents, gemstone garnet was produced near the study area at Potato Field Gap, about 3 km to the southwest. Field investigations failed to locate abandoned workings or other evidence of prospecting, but garnets as large as 5 cm are common in outcrop and float material. Many of the crystals are highly fractured and not easily removed from the parent rock; a few handpicked gem-quality stones might be recovered.

Within the proposed wilderness area, garnets are both randomly disseminated and in enriched veinlike concentrations in the schistose rocks. Crystals are generally 1–7 mm. The garnets are mostly almandine and contain less pyrope than do either the rhodolite garnet from Macon County, N.C., used as a gemstone, or the garnet from Gore Mountain, N.Y., most widely used as an abrasive (table 7). Garnet content of the rocks in the study area ranges from a trace to 28 percent and may average 5–10 percent. Inclusions of quartz, mica, and feldspar are common in the garnet crystals, averaging 25 percent by volume. Preliminary tests show a poor conchoidal fracture and a Mohs hardness of about 7. Most of the garnet is not of gem quality but might be used for industrial abrasive.

STONE

Gneiss and schist similar to those in the study area have been used for crushed stone and rough building stone in the Asheville region for many years (Councill, 1955, p. 20; Nelson and Bundy, 1972, p. 5). An abandoned quarry on Mineral Creek Road at the edge of the Craggy Mountain Extension area is a local source of road metal and fill (pl. 1*B*, no. 4). The quarry measures 24 m by 12 m and has an 18-m face of mica-garnet schist and gneiss. A 1.2-m greenish-gray weathered zone through the face of the quarry analyzed 15–20 percent kyanite, and a 0.3-m boulder containing flake mica was found on the quarry floor.

TABLE 7.—*Composition, in mole percent, of garnet in schist from the Craggy Mountain area, Buncombe County, and Celo kyanite mine, Yancey County, compared with that of type rhodolite from Mason Mountain, Macon County, N.C. and that of garnet from Gore Mountain, Essex County, N.Y.*

[Figures based on microprobe, X-ray, and microscopic analyses by P. J. Loferski, U.S. Geological Survey]

Garnet molecules	Sample				
	1	2	3	4	5
Pyrope ($Mg_3Al_2Si_3O_{12}$)	56	27	17	14	43
Almandine ($Fe_3Al_2Si_3O_{12}$)	40	66	73	77	40
Spessartine ($Mn_3Al_2Si_3O_{12}$)	2	3	6	4	1
Grossular ($Ca_3Al_2Si_3O_{12}$)	1	2	2	2	14
Andradite ($Ca_3(Fe,Ti)_2Si_3O_{12}$)	1	2	2	2	2
Index of refraction	1.760	1.790	1.800	1.800	1.766
Lattice constant (Å)	11.493	11.533	11.553	11.540	11.543

Description of samples

1. Rhodolite garnet from Mason Mountain, Macon County, N.C., type locality.
2. Pink garnet from NCC 015, Mineral Creek road near Beetree Gap, Craggy Mountain area, Buncombe County, N.C.
3. Pink garnet from NCC 041, Blue Ridge Parkway, west side of Craggy Dome, Buncombe County, N.C.
4. Pink garnet from Celo kyanite mine, sample NCC 060, Yancey County, N.C.
5. Type garnet, B110, Barton Mine, Gore Mountain, Essex County, N.Y. (from Levin, 1950, p. 531, table 2).

Currently, because other sources of crushed and pebble aggregate are available, only small quantities of metamorphic rock are used for road metal. The study area is too far from markets to be a supplier of aggregate, and road access is poor. These factors, coupled with the abundance of similar material throughout the region, make rocks of the study area of no significant value for the usual uses of stone.

OIL AND GAS

Recent seismic studies (Cook and others, 1979) indicate that the Blue Ridge in North Carolina contains a sequence of sedimentary rocks 1,000–5,000 m thick below a layer of metamorphic rocks 1,500–15,000 m thick. The metamorphic rocks, of which those of the Craggy Mountain Wilderness Study Area and Extension are a part, have moved 260 km or more up and over the younger sedimentary rocks. These sedimentary rocks have an unknown potential for hydrocarbons. The depths at which they are found and the implied degree of metamorphism of the sedimentary rocks suggest that any hydrocarbons present would be in the form of natural gas and not oil (Cook and others, 1979, p. 566). The chances of finding concentrations of this gas are uncertain. Until some deep drilling is done to test the results of the seismic studies, no reasonable estimate of the gas potential can be made, but the presence of gas cannot be totally discounted.

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