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

by

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GEOLOGICAL SURVEY

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STUDIES RELATED TO WILDERNESS

STUDY 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 PL93-622, 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, 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.

Table of contents

List of Illustrations

Tables

Studies related to Wilderness--Wilderness Study Areas
Mineral resources of the Craggy Mountain Wilderness Study Area, North Carolina

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Summary

The Craggy Mountain Wilderness Study Area covers about 550 hectares of steep forested ridges in the Blue Ridge Mountains of western North Carolina. The area includes the upper drainage basin of Carter Creek above the mouth of Peach Orchard Creek on the steep western slope of the Great Craggy Mountains in the Pisgah National Forest in Buncombe County. Bedrock is mostly interlayered mica-garnet schist, much of which contains kyanite, and quartz-biotite gneiss; minor layers of amphibolite and a few dikes of trondhjemite and granitic pegmatite are poorly exposed in the vicinity.

No metallic mineral resources have been identified in or near the study area. Reconnaissance geochemical surveys including analyses of stream sediments and rock samples 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 garnet as a byproduct 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.

Introduction

The Craggy Mountain Wilderness Study Area covers about 550 hectares of the Pisgah National Forest in the Blue Ridge Mountains of western North Carolina (fig. 1). The area is 21 km northeast of Asheville, Buncombe County, N.C., 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 Big Fork Ridge (Plate 1b). It 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.

Figure 1 near here.

The study area is on the northwest slope of the Great Craggy Mountains, a south-trending extension of the Black Mountains of

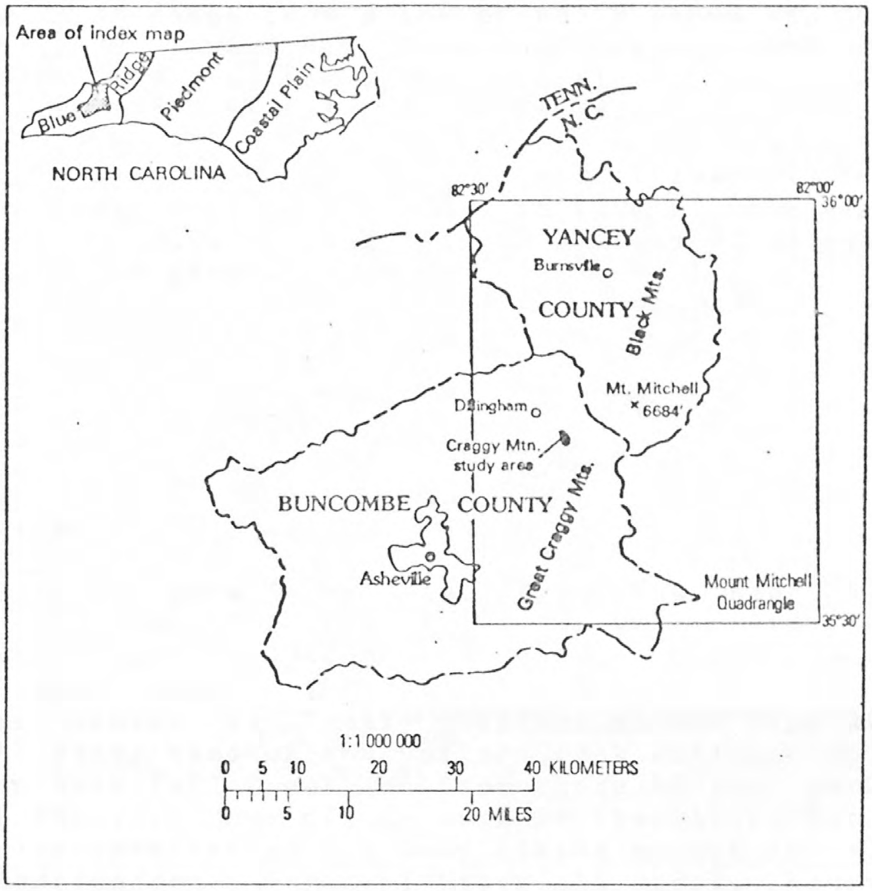

Figure 1.--Index map showing location of Craggy Mountain Wilderness Study Area and the old Mount Mitchell 30-minute quadrangle, North Carolina (Keith, 1905).

which Mount Mitchell is a part (fig. 2). The hillsides are steep and wooded. Elevations range from a low of 885 m above sea level on Carter Creek to 1796 m above sea level on Craggy Pinnacle. Maximum relief is about 910 m; the average vertical rise is about 190 meters per kilometer, a slope of 11 degrees. Many of the slopes, however, are between 30 and 40 degrees. The waterfalls on Waterfall Creek are the most notable physical features. The upper falls (fig. 3) drops free for more than 20 m; the lower falls is equally spectacular, being flanked by tens of meters of nearly vertically-walled gorge.

Figure 2 near here.

Figure 3 near here.

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, and from an unnamed road up Carter Creek at the north end. 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 is trailless, but the woods are generally open enough for easy hiking except for 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 Formation. Hadley and Nelson (1971) made a reconnaissance study of the area during the mapping of the Mount Mitchell 2 degree quadrangle and included the rocks in their Great Smoky Group undivided (Plate 1A).

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. The samples were analyzed by the U.S. Bureau of Mines, Reno Metallurgy Research Center, Reno, Nevada.

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. All the samples were analyzed in the U.S. Geological Survey Laboratories in Denver, Colorado. A few additional analyses were made at Survey laboratories in

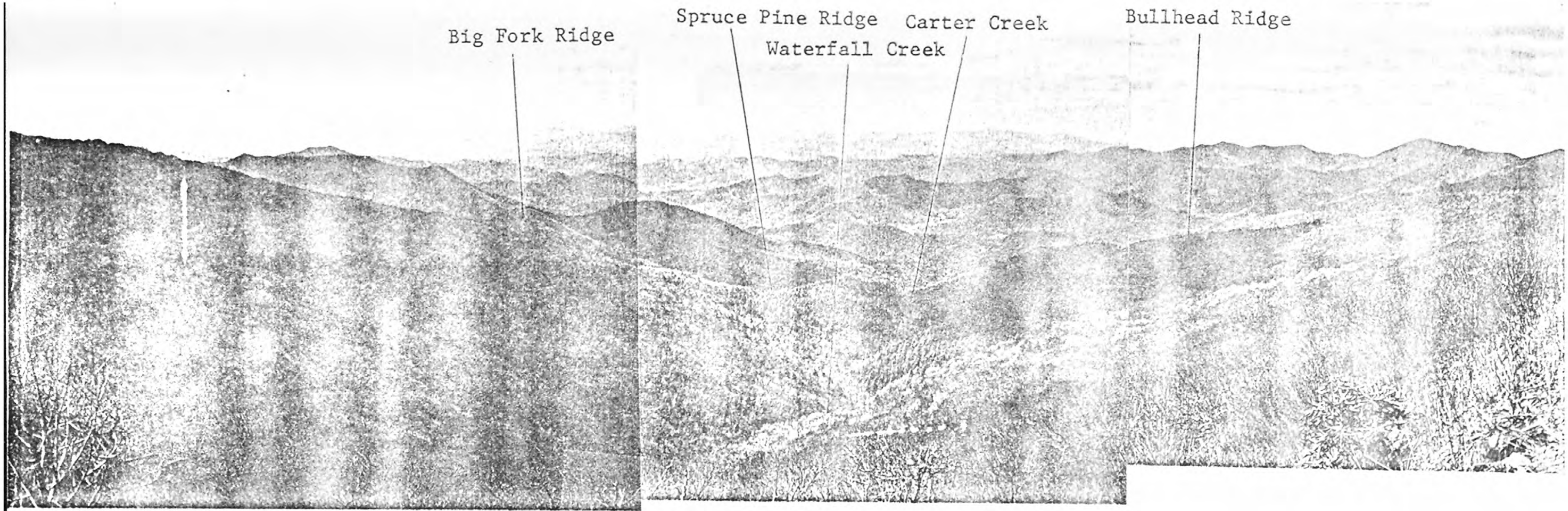

Figure 2.--Panorama of Craggy Mountain study area taken from the Blue Ridge Parkway, looking northwest.

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.

Reston, Virginia.

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 Mineral Resources, 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 contains high-grade regionally metamorphosed sedimentary rocks, possibly equivalent to the Great Smoky Group of late Precambrian age. Mica-garnet schist, locally containing abundant kyanite and sillimanite, is interlayered with biotite-quartz-garnet gneiss and rare 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 just outside the study area, 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 pyrite.

Biotite is the more abundant of the two micas, biotite and muscovite, commonly present (table 1). The biotite content ranges from 10 to 45 percent; muscovite from 5 to 30 percent. The average mica flake is about one to three mm across. Parallel orientation of the mica flakes produces the well-developed 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 lesser amounts of spessartine, grossular and andradite (Table 6). The crystals, one to five mm in diameter, are usually well developed, 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 to 15 percent kyanite. The kyanite crystals are irregular and poorly formed. They range from one to ten mm long. 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.

Table 1.--Mineral composition of kyanite-bearing schist from 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 electrostatic mineral separation methods. Samples were crushed and sieved to pass 18 mesh and rest on 200 mesh. Sample locations for Craggy Mountain samples shown on Plate 1C. Celo mine location shown on Plate 1A.

Sample Number	NCC015	NCC027	NCC030	NCC041	NCC052	NCC057	NCC060
Sample Wt. in grams	90	57	22	88	150	50	120
Minerals			Weight percent				
Kyanite	21	21	4	9	19	18	8
Sillimanite	3	--	0.5	5	0.5	--	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 & feldspar	28	14	14	24	17	38	44
Graphite	1	--	--	1.5	0.5	--	--
Pyrite	1	--	--	1	1	--	--
Opaques	--	tr	0.5	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/ Al_2O_3 in percent determined by X-ray methods by A.E. Hubert.

Sample description

NCC015	1 m chip sample, garnet-kyanite-mica schist
NCC027	1 m chip sample, biotite-kyanite-garnet schist
NCC030	2 m chip sample, mica-garnet schist
NCC041	3 m chip sample, biotite-garnet schist
NCC052	1 m chip sample, biotite-kyanite-garnet schist
NCC057	2 m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey Co., N.C.; sample from area of channel sample D23 of Chute (1944)
NCC060	2 m chip sample, mica-kyanite gneiss, Celo kyanite mine, Yancey Co., N.C.; sample from area of channel sample A2 of Chute (1944)

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 kyanite. The needle-like 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, plate-like crystals; zircon, which forms small rounded crystals; and ilmenite and other opaque minerals. Pyrite, which is found in about half the schist samples, is present from a trace to as much as one percent of the rock. Schist in the eastern and southern part of the area contains more pyrite than that in the northern and western part (Plate 1C).

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

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 exposed as well, except along road cuts. 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 to 2 m thick. Locally, gneiss units 3 to 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. Only one outcrop of amphibolite was seen in the study area, in the upper reaches of Waterfall Creek just west of Bullhead Gap (Sample NCC053, Plate 1C). A layer of amphibolite about 2-3 m thick is exposed in the stream bed. It 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.

The alluvium along the lower reaches of Carter Creek contains scattered boulders of fine- to coarse-grained amphibolite. Keith (1905) mapped a narrow unit of amphibolite just west of the study area, and some of the alluvial material may be from this body of rock.

Table 2.--Chemical composition, in percent, of typical schist and gneiss from 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.G.S. Bull. 1401, done in U.S.G.S. Rapid Rock Analysis Laboratories, Reston, Va. by Z.A. Hamlin, Hezekiah Smith, and F.W. Brown.

Lab. No.	W-195712	W-195713	W-195715	W-195716	W-195717	W-195719	Average Pelite Great Smoky Group 1/	W-195714	W-195718	Average Graywacke 2/
Field No.	NCC015	NCC041	NCC056	NCC057	NCC058	NCC060		NCC055	NCC059	
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	0.83	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	0.83	2.0
H_2O +	1.3	1.8	1.2	1.1	1.5	1.2	3.61	0.94	0.31	2.4
H_2O -	0.50	0.61	0.34	0.34	0.37	0.31	--	0.36	0.27	.6
TiO_2	1.3	1.3	1.0	0.98	1.0	0.96	.87	1.2	0.66	.6
P_2O_5	0.24	0.22	0.32	0.29	0.32	0.33	.19	0.18	0.12	.2
MnO	0.24	0.17	0.11	0.12	0.13	0.12	.32	0.05	0.06	.1
CO_2	0.02	0.00	0.01	0.00	0.01	0.01	--	0.01	0.00	1.2
SO_3	--	---	--	--	--	--	--	--	--	.3
S	1.0	0.94	0.34	0.22	0.25	0.20	.73	0.02	0.02	.1
C	--	--	--	--	--	--	.95	--	--	.1
SUM	101	101	101	101	101	100	100.00	101	100	100.4

1/ Hadley and Goldsmith, 1963, p. B45, table 9.

2/ Pettijohn, 1963, p. S15, table 12.

Sample description

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

Pegmatite

A few medium-grained dikes of quartz-feldspar-biotite and quartz-feldspar-muscovite pegmatite are exposed in road cuts along the Blue Ridge Parkway (figure 4), and several large masses

Figure 4 near here.

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 to 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 merely due to better exposures in the road cuts 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 indicated on Plate 1B by letter symbol. Some of the float in the study area contains muscovite crystals 2 to 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 to 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) show 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 prominent features in most

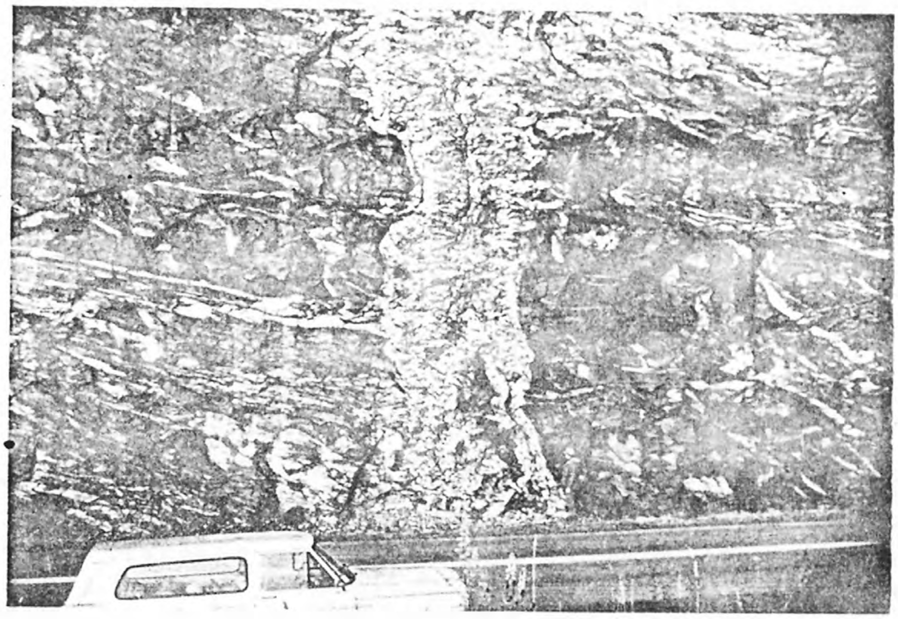

Figure 4.--Irregular granitic pegmatite dike cutting mica gneiss in road cut on the Blue Ridge Parkway 0.5 km south of Pinnacle Gap.

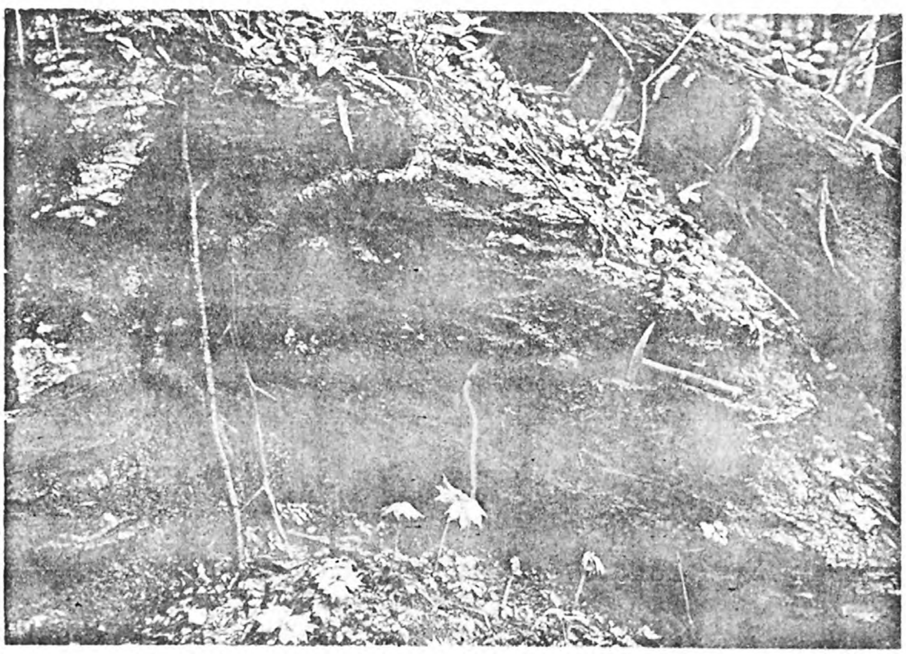

Figure 5.--Chevron folds in mica-garnet schist near the upper falls on Waterfall Creek.

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

Figure 5 near here.

Metamorphism

The rocks of the Craggy Mountain study area were originally interbedded sandstones and clay-rich shales, possibly 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 with the appropriate alumina-rich composition have sillimanite. The kyanite, which is meta stable or which may be coexisting with sillimanite along a 2-phase boundary, probably formed 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 24 bulk samples of stream sediments, 18 panned concentrates, and 44 rock samples, all collected by the Geological Survey (Plate 1C). In addition, the U.S. Bureau of Mines collected 17 rock samples and two panned concentrates (Plate 1C).

We sampled all small drainage basins within and many adjacent to 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 fractions. We studied the 18 panned concentrates microscopically to determine mineral content. We further separated ten of the panned concentrates by heavy liquids, and had the magnetic and non-magnetic fractions 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 alumina rich. Half of the mica schist samples contain iron-sulfides in amounts ranging from a trace to several percent.

All rock 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 ten selected panned concentrates were analyzed spectrographically for 30 elements. Table 3 summarizes the results; for complete results, see Motooka and others (1978).

Bureau of Mines samples were analysed at the Reno Metallurgy Research Center, Reno, Nevada. Testing included semiquantitative spectrographic analyses for 42 elements on eight samples, fire assay for gold and silver on 12 samples (table 4) and petrographic determination of kyanite and garnet on six samples (table 5).

Results

Only normal background values of the elements tested for were found in the rock and stream sediment samples (Table 3). No 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 six rock and eight stream sediment samples from the study area, and traces of silver in ten rock samples and one stream sediment sample (Table 4, Plate 1D), are not considered significant. No other unusual concentration of metallic elements was found in the samples analyzed.

Table 3.--Range and median values for 23 elements in rock and stream sediment samples from Craggy Mountain Wilderness Study Area and vicinity, Buncombe County, N.C. All analyses by semiquantitative spectrographic methods by J. M. Motooka, except gold and zinc, which are by atomic absorption by J. D. Sharkey. Spectrographic analyses are reported to the nearest number in the series 1, 1.5, 2, 3, 5, 7, and 10, which represent approximate midpoints of group data on a geometric scale. The assigned groups for the series will include the quantitative value about 30 percent of the time. Letter symbols: L, detected but below limit of determination (value shown in parenthesis after element symbol); N, not detected; G, greater than. Elements looked for spectrographically but not found and their lower limits of determination: As(200), Au(20), Bi(10), Cd(20), Sb(100), Sn(10), and W(50).

	Schist							Gneiss				Stream sediments								
												Bulk			Panned concentrates					
	14 samples w/o pyrite			13 samples w/pyrite			average in shale 1/	9 samples			average in sandstone 1,2/	24 samples			Magnetic 10 samples			Non-magnetic 10 samples		
Element Percent	Low	High	Median	Low	High	Median		Low	High	Median		Low	High	Median	Low	High	Median	Low	High	Median
Ca (0.05)	0.07	1.0	0.4	0.07	1.5	0.5	2.2	0.3	1.0	0.5	3.9	0.3	1.0	0.6	0.7	1	1	0.05	0.15	0.07
Fe (0.05)	5	15	8.5	5	15	10	4.7	2	7	3	0.98	1.5	7	5	15	20	20	1.5	2	2
Mg (0.02)	1.5	2	1.5	1	2	1.5	1.5	0.5	1.0	0.7	0.7	0.2	1.0	0.5	1.5	1.5	1.5	0.5	0.7	0.5
Ti (0.002)	0.3	0.7	0.5	0.3	0.7	0.7	0.46	0.3	0.7	0.5	0.15	0.3	G1	0.7	0.5	G1	1	0.7	G1	G1
Elements Parts per million																				
Ag (0.5)	N	N	N	N	L	N	0.07	N	N	N	0.0X 3/	N	L	N	N	N	N	N	N	N
Au (0.05)	N	L	N	N	L	N	0.00X 3/	N	N	N	0.00X 3/	N	L	N	N 4/	N 4/	N 4/	N 4/	N 4/	N 4/
B (10)	L	20	L	L	20	L	100	L	L	L	20-30	L	15	10	L	L	L	L	50	20
Ba (20)	300	1000	700	300	1000	700	580	300	1000	500	300	300	700	500	50	100	70	70	200	125
Be (1)	N	3	1.5	N	3	1	3	L	1.5	1	2	L	3	1.5	N	L	L	L	10	L
Co (5)	7	50	20	15	50	20	19	7	15	10	0.3	10	50	20	20	50	30	5	10	7
Cr (10)	50	150	70	50	150	70	90	20	70	30	10-20	20	100	50	100	150	150	150	200	200
Cu (5)	5	70	30	15	150	50	45	N	20	10	10-20	5	50	20	L	15	8.5	L	15	7
La (20)	50	150	100	50	150	100	92	N	50	30	30	50	300	125	N	70	70	200	700	400
Mn (10)	1000	G5000	1500	1000	5000	1500	850	500	1000	700	500	1000	3000	2000	G5000	G5000	G5000	200	500	300
Nb (20)	L	L	L	N	20	L	11	L	L	L	0.X 3/	N	30	20	20	100	30	20	70	25
Ni (5)	10	50	30	15	70	30	68	5	50	15	2	10	50	30	L	20	10	L	15	10
Pb (10)	L	30	20	L	20	10	20	N	15	L	9	15	50	30	N	N	N	L	10	L
Sc (5)	15	30	18	10	30	20	13	7	15	10	1	7	15	15	70	100	100	L	15	5
Sr (100)	N	500	125	N	700	150	300	100	300	150	20	100	500	250	N	N	N	N	N	N
V (10)	70	200	150	70	200	150	130	50	150	70	10-20	30	150	100	150	150	100	200	300	200
Y (10)	50	100	70	30	70	70	26	15	50	30	40	30	70	70	300	500	300	30	100	50
Zn (5)	30	120	90	10	130	80	95	30	80	40	16	40	100	70	N 4/	N 4/	N 4/	N 4/	500 4/	N 4/
Zr (10)	100	300	150	100	300	150	160	150	500	300	200-250	150	1000	300	70	150	100	200	G1000	600

1/ Turekian, K. K., and Wedepohl, K. H. (1961).

2/ Pettijohn, F. J. (1963, p. S11).

3/ Order of magnitude estimated by Turekian and Wedepohl (1961).

4/ Spectrographic analyses only, limit of determination: Au(20 ppm), Zn(200 ppm).

Table 4.--Distribution of gold and silver in stream sediments and rock samples from Craggy Mountain Wilderness Study Area and vicinity, Buncombe County, N.C. Gold analyses by atomic absorption methods by J.D. Sharkey and silver by semiquantitative spectrographic analyses by J.M. Motooka and J.A. Domenico, except sample NCC 015, for which Ag is by computerized emission spectrographic methods by L. Mei, and samples NCC 314 and 316, for which Au and Ag are by fire assay methods by U.S. Bureau of Mines, Reno Metallurgy Research Center, Reno, Nev. 1/. For sample locations see Plate 1D. Letter symbols: L, detected but below the limit of determination in parentheses; N, not detected at limit of detection.

Sample No.	Gold (Au)	Silver (Ag)	Sample descriptions
	Parts per million (ppm)		
NCC 023	L(0.05)	N(0.5)	Bulk stream sediment
NCC 024	L(0.05)	"	"
NCC 025	L(0.05)	"	"
NCC 036	L(0.05)	"	"
NCC 202	L(0.05)	"	"
NCC 204	L(0.05)	"	"
NCC 215	L(0.05)	"	"
NCC 216	L(0.05)	"	"
NCC 219	N(0.05)	L(0.5)	
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 with pyrite
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 with pyrite
NCC 012	L(0.05)	N(0.5)	1 m chip sample quartz-biotite gneiss
NCC 015	N(0.05)	0.18	1 m chip sample biotite-garnet schist with pyrite
NCC 041	N(0.05)	L(0.5)	3 m chip sample biotite-garnet schist with pyrite
NCC 042	N(0.05)	L(0.5)	2 m chip sample biotite-garnet schist with pyrite
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 with pyrite
NCC 053	L(0.05)	N(0.5)	2 m chip sample amphibolite
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	--	0.7	0.6 m chip sample quartz boulder

1/ Three samples of quartz boulders, NCC 311, 315 and 318, 4 samples of quartz veins, NCC 306, 308, 310, and 319, and 2 panned concentrates, 301 and 302, were also tested by fire assay by the U.S. Bureau of Mines, but contained no gold or silver.

Mineral resource potential

Kyanite, garnet, and building stone are the only potential mineral resources in the Craggy Mountain Wilderness Study Area; none is important economically at this time. 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 eight km radius of the study area (Lesure, 1968; Sterrett, 1923, p. 184-188). The New Balsam Gap and Rock Stand mica mines (Plate 1B, no. 1a and 1b) are about three 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 open cuts and some underground workings (Sterrett, 1923, p. 184-186; Lesure, 1968, p. 92). The Corner Rock mica mine (Plate 1A, no. 5) is about four 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 open cut and some underground workings during World War II (Lesure, 1968, p. 90). No other mine or prospect is within three km of the area (Plate 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) 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). Small productions of some of these materials are 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 was reported. The Kirstein prospect is in rocks not found in the study area (Plate 1A); the location of other prospect 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 economic importance in the future is kyanite, an aluminum silicate ($Al_2O_3 \cdot SiO_2$) 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 study area. 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 and 5); 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 needle-like or fibrous sillimanite crystals are smaller and generally form clusters or bundles. The kyanite grains commonly contain inclusions of biotite, quartz, garnet, pyrite, 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 intimately mixed with mica or other minerals that even finer grinding is necessary to obtain a concentrate. For this reason, sillimanite here is not as desirable as kyanite for economic use.

Table 5.--Petrographic determinations of kyanite and garnet percentages in schist samples from the Craggy Mountain Wilderness Study Area 1/

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

1/ Analyses by U.S. Bureau of Mines, Reno Metallurgy Research Center, Reno, Nev. Determinations made by visual estimate from 2 x 4 cm thin sections.
2/ Samples are random chips taken every 5-15 cm through the interval noted.
3/ Hand sample for NCC 304 displayed two distinct zones.

The schist 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 undivided in the Knoxville quadrangle (Plate 1A). 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. (Plate 1a). 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 sampled (tables 1 and 2, samples NCC057 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 Bureau of Land Management issued a prospecting permit for kyanite on a locality on Brush Fence Ridge, about 0.8 km north of Balsam Gap (Plate 1A, 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 was composed of 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 to 3 m thick and 100 to 1,000 m long. A coarser grained rock was mined at the Celo mine, and 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.

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).

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 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 (Plate 1B, no. 2). The prospect consists of a badly slumped trench 1 to 3 m deep, 1.5 to 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 square 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.

About 46 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. No mineral of economic value was seen, but because of the mine′s proximity to the kyanite-bearing pegmatite discussed above, it is assumed 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 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, 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 production occurred 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 occur both randomly disseminated and in enriched veinlike concentrations in the schistose rocks. Crystals generally range in size from 1 to 7 mm. The garnets are mostly almandine and contain less pyrope than 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 6). Garnet content of the rocks in the study area ranges from a trace to 28 percent and may average 5-0 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 (Council, 1955, p. 20; Nelson and Bundy, 1972, p. 5). An abandoned quarry about 1 km southwest of the study area on Mineral Creek Road was a local source of road metal (Plate 1b). 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 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.

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 for 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.

Table 6.--Composition of garnet in schist from Craggy Mountain area, Buncombe Co., and Celo kyanite mine, Yancey Co., compared with type rhodolite from Mason Mountain, Macon Co., N.C. and garnet from Gore Mountain, Essex Co., N.Y. Based on microprobe, X-ray, and microscopic analyses by P. J. Loferski.

Garnet molecules	1	2	3	4	5
			Mole percent		
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
n (Index of refraction)	1.760	1.790	1.800	1.800	1.766
a(A) lattice constant	11.493	11.533	11.553	11.540	11.543

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

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