Mineral resources of the Citico Creek Wilderness Study Area, Monroe County, Tennessee

79-231

by

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Paul T. Behum, and Bradford B. Williams

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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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 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 lands in the Citico Creek study area, Tennessee, that is being considered for Wilderness designation (PL 93-622, January 3, 1975). The area studied is in the Cherokee National Forest in Monroe County, Tennessee.

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SUMMARY

The proposed Citico Creek Wilderness comprises about 5,670 hectares (56.7 km2) in the Cherokee National Forest south of the Little Tennessee River in easternmost Monroe County, Tennessee. Principal drainages are Citico Creek and Doublecamp Creek. Rocks of the study area include greenschist-facies arkosic metasandstone, metagraywacke, slate, and metaconglomerate of the Great Smoky Group of late Precambrian age. Minor deposits of unconsolidated Quaternary alluvium locally mantle the bedrock. Deformation is shown by asymmetric and overturned folds and by several major faults.

More than 500 samples of soil, rock, and stream sediment were collected and analyzed for 31 major, minor, and trace elements by semiquantitative spectrographic, atomic absorption, and fire assay methods. No significant metal anomalies were detected. Concentrations of Cu, Co, As, Pb, and Zn slightly higher than background are found within sulfidic parts of a distinctive stratigraphic unit composed of graphitic slate and metagraywacke. Pyrite and pyrrhotite are the chief sulfide minerals, with traces of accessory sphalerite, chalcopyrite, galena, and arsenopyrite occurring as microscopic intergrowths. A reconnaissance ground radiometric survey and subsequent neutron activation analyses of selected radioactive rock samples show that the sulfidic parts of the graphitic slate unit have a relatively high content of Th and U, but are not potentially economic.

No metallic mineral resources appear to exist within the Citico Creek Wilderness Study Area. Resources of slate, silica, and stone are present, but they display no special qualities to differentiate them from other such material throughout the region. Ceramic evaluation tests on selected samples of slate indicate that the slate would have only marginal use for structural clay products such as brick and tile. Minor sand and gravel deposits occur along a few streams but are present in larger quantities and are more easily recovered in other areas.

INTRODUCTION

Location and Description

The proposed Citico Creek Wilderness comprises approximately 5,670 hectares (14,000 acres or 56.7 km2) of National Forest land south of the Little Tennessee River in easternmost Monroe County, Tennessee (Fig. 1). The study area is entirely within the

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Figure 1 near here.

Cherokee National Forest, along the southern continuation of the Great Smoky Mountains in the Blue Ridge physiographic province. Surface and mineral rights are entirely owned by the U.S. Government, with the 72-hectare Falls Branch Scenic Area being the only easement. The Joyce Kilmer-Slickrock Wilderness and the North Carolina state line together form the eastern border of the area. Principal drainages are Citico Creek (Fig. 2) and one of its major tributaries, Doublecamp Creek, that is the northwestern

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Figure 2 near here.

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boundary of the study area. Total relief is more than 1100 meters. The lowest elevation (430 m) is at the confluence of Doublecamp and Citico Creeks; the highest (1575 m) is astride the Tennessee-North Carolina border near Brush Mountain. The topography is typical of much of the Great Smoky Mountains, with narrow valleys, steep slopes, and sharp ridge crests.

Principal access is from the southwest along Tennessee State Route 68 from Madisonville and Tellico Plains. U.S. Forest Service Road 217-1 continues from Route 68 to the northeast along Sassafrass Ridge, where it forms the southern border of the study area. Roads 217-H and 217-G extend into the southeastern interior. Forest Service Road 35 provides entry from Citico Beach and other northwest locations, with road 59 extending up Doublecamp Creek to Farr Gap, and road 29 a short distance up Citico Creek. Road 81, along Santeetlah Creek, allows access from the North Carolina (eastern) side to Beech Gap, from where a dirt road (217-H) heads northward along the Tennessee-North Carolina border for about 2 km. The area has been heavily logged in the past and many hiking trails follow old railroad grades along major stream valleys.

Land Status

The Citico Creek Wilderness Study Area comprises portions of two tracts of land purchased by the Forest Service under the authority of the Weeks Act of 1911. Surface and mineral rights were purchased from Babcock Lumber and Land Company and the Tellico River Lumber Company. The 72-hectare Falls Branch Scenic Area near the south-central boundary is the only easement within the study area. The southern boundary of the area will be slightly modified to accomodate a new scenic highway, Forest Service Route 217-I.

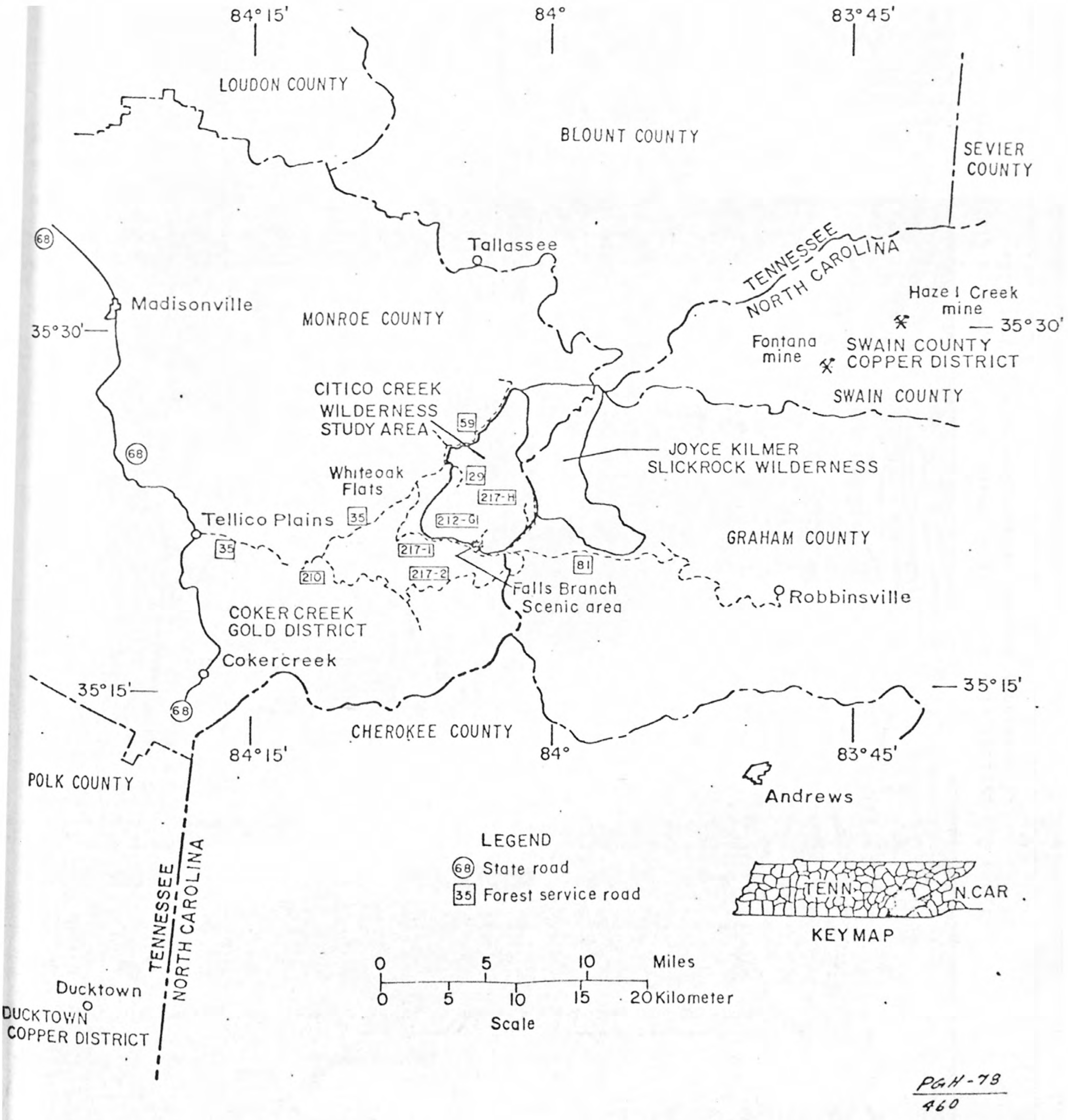

Figure 1. Index map, Citico Creek Wilderness Study area.

Figure 2. Typical view along Citico Creek, showing outcrops (left foreground) of metasandstone and metaconglomerate of Unit III.

Previous Work

Early geologic studies in the southern Great Smoky Mountains were made by Safford (1856; 1869) and Keith (1907), who reported on the reconnaissance mapping of both eastern Tennessee and western North Carolina. King and others (1950) described the geology of the Murphy quadrangle, which includes the Citico Creek Wilderness Study area. More detailed investigations of the western Great Smoky Mountains were published by Neuman and Nelson (1965). Merschat and Wiener (1973) 1/ compiled a provisional geologic map of the Ocoee Supergroup in this region from available data and their own reconnaissance. Hale (1974) studied the nearby Coker Creek gold district. The most recent geologic work in the area by Lesure and others (1977) describes the geology and mineral resources of the Joyce Kilmer-Slickrock Wilderness, which borders the present study area on the east (fig. 1).

Present Investigations

Field work during October, 1976, was done by Slack, Force, and F.G. Lesure, assisted by A.E. Grosz, M.P. Foose, and C.E. Brown, all of the U.S. Geological Survey. Several additional days of mapping were done in October, 1977, by Slack and Force, assisted by R.H. Ketelle and Grosz. Behum and Williams of the U.S. Bureau of Mines conducted field reconnaissance in April, 1977. Samples of soil, rock, and stream sediment were collected by U.S.G.S. personnel and submitted for geochemical analysis. Radiometric surveys were made along major roads with a hand-held scintillometer and subsequently checked by a gamma ray spectrometer.

1/ Revised and updated in 1978.

Acknowledgements

Field radiometric measurements and panning of heavy mineral concentrates from stream sediments were made by A.E. Grosz. Mineral identification by x-ray diffraction was done in the laboratory by P.J. Loferski and M.E. Mrose; R.B. Finkelman assisted in electron microprobe work. Grosz also separated minerals from panned concentrates using heavy liquids and identified the minerals. M.P. Foose helped during our prolonged attempts to unravel the geologic structure of the study area, and provided insight into possible solutions. C.E. Merschat and L.S. Wiener of the North Carolina Division of Mineral Resources provided a preliminary map compilation of the geology of the southern Great Smoky Mountains, and discussed with us the general stratigraphy of the region. Merschat also lent polished sections of sulfide-rich rock collected from the Farner (N.C.-Tenn.) quadrangle southwest of the Citico Creek area. R.C. Hale and the late J.M. Fagen, Tennessee Valley Authority, Knoxville, Tenn., provided unpublished information and mine locations. R.A. Laurence, U.S.G.S., Knoxville, also supplied information about former mines. U.S. Forest Service personnel from the Watershed and Minerals Branch, Atlanta, Georgia, furnished maps and tabulations on mineral and surface ownership and prospect data. Additional prospect information was obtained from the Bureau of Land Management, Washington, D.C.

GEOLOGY

Stratigraphy and Lithology

Rocks of the Citico Creek Wilderness Study Area are greenschist-facies metasedimentary strata of the late Precambrian Great Smoky Group, which make up part of the Ocoee Supergroup. Unconsolidated alluvial deposits of Quaternary age occur locally in some major stream drainages. Precambrian rocks northeast of the map area and just north of the Little Tennessee River in the western part of the Great Smoky Mountains National Park have been subdivided by Neuman and Nelson (1965). More recently, Merschat and Wiener (1973) compiled a reconnaissance geologic map of the southern part of the Great Smoky Mountains of eastern Tennessee and western North Carolina, including both the Citico Creek and Joyce Kilmer-Slickrock Wilderness areas. Merschat and Wiener were unable to project lithologic units for long distances southwestward from the National Park, and therefore used different subdivisions and nomenclature to the southwest as established by Hernon (1968) near Ducktown, Tennessee. Merschat and Wiener (1973) extended Hernon's slaty unit, his unit 1, and his unit 2 northeastward to the area of the proposed Citico Creek Wilderness and recently (Wiener and Merschat, 1978) designated them the Farner, Boyd Gap, and Buck Bald Formations, respectively. To portray as detailed a stratigraphic and structural picture as possible, we have subdivided Hernon's units into more specific lithologic types, designated by Roman numerals. Owing to a different structural interpretation, we are unable to correlate our subdivisions completely with those in the adjacent Joyce Kilmer-Slickrock Wilderness (Lesure and others, 1977), but those units which are correlative are so indicated on the map legend (pl. 1). Lithologic descriptions of individually mapped units are given on the geologic map.

Structure

The metasedimentary rocks of the Citico Creek area are deformed by open and closed folds and by several major faults. The Nichols Cove fault (Lesure and others, 1977) divides the map area into two stratigraphic sequences which display different fold styles. Northwest of the fault, on and near Pine Ridge, the structures are extremely complicated. We have carefully walked selected contacts here, but as yet are uncertain of the exact nature of the structure. We wish to emphasize that the geology of this particular area is complex and adds uncertainty to our interpretations of structural and stratigraphic features.

Folds--Northwest of the Nichols Cove fault, open folds with long subhorizontal east limbs and short steeply-dipping west limbs (with respect to anticlines) are characteristic (fig. 3).

Figure 3 near here.

These folds, which we term "step folds," form a generally eastward-rising flight of steps that are present at various scales from mesoscopic (outcrop) to megascopic (major Pine Ridge syncline, pl. 1). Along Citico Creek, between the former Warden Station and Doublecamp Creek, an enveloping surface of such folds can be traced using the upper boundary of unit III; it dips gently to the northwest. A hinge of the major syncline shown within unit III is exposed where it crosses the North Fork of Citico Creek.

Southeast of the Nichols Cove fault, the deformation style is characterized by inclined or upright closed folds. These folds differ from the step folds on the northwest side of the fault, in that they commonly are symmetric with either gentle or steep limbs; some small folds are isoclinal. Several larger folds of this type strongly influence the topography. Two major anticlines on either side of Grassy Gap (pl. 1) are coincident with prominent linear ridges trending north (Hampton Lead) and northeast (Brushy Ridge). To the north along the South fork of Citico Creek, another anticlinal axis coincides with a northeast-trending ridge that forms a spur on the southwest side of Brush Mountain, near the headwaters of Ike Camp Branch.

In some areas, complex folding and transposition of beds are evident. Along the new Sassafrass Ridge road, excellent exposures show abrupt local terminations of coarse clastic beds in a sequence of interlayered metagraywacke and graphitic slate. At one location, highly contorted beds of metagraywacke occur within a simple homoclinal section (fig. 4); we believe preconso-

Figure 4 near here.

lidation (soft-sediment) slumping caused such folds. Other exposures show intensely folded slate between unfolded beds of more competent metasandstone or metagraywacke, reflecting disharmonic folding.

Plunges of fold axes and of lineation structures representing cleavage-bedding intersections appear to be shallow throughout the study area. Axes of minor folds with amplitudes less than a few meters typically plunge 10 to 20 degrees to the northeast, parallel to the axes of major folds of the region.

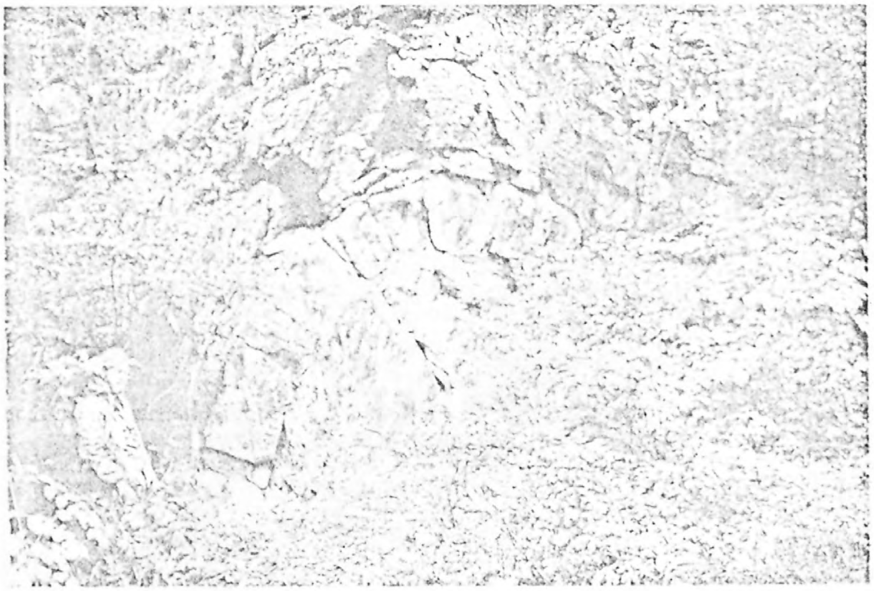

Figure 3.--Small step-fold exposed along Doublecamp Creek, within metasandstone and slate of unit II. View looking north.

Figure 4.--Contorted beds of metagraywacke and thin interbeds of dark slate exposed along new roadcut at Sassafrass Ridge. Note man for scale.

Faults--The major fault within the study area is the Nichols Cove fault, previously described by Lesure and others (1977) to the northeast. We have interpreted this fault as a thrust, although locally it may be a high angle reverse fault. It divides the Citico Creek area into two different stratigraphic sequences. The fault separates gray slate and arkosic metasandstone and metaconglomerate on the northwest from dark graphitic slate and metagraywacke on the southeast. In general, strata on both sides of and close to the fault are moderately to strongly overturned to the southeast. The fault crosses the Sassafrass Ridge road at Eagle Gap (pl. 1), where rocks of the upper plate are crushed, mylonitized, and in places display transposed bedding. The dip of the fault is not determinable except near Harrison Gap, where its position on adjacent ridges and in valleys suggests a dip of about 45 degrees to the southeast.

Tear faults that probably formed synchronously with folding strike north-northwest on the north side of Pine Ridge. These faults separate two blocks where the lower and upper contacts of the same unit (III) are juxtaposed. Thus, they separate areas where unit III is in contact with lower slates of unit II, from areas where unit III is in contact with upper slates of unit IV. Younger faults in this same region strike east-west and offset lithologic boundaries and fold axes. The largest of these east-west faults is traceable from the lower parts of Rocky Flats Branch to Big Stack Gap. On aerial photographs, this fault is expressed by a strong lineament which is visible at least 5 km eastward to beyond Big Fat Gap, at the eastern edge of the Joyce Kilmer-Slickrock Wilderness. In the Citico area, the magnitude and direction of fault movement are not determinable, but offsets of rock formations on the map suggest measurable movement. Geologic contacts mapped by Lesure and others (1977) to the east are not offset by the fault, however, indicating little displacement along this fault within their map area.

Another fault is present on the south and east sides of Pine Ridge. It strikes northeast from Flats Mountain to just west of Big Fodderstack, and is a conspicuous lineament on aerial photographs. Strata on both sides of this fault dip steeply to the southwest and are in places overturned. The northward bend of the fault trace near Big Fodderstack suggests a west-dipping fault plane, but the direction and amount of movement along this fault are unknown.

Cleavage and jointing--Cleavage and jointing are well-developed throughout most of the Citico map area. Slaty cleavage is prominent in fine-grained rocks and is characteristically at an angle to bedding (fig. 5). It strikes

Figure 5 near here.

uniformly northeast and dips moderately to steeply to the southeast. The majority of slate outcrops show both bedding and cleavage. We have inferred that bedding is overturned where cleavage dips less than bedding. Various sedimentary structures (chiefly graded beds and cross-laminations) support this inference.

Cleavage in slates appears to be parallel to the axial planes of step folds northwest of the Nichols Cove fault, and to closed folds southeast of the fault. Quartz veins are oriented along cleavage directions in many slaty rocks. Near Hemlock Knob, on the southern border of the study area, a new roadcut exposes a group of parallel quartz veins that are aligned within the axial plane cleavage of a prominent anticline.

A second and younger, more widely spaced cleavage, commonly deforms the earlier slaty cleavage of fine-grained rocks. It is visible locally in outcrops as dark, herring bone-like partings. In some slate outcrops, this parting or fracture cleavage forms minor crenulations on the earlier cleavage surfaces, and is associated with chevron folds of small amplitude (<0.1 m). The strike of the fracture cleavage generally parallels the fold axes and the dip is steep or vertical. As seen in thin section, the older penetrative slaty cleavage is kinked and in places transposed by the younger cleavage. The younger fracture cleavage is marked by concentrations of organic material. The origin of this secondary fracture cleavage is unclear. Stereonet plots demonstrate that it is not a simple bedding-cleavage intersection. It may be a minor axial plane cleavage developed during or after the main period of regional deformation. However, no mappable folds seem to be associated with it.

Metamorphism

The entire study area appears to be within the greenschist facies of regional metamorphism (Swingle and others, 1966; Carpenter, 1970). The chlorite-biotite isograd, determined mainly by petrographic study, extends west-southwest from near Big Fodderstack to the northern part of Flats Mountain (pl. 1). The biotite-almandine garnet isograd passes through the central part of the Joyce Kilmer Memorial Forest, about 4 km east of the southeast corner of the present study area. The isograds cannot be correlated with mappable rock units (as designated by Roman numerals on pl. 1), either in the Citico Creek area or in the adjacent Joyce Kilmer-Slickrock Wilderness (Lesure and others, 1977, pl. 1).

Minor amounts of chlorite and muscovite form the matrix for many of the metasandstones and metasiltstones of units I-IV. Megascopic biotite is restricted to the southern part of the study area, where it occurs as porphyroblastic flakes up to 1 mm in diameter in schistose metagraywacke of units V and VI.

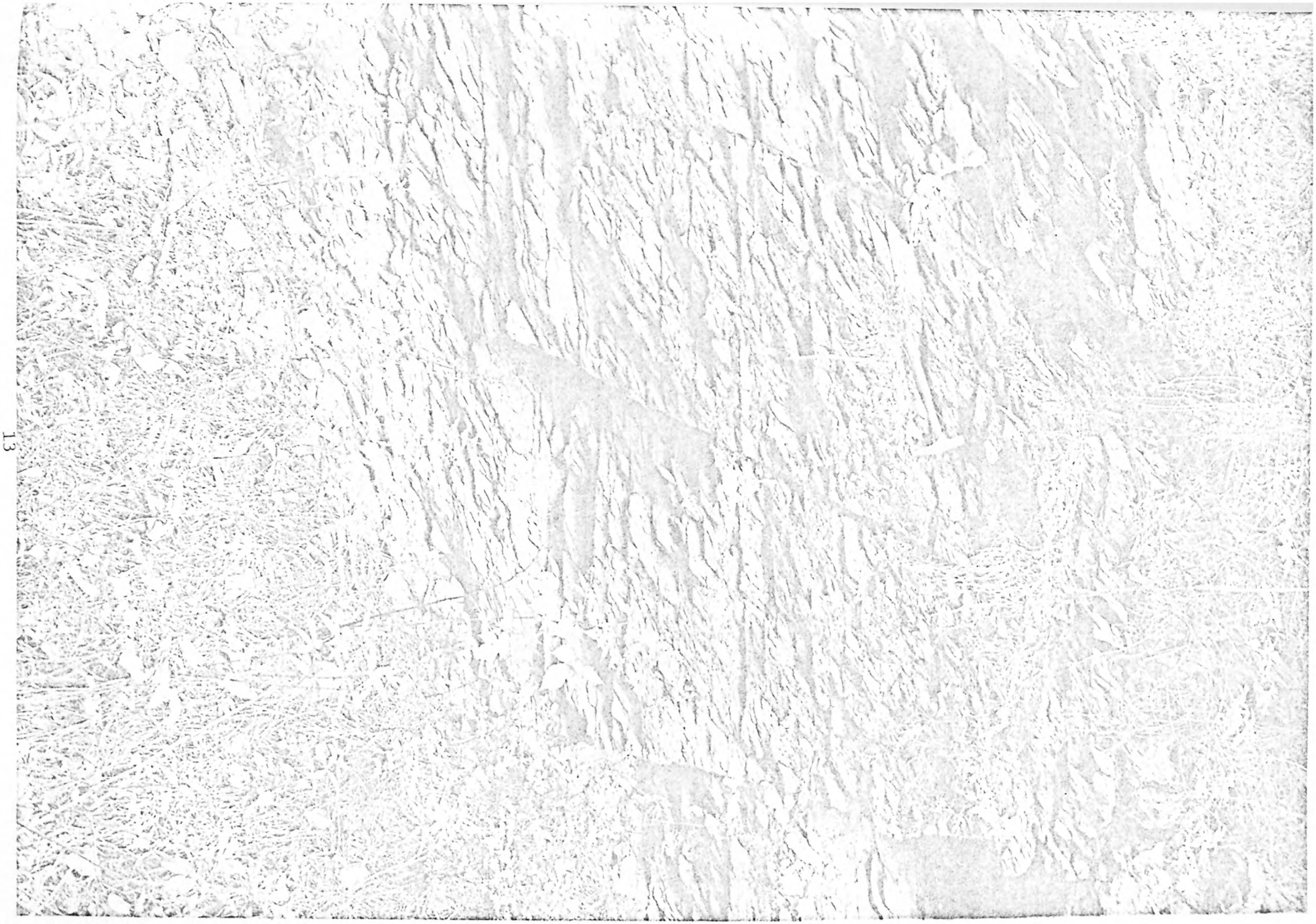

Figure 5. Typical view of bedding-cleavage relations within unit IV slates. Bedding here is nearly horizontal, cleavage is inclined.

Finer-grained biotite was noted in thin sections from a number of metasandstones and metagraywackes south of Pine Ridge. Biotite is also common in most rocks of the upper plate southeast of the Nichols Cove thrust fault, except in highly graphitic slate of unit V, where bulk compositions (or graphite) may have prevented its formation. The apparently greater deformation of lower plate rocks near the Nichols Cove fault and the distribution of biotite on the north side of and close to the fault suggest that the biotite isograd may be related to this major thrust.

Garnet was identified by optical and x-ray methods in 8 of 14 heavy mineral concentrates from panned stream sediment. Two types of garnet were found, one a lavender or pale pink, the other pale clove brown ("colorless" of Lesure and others, 1977). Preliminary x-ray powder camera studies suggest that the pink garnet is similar to rhodolite, which is a magnesium-iron garnet. The brownish type has a d-spacing almost identical to that of spessartine, a manganese-rich garnet. These garnets were collected in streams that drain small basins, but thin sections of rocks from the same basins do not contain garnet. Garnets were also noted in a panned concentrate from the mouth of Crowder Branch (pl. 1), well within the chlorite zone as determined by our petrographic study. Although manganiferous garnet can form during lower greenschist-facies metamorphism (Turner, 1968, p. 72), magnesium-rich garnet, characteristic of high-grade metamorphic zones, should not form there. Assuming that the magnesium garnets are not now part of a second cycle, their widespread distribution suggests that most of the Citico Creek map area is within the garnet zone of regional metamorphism. Possible explanations for the apparent conflict between data from thin sections and from panned stream sediment samples are that either our hand specimen sampling has been too sparse (over 200 samples), or that bulk compositions of most of the local rocks are not appropriate for the formation of garnet, so that only a few selected horizons (unsampled) provided the detrital garnets which we found by panning. We have here followed Lesure and others (1977) who had the same problem, and have drawn metamorphic isograds solely from our petrographic studies of hand specimens and thin sections.

GEOCHEMICAL SURVEY

Sampling and analytical techniques--Samples of rock, soil, stream sediment, and vein quartz were collected from throughout the Citico Creek Wilderness Study area (pl. 2). An attempt was made to uniformly sample each type of material. Full coverage was limited by dense vegetation in some areas, especially to the south near Jeffrey Hell.

Rock samples were taken by a composite chip method from several parts of each sampled outcrop. The chip samples are representative of all major rock types of the area including vein quartz, as well as all the rock units shown on the geologic map. Soil samples were taken below surficial organic material generally from the lower to middle parts of the A horizon, but in some places from the upper part of the B horizon. Soil samples were sieved to minus 80-mesh prior to analysis. Stream sediment was sampled from active and a few small intermittent tributaries draining into Citico Creek and Doublecamp Creek. Additional samples were collected from outside the study area, from drainage basins that are partly within the study area. Stream sediment samples were sieved to minus 80-mesh; some organic-rich samples were ashed before analysis in order to avoid spectral interference. Panned concentrates of heavy minerals were collected from major streams using standard gold-panning techniques. Samples were taken either from loose gravel in or near a stream, or from potholes where streams flow over bedrock, especially from lower Citico Creek and its tributaries.

A semiquantitative spectrographic analysis for 31 elements was made for every sample. Concentrations of gold, silver, and zinc were determined more accurately by atomic absorption and fire assay methods. Samples were analyzed by the laboratories of the U.S. Geological Survey, Denver, Colorado, and the U.S. Bureau of Mines Metallurgy Research Center, Reno, Nevada. The semiquantitative spectrographic values 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 geometric midpoints of the concentration ranges. The precision is shown to be within one adjoining interval on each side of the reported value 83 percent of the time and within two adjoining intervals 96 percent of the time (Motooka and Grimes, 1976).

In their study of the adjacent Joyce Kilmer-Slickrock Wilderness, Lesure and others (1977) compared geochemical data from their area with those from the nearby Hazel Creek and Fontana copper mines, plotted on cumulative frequency distribution diagrams in order to determine which Wilderness samples contained anomalously high values. We have evaluated our geochemical data from the Citico Creek area by similar comparisons with those both from the known mineralized areas and from the Joyce Kilmer-Slickrock Wilderness. In the tabulation and discussion of the geochemical data, selected elements of economic interest, particularly Au, Ag, Pb, Cu, Zn, Ni, Co, and Sn are emphasized. Concentrations of other major, minor, and trace elements (Fe, Mg, Ca, Ti, Mn, B, Ba, Be, Cr, La, Nb, Sc, Sr, V, Y, Zr) fall within expected ranges of background values and are not discussed. Complete analyses for rock, soil, and stream sediment are available in Hopkins and others (1979).

Stream sediment samples--Analyses of 119 stream sediment samples collected in 1976 and 25 samples collected in 1973 (Lesure and others, 1977) showed no significant metal anomalies. Silver and gold were not detected in any samples. Other elements of major economic interest (Co, Cu, Ni, Pb, Sn, Zn) were generally found to have concentrations within expected ranges (table 1). Tin was detected in three samples, but with a high value of only 15 ppm. The sediment in a few streams contains slightly anomalous concentrations of zinc, with a high of 145 ppm; however, no systematic geographic distribution exists for these occurrences. One stream sediment sample collected by Lesure and others (1977, table 2, no. 2355) from just west of Bob Bald contains 180 ppm lead. A second sample from the same drainage basin, collected in 1976, yielded only 30 ppm lead.

Table 1.--Range and median values (in ppm) for selected elements in samples of soil, stream sediment, and panned concentrates collected in 1976 from the Citico Creek Wilderness Study area, Monroe County, Tennessee. All analyses by semiquantitative spectrographic methods except those for gold and zinc which are by atomic absorption. Spectrographic data are reported to the nearest number in the series 1, 1.5, 2, 3, 5, 7, 10, etc., which represent approximate midpoints of group data on a geometric scale (see text). Analyses by R.T. Hopkins, C.A. Curtis, and J. Sharkey, Branch of Exploration Research, USGS, Denver, Colo. Letter symbols: L, detected but below limit of determination (value in parentheses); N, not detected. Elements looked for but not found and their lower limits of detection, in ppm: Ag(0.5), As(200), Bi(10), Cd(20), Mo(5), Sb(100), W(50). Au found only in two soil samples at limit of detection (0.05 ppm).

	Soil (128 samples)			Stream sediment (119 samples)			Panned concentrate (14 samples)		
Elements	Low	High	Median	Low	High	Median	Low	High	Median
Co (5)	N	30	5	N	50	15	N	20	N
Cu (5)	7	70	20	5	30	15	L	30	7
Ni (5)	L	50	15	L	70	15	L	20	5
Pb (10)	10	70	30	10	70	30	10	30	15
Sn (10)	N	N	N	N	15	N	N	20	N
Zn (5)	10	140	50	30	145	70	N*	N*	N*

* Determined by emission spectrographic methods only; detection limit 200 ppm.

Panned concentrates--Splits of 14 panned concentrates were analyzed by spectrographic and atomic absorption methods (table 1). No elements are present in anomalously high concentrations. A heavy mineral fraction was separated from the remainder of each sample by standard heavy liquid methods. The principal heavy minerals are epidote, tourmaline, zircon, hematite, magnetite, "limonite," garnet, and ilmenite. One 0.5 mm ribbon-shaped grain of gold was found in a sample from the mouth of Flint Branch of Doublecamp Creek. The Flint Branch drainage basin is outside the boundaries of the present study area, however.

Soil samples.--Soil samples collected in 1976 (128) were analyzed and showed no anomalously high metal values (table 1). Gold and zinc are the only elements with local concentrations slightly higher than background that might be of possible interest. Gold is at the limit of detection (0.05 ppm) in two samples. Zinc concentrations of 140 ppm occur in two areas, but neither area correlates geographically with areas where similar values of zinc are found in rock and stream sediment.

Of nineteen soil samples collected in 1973 within the Citico Creek area, only one, a dark silty loam, is considered to have anomalously high metal values. That sample (Lesure and others, 1977, table 3, no. 1391) contains 0.5 ppm Ag, 410 ppm Cu, and 300 ppm Pb. This soil sample was taken near Farr Gap in the northernmost part of the study area along the eastern boundary with the Joyce Kilmer-Slickrock Wilderness.

Rock samples--Spectrographic analyses (table 2) of rock chips of metasandstone, metagraywacke and metaconglomerate (113 samples) and of slate (79 samples) reveal no metal anomalies with economic potential. Seventeen rock chip samples collected in 1973 along the common (eastern) boundary with the Joyce Kilmer-Slickrock Wilderness (Lesure and others, 1977) also do not contain any significant anomalously high metal values. However, slightly higher-than-background concentrations of As, Co, Pb, Cu, and Zn are associated with sulfidic and graphitic parts of unit V, extending along the Sassafrass Ridge road from Eagle Gap northeastward to near Harrison Gap (pl. 1). Roadcuts at Eagle Gap and Hemlock Knob provided excellent exposures of sulfidic rocks within this section.

Table 2.--Range and median values (in ppm) for selected elements in 192 rock chip samples collected in 1976 from the Citico Creek Wilderness Study area, Monroe County, Tennessee. All analyses by semiquantitative spectrographic methods except those for gold and zinc which are by atomic absorption. Spectrographic data are reported to the nearest number in the series 1, 1.5, 2, 3, 5, 7, 10, etc., which represent approximate midpoints of group data on a geometric scale (see text). Analyses by R.T. Hopkins, J. Sharkey, and C.A. Curtis, Branch of Exploration Research, USGS, Denver, Colo. Letter symbols: L, detected but below limit of determination (value in parentheses); N, not detected. Elements looked for but not found and their lower limits of detection, in ppm: Au(0.5), Bi(10), Cd(20), Sn(10), Sb(100), W(50); other elements discussed in text.

	Metasandstone, metagraywacke, metaconglomerate (113 samples)				Slate (79 samples)			
Elements	Low	High	Median	Average Sandstone1,2/	Low	High	Median	Average Shale3/
Ag (0.5)	N	N	N	0.0X4/	N	1	N	0.1
As (200)	N	N	N	1	N	700	N	6.6
Co (5)	N	20	5	0.3	N	100	10	20
Cu (5)	N	30	10	10-20	5	70	20	57
Mo (5)	N	L	N	0.2	N	7	N	2
Ni (5)	L	70	10	2	L	70	15	95
Pb (10)	L	70	20	9	L	150	30	20
Zn (5)	N	120	40	16	L	200	90	80

1/ Pettijohn (1963); 2/ Turekian and Wedepohl (1961); 3/ Krauskopf (1967, Appendix III); 4/ Order of magnitude estimated by Turekian and Wedepohl (1961).

Sulfide minerals occur in variable amounts in these rocks and locally comprise up to 10 percent by volume. Metagraywacke rarely contains more than 2 to 3 percent sulfides; laminated graphitic slate and metasiltstone contain up to 10 percent sulfides which typically are concentrated along lenses and microlaminations of the coarser silty beds (fig. 6).

Figure 6 near here.

The preferential distribution of these sulfide minerals along specific beds suggests that they formed by syngenetic processes contemporaneously with their host rocks. In most outcrops of slate or metasiltstone (on the southeast side of the Nichols Cove Fault), the sulfide minerals are transposed into the major slaty cleavage and show a strong preferred lineation. Pyrrhotite and pyrite are the chief sulfides, pyrrhotite occurring as disseminations in the metagraywacke, and pyrite as porphyroblastic cubes (to 3 cm) or streaked aggregates (with minor pyrrhotite) in slate.

Microscopic studies of selected sulfide-rich samples reveal the presence of very minor amounts of other sulfides of economic interest, principally sphalerite and chalcopyrite plus traces of arsenopyrite and galena. The accessory sulfides generally form marginal intergrowths with pyrrhotite (partly altered to marcasite) in either metagraywacke or slate. Their presence readily explains the high background concentrations of Cu, Zn, As, and Pb in these rocks. Similar occurrences of minor base-metal sulfides were found by Merschat and Larson (1972) in correlative rocks in the Farner quadrangle about 30 kilometers southwest of the Citico Creek area.

Because of the unusual concentration of sulfide minerals in this area the rocks were resampled in more detail. Composite chip samples were taken at approximately 1-meter spacings for each lithologic unit. A composite sample weighing at least 10 Kg was taken of each of six units containing different proportions of graphitic slate, metagraywacke, and laminated graphitic metasiltstone and slate. No anomalous metal concentrations were found in these samples and in four other sulfide-rich specimens, except for slightly high values for Zn (200-300 ppm).

Sulfide concentrates from two bulk samples (metagraywacke and graphitic slate) collected near Eagle Gap were separated by density (heavy liquids), grain size, and magnetic susceptibility. Eleven concentrates from the two bulk samples, mainly of pyrite and pyrrhotite, were analyzed for 31 major, minor, and trace elements. Anomalously high metal values were found for several elements in some sulfide concentrates. A few samples, particularly finer-grained splits, contain up to 20 ppm Ag, 50 ppm Sn, 500 ppm Pb, 500 ppm Ni, 2000 ppm Co, 2000 ppm Cu, 3000 ppm Zn, and >1% As.

<u>Quartz veins and gossan</u>--Quartz veins occur throughout the study area. They are most common in slate, and typically are a meter or less in width and traceable for several meters or tens of meters along strike. Locally some quartz veins are folded or deformed into pods or boudins, particularly near the Nichols Cove

Figure 6.--Thin laminations of sulfide minerals (mainly pyrite) within dark graphitic slate of unit V, at Eagle Gap roadcut.

fault. The majority of veins are barren milky quartz, although a few contain minor amounts of pyrite. One unusual vein from the Hemlock Knob roadcut contains quartz, albite, and minor pyrite and siderite.

Four of 32 quartz-vein samples collected in 1976 (table 3) and one collected in 1973 contain slightly anomalous metal concentrations. Silver is present in three samples, with a high value of 5 ppm (0.15 oz/ton--sample no. 5021). A minor amount of gold (0.3 ppm) is present in a quartz vein (no. 6041) from Crowder Branch in the northern part of the study area; three other veins contain traces of gold at the limit of detection, 0.17 ppm (TCC-2, 10, 12; table 6). Weak lead anomalies (100-150 ppm) occur in the same samples that have detectable silver, suggesting a common host mineral such as galena. A lead concentration of 550 ppm is present in a sample of iron-stained quartz collected on Rockstack, along the common boundary with the Joyce Kilmer-Slickrock Wilderness (Lesure and others 1977, table 1, no. 1438). One sample of a gossan-cemented breccia from the Sassafrass Ridge road just west of Eagle Gap contains 15 percent Fe, 3000 ppm Mn, 200 ppm Zn, and 100 ppm each of Co and Cu (table 3, no. 5003). This sample, although indicating anomalous base-metal mineralization, does not contain metal contents high enough to be of economic interest.

RADIOMETRIC SURVEY

Radiometric readings were made at 152 separate stations on rock exposures along the new Sassafrass Ridge road that forms the southern boundary of the study area, and along the Doublecamp-Farr Gap road. Readings were taken with a hand-held scintillometer at spacings of 100-200 meters. Graphitic and sulfidic rock of Unit V has the highest radioactivity values (table 4). Selected samples from areas of high radioactivity were analyzed quantitatively by neutron activation (table 5). Anomalously high radioactivity readings within Unit V are believed to be caused by minor concentrations of monazite in metagraywacke, slate, and metasandstone. Thin section study indicates that most of these rocks contain at least traces of monazite, and some samples contain as much as one percent. Laminated silty argillite or slate from Unit V in places have thin (1mm) detrital bands rich in zircon, epidote, and monazite. Semiquantitative electron microprobe scans of two monazite grains reveal high concentrations of rare earth elements and a high Th/U ratio, in agreement with the whole rock analyses (table 5). However, neither the uranium nor thorium contents of these rocks appear high enough to be of economic interest.

Table 3.--Partial analyses of selected samples of vein quartz and gossan collected in 1976 from the Citico Creek Wilderness Study area, Monroe Co., Tenn. All analyses by semiquantitative emission spectrographic methods except those for gold and zinc which are by atomic absorption. Spectrographic analyses are reported to the nearest number in the series 1, 1.5, 2, 3, 5, 7, 10, etc., which represent approximate midpoints of group data on a geometric scale (see text). Analyses by R.T. Hopkins, J. Sharkey, and C.A. Curtis, Branch of Exploration Research, USGS, Denver, Colo. Letter symbols: L, detected but below limit of determination (value in parentheses); N, not detected. Elements looked for but not found and their lower limits of detection, in ppm: As(200), Cd(20), Mo(5), Nb(20), Sb(100), Sn(10), Sr(100), W(50).

	Sample Numbers				
Elements percent	4165	4239	5003*	5021	6041
Ca (0.05)	N	L	0.05	N	0.1
Fe (0.05)	1.5	0.3	15	0.1	0.7
Mg (0.02)	0.15	L	0.1	L	0.02
Ti (0.002)	0.1	0.02	0.15	0.07	0.03
Elements ppm					
Ag (0.5)	1.5	2	N	5	N
Au (0.05)	N	N	N	N	0.3
B (10)	150	15	300	N	N
Ba (20)	700	70	500	50	100
Be (1)	5	L	7	N	L
Bi (10)	N	10	N	N	N
Co (5)	N	N	100	N	N
Cr (10)	20	L	20	N	L
Cu (5)	50	7	100	7	N
La (20)	50	L	200	N	N
Mn (10)	100	70	3000	500	500
Ni (5)	7	L	50	7	5
Pb (10)	150	150	10	100	L
Sc (5)	10	N	15	N	N
V (10)	30	10	30	10	L
Y (10)	15	N	70	N	N
Zn (5)	20	10	200	220	10
Zr (10)	70	N	150	15	50

* Sample of gossan-cemented breccia

Table 4.--Radioactivity ranges and mean values in rocks of the Citico Creek area, grouped by lithologic map unit (pl. 1). Radioactivity determined by hand-held scintillometer and checked by gamma ray spectrometer.

Map Unit(s)	Radioactivity Range (ur)1/	Approximate Mean Value of Radioactivity (ur)
I-IV metasandstone/ metaconglomerate)	20-30	23
I-IV (slate)	27-43	33
V	27-60	42
VI	17-50	28

1/ one ur (radioelement unit) is the radioactivity produced by 1 ppm U in radioactive equilibrium with all daughter products.

Table 5.--Concentrations of U and Th in selected rock samples of unit V, Citico Creek area (see pl. 1). Analyses by delayed neutron activation by H.T. Millard, Jr., C.M. Ellis, and V.C. Smith, U.S. Geological Survey, Denver, Colo.

Field No.	Radioactivity (ur)	Th (ppm)	U (ppm)	Th/U
S3	40	21.9	5.1	4.3
S4	60	19.2	4.4	4.4
S5	50	17.5	5.0	3.5
S10	40	19.0	3.0	6.3
S24	40	36.6	3.8	9.6
S30	30	15.1	4.3	3.5
S33	30	16.9	4.6	3.7

MINERAL APPRAISAL

Metallic Resources

Precambrian metasedimentary rocks of the Ocoee Supergroup locally contain important metallic mineral deposits, chiefly of copper and gold. The only metal anomalies within the proposed Citico Creek Wilderness are associated with minor amounts of sulfide minerals disseminated in graphitic slate and metagraywacke of unit V (see pl. 1). These strata contain up to 10 percent pyrite and (or) pyrrhotite, plus minor amounts of intergrown chalcopyrite and sphalerite, and rare galena and arsenopyrite. Concentrations of As, Co, Pb, Cu, and Zn slightly higher than background values are shown by spectrographic analysis. No potential economic value appears to be associated with this sulfide mineralization, however.

<u>Copper</u>--Copper sulfide mineralization occurs in rocks of the Ocoee Supergroup in several places near the study area. The Ducktown copper district, with one of the largest massive sulfide deposits in the world, is 42 km southwest of the proposed wilderness in southeastern Polk County, Tennessee. Primary ore now being mined there consists mainly of pyrrhotite and pyrite with associated minor chalcopyrite, sphalerite, and magnetite (Magee, 1968). Sulfuric acid is the major product of value, but copper, iron (as pellets), zinc, and minor amounts of gold and silver also are recovered.

Another region of similar sulfide mineralization occurs in western Swain County, North Carolina, at the former Fontana and Hazel Creek mines, in phyllitic rocks of the Ocoee Supergroup. The Fontana mine, about 30 km northeast of the study area, was mined between 1926 and 1944, producing more than 37,800 metric tons of copper (Espenshade, 1963). The Hazel Creek mine, also known as the Everett or Adams mine, is about 40 km northeast of the Wilderness Study Area. Mining there began about 1900 and continued intermittently until 1944. Reserves at the Hazel Creek property were estimated in 1942 to be 15,500 metric tons of high grade ore (3 to 3.5 percent each of copper and zinc), of which about 2,700 metric tons have since been mined. Approximately 29,000 metric tons of low-grade ore containing 1 to 1.7 percent combined copper and zinc also is reported (Espenshade, 1963). Both mines were permanently closed in 1944, when rail and road access was blocked by the rising waters of Fontana Reservoir.

No major gossans or abundance of copper minerals were identified within the wilderness study area. Regional geologic studies such as that by Merschat and Wiener (1973) suggest that the host rocks for the Ducktown and Fontana-Hazel Creek ores are stratigraphically higher than rocks of the Citico Creek area. Merschat and Wiener (1973) show that strata probably correlative with the massive sulfide terranes are exposed about 3 km southeast of the Wilderness Area boundary. The potential for discovery of significant copper mineralization is therefore judged to be low in the study area.

<u>Gold</u>--The proposed wilderness is about 13 km northeast of the Coker Creek district, a gold-producing area of approximately 5,000 hectares in southern Monroe County. Here, gold originating from quartz veins and fine-grained, ankeritic country rock of the

Ocoee Supergroup was discovered in 1827 and worked periodically through the 1920's (Hale, 1974). Most production has come from placer deposits and terrace gravels along main streams and their tributaries. Several attempts at underground mining, all unsuccessful, were made between 1869 and the mid-1920's. Total production of Au from the district has been estimated to be about 9,000 ounces (Hale, 1974).

Gold in or near the study area has been known for more than a century and a half, since Troost (1837) reported small amounts of gold in the Tellico River. Safford (1869, p. 489-490) cited the occurrence of gold "on the waters of Coker Creek" and projected the trend of gold-bearing rocks of the district into the Whiteoak Flats area, about 0.5 km west of the study area. Gold in Whiteoak Flats was later reported between Ballplay and Citico Creeks by Ashley (1911), and along Flats Creek and Gold Branch by Rove (1926). Rove also mentioned "vague rumors" of gold-bearing quartz veins "on the headwaters of Citico Creek."

During this study, measurable quantities of gold were detected in four rock samples and traces were found in four others. Two soil samples also contain detectable gold. All major streams of the area were panned for gold, but fire assays and atomic absorption analyses of the stream sediment samples show none present.

In addition to the gold in samples from the present study, gold was found previously in or near the Citico Creek area by Lesure and others (1977) and by the Tennessee Valley Authority (TVA, Hale, 1977, written commun.). Table 6 lists gold-bearing samples, and figure 7, illustrates the distribution of gold

Figure 7 near here.

occurrences in and near the Citico Creek Wilderness Study Area.

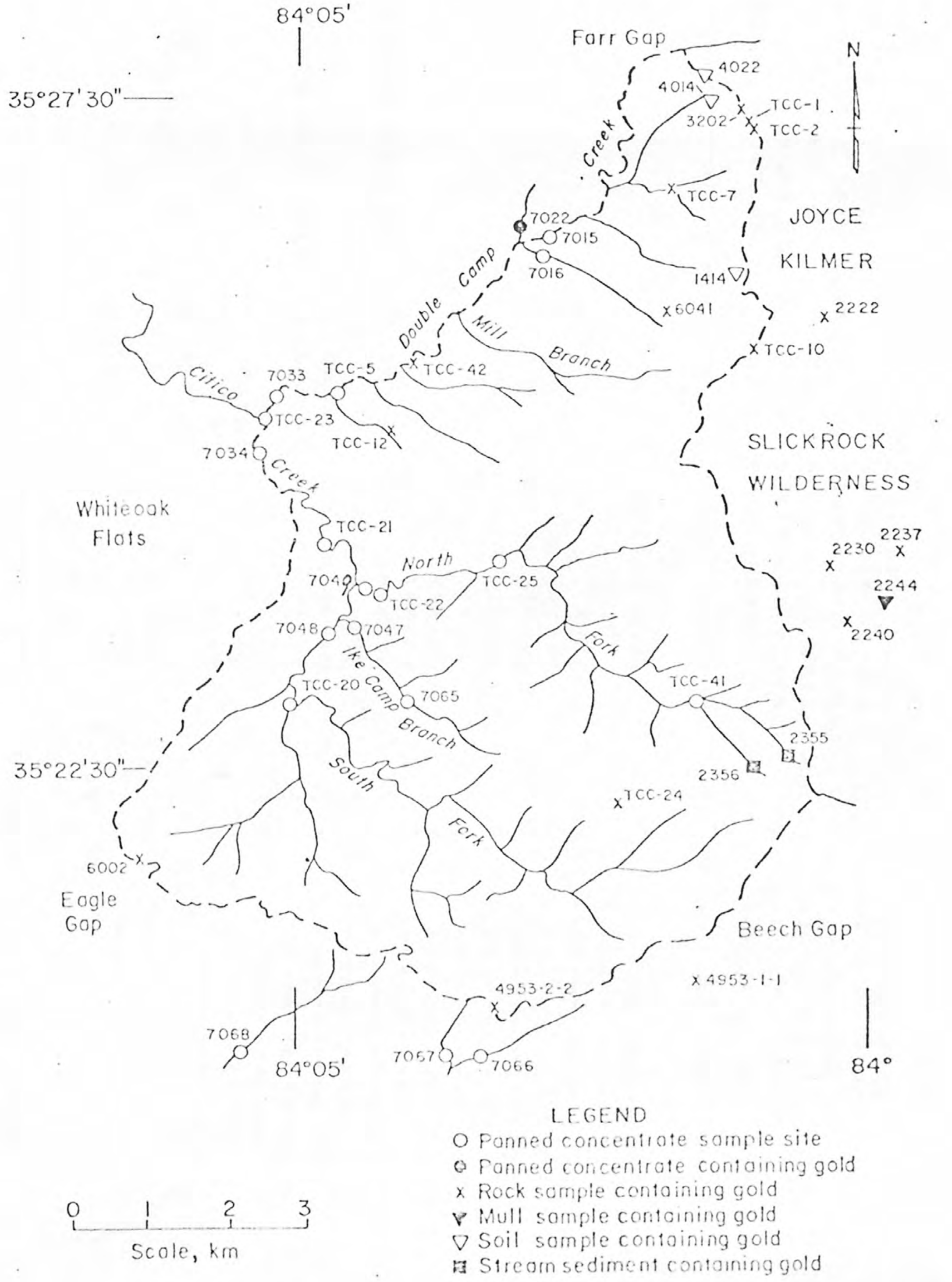

Figure 7.--Gold distribution in the Citico Creek Wilderness Study Area and vicinity.

Table 6.--Gold content of samples from the Citico Creek Wilderness Study Area and vicinity. All values are listed in parts per million (ppm), where 1 ppm = 0.0001 percent = 1 gram per metric ton. Sample locations are shown in figure 7.

Sample number 1/	Au content (ppm)	Sample description
TCC-1----------	0.21	Dark gray slate
TCC-2----------	L(0.17) 2/	Vein quartz
TCC-7----------	0.31	Dark gray slate
TCC-10---------	L(0.17)	Vein quartz
TCC-12---------	L(0.17)	Do.
TCC-24---------	0.34	Dark gray slate
TCC-42---------	L(0.17)	Pyrite concentrate
1414-----------	L(0.1)	Soil
2222-----------	0.3	Interlayered pale and medium gray slate
2230-----------	0.1	Arkosic metaconglomerate
2237-----------	0.1	Dark gray slate
2240-----------	0.1	Sheared light olive gray arkosic metasandstone
2244-----------	L(0.12)	Forest litter
2355-----------	L(0.05)	Stream sediment
2356-----------	L(0.05)	Do.
3202-----------	0.3	Pyrite concentrate
4953-1-1-------	0.03	Metagraywacke
4953-2-2-------	0.02	Coarse metasandstone
4014-----------	L(0.05)	Soil
4022-----------	L(0.05)	Do.
6041-----------	0.3	Vein quartz

1/ TCC prefixed numbers from present investigation, fire assay tests; one, two, and three thousand numbers from Lesure and others, 1977, atomic absorption analyses; 4953 numbers from Robin C. Hale, Tennessee Valley Authority, Geologic Branch, Knoxville, Tennessee, written commun., 1977, atomic absorption analyses; 4014, 4022, and 6041 samples from this study, atomic absorption analyses.

2/ L( ) = Detected but below limit of determination or below value shown.

Traces of gold were found along Doublecamp Creek and the Unicoi Mountain highlands in gray, pyritic slates and in thin quartz veins. Lesure and others (1977, p. 26) report 0.3 ppm gold in a sample of pyrite porphyroblasts from slate (no. 3202) on Little Fodderstack Mountain on the eastern boundary. A similar porphyroblast sample (TCC-42) from a roadcut along the lower reaches of Doublecamp Creek contains a trace of gold (<0.17 ppm). Three samples of vein quartz (nos. TCC-2, 10, 12) have detectable gold; a sample of quartz (no. 6041) from the area of Crowder Branch contains 0.3 ppm gold. One panned concentrate sample collected from Flint Branch along the northwest boundary of the study area yielded a 0.5 mm ribbon-shaped grain of gold.

Minor amounts of gold also were found in the highlands surrounding the headwaters of the north and south forks of Citico Creek; this coincides with the "vague rumors" of gold mentioned by Rove (1926, p. 67). Here, traces of gold occur in dark gray slates, metasandstones, metaconglomerates, and thin quartz veins of units IV and V. Lesure and others (1977, p. 23) reported gold in the same area, from two stream sediment samples (2355 and 2356), four rock samples (2222, 2230, 2237, and 2240), a soil sample (1414), and a mull sample (2244). The gold-bearing TVA samples (4953-1-1 and 4953-2-2) are also from this region. According to Hale (1974, p. 16), Unit 2 (of Merschat and Wiener, 1973; Unit III of this study) in the Great Smoky Group contains the so-called "Unaka veins," but gold was not detected in two quartz veins sampled from this unit during the present study. Rove (1926, p. 28) reported gold in similar veins in the Unicoi Mountains east of Coker Creek, Tennessee. In the present study, also, gold was not detected in samples of conglomerate from Unit 2 which Rove (1926, p. 26) indicated to be gold-bearing in the Coker Creek area. Because of the low tenor of gold-bearing rocks in the study area and the lack of large alluvial deposits, it is doubtful that commercial quantities of gold exist there.

<u>Iron</u>--Troost (1837) first noted traces of iron (possibly pyrite altered to limonite) in Citico Creek, north of the study area. Safford (1869) later included the general area in the Eastern (Tennessee) Iron Region which, in 1854, had nine operating furnaces. One of the largest operations, the Tellico Iron Works, was 15 km west of the study area on the Tellico River. Much of the ore was mined from ferruginous sandstones of the Ocoee Supergroup, and most of the iron was siliceous and high in phosphorous. Gossan was mined for iron in the Ducktown Copper district until depletion in 1907. Since that time, iron sinter and pellets have been produced at Ducktown as a by-product of sulfuric acid manufacture from primary iron sulfides.

Neither highly ferruginous sandstone nor major gossan deposits were found in the study area. One small exposure of gossan-cemented breccia contains 15 percent iron (table 3); another red oxidized metasandstone (Sample TCC-36) contains only 4 percent iron. Most rocks in the study area have traces of pyrite or pyrrhotite, with as much as 10 percent present locally. However, these concentrations of iron in sulfides, as well as in the gossan, are too low to be of current economic interest.

Nonmetallic Resources

Nonmetallic mineral resources within the Citico Creek study area include slate, graphite, stone, silica, and sand and gravel. Some slate might find marginal use for structural clay products, but like the other nonmetallic resources, is present in larger quantities and is more easily recovered outside of the proposed Wilderness.

Slate--Slate units generally do not crop out in the study area, but are exposed along roadcuts and streambeds. Commonly slates are gray to black in color, are in many areas pyritic, and also are locally graphitic. Variegated yellow, red, violet, blue, and brown slate is also present, typically with cleavage at a high angle to bedding (fig. 5), creating attractive banded slabs. Some of the slate could probably be crushed for use as roofing granules and pulverized for mineral filler. For these uses color uniformity and rock purity (lack of carbonate, sulfides) would be necessary, although many slate granules are artificially colored (Bates, 1960).

Neither variety of slate would be suitable for dimension slate that is competitive with other products. Detrimental factors include: (1) pyrite porphyroblasts forming "knots", which, aside from contributing to waste, would weather and stain; (2) lack of color uniformity (in the variegated variety) required of dimension stone (Pa. State Coll., 1947); and (3) cleavage at a high angle to bedding (Fig. 5), which where present creates rod-shaped pieces that make the rock useless as dimension stone.

Ceramic evaluation tests by the Bureau of Mines Metallurgy Research Center, Tuscaloosa, Alabama, of three slate samples (TCC-13, 14, and 15) showed that all would have only marginal use for structural clay products such as building brick or tile (see table 7). The lack of a nearby market area in the foreseeable future suggests a low economic potential for these rocks.

Graphite--Dark slate of Unit V in places is sooty black and shiny surfaced, especially near Eagle Gap along the Sassafrass Ridge road. This material, which in hand specimen appears graphitic, is typically very fine-grained, occurring either disseminated throughout the rock, or concentrated in irregular flattened chips, 1-5 cm across. No high-quality flake graphite was seen in any of these rocks, presumably because of the low metamorphic grade of the area.

Qualitative X-ray emission tests revealed the presence of major graphite peaks in unit V slate samples TCC-24 and TCC-31. Special chemical tests were performed in which residues from HCl- and HF-treated samples were burned to determine total carbon and organic carbon content. Sample TCC-24 contains 1.5 percent total carbon and 0.95 percent organic carbon, leaving 0.55 percent inorganic carbon, which probably is graphite. Similarly, TCC-31 has 0.92 percent total carbon, 0.62 percent organic carbon, and 0.30 percent inorganic carbon or graphite. Additional x-ray studies of several shiny black specimens of slate from near Eagle Gap failed to show any characteristic graphite peaks, suggesting an amorphous rather than crystalline state. Five analyzed samples from here contain less than 2 percent non-carbonate carbon. These fine-grained deposits of graphitic-like rock

TABLE 7. - Ceramic evaluation of slates

Sample number	Sample interval (meters)	Raw properties 1/	Slow firing test: Temp. 2/ °C.	Munsell color	Mohs' hardness	Total shrinkage (percent)	Absorption (percent)	Apparent porosity (percent)	Bulk density (gm/cc)	Potential use
TCC-13	7.6	Water plasticity: 20.0%	1000	5 YR 7/6	2	2.5	25.6	41.1	1.61	Marginal for structural clay products
		Color: gray	1050	2.5 YR 7/6	2	2.5	24.6	40.1	1.63	
		Drying shrinkage: 2.5%	1100	2.5 YR 5/8	2	2.5	17.8	32.4	1.82	
		pH: 7.2	1150	10 R 5/6	3	7.5	10.6	22.1	2.09	
			1200	10 R 4/4	4	10.0	7.2	16.2	2.24	
			1250	-	-	Melted	-	-	-	
TCC-14	4.6	Water plasticity: 22.0%	1000	5 YR 7/6	2	2.5	24.7	40.1	1.63	Marginal for structural clay products
		Color: gray	1050	2.5 YR 6/8	2	2.5	24.1	39.9	1.65	
		Drying shrinkage: 0.0%	1100	2.5 YR 5/8	3	2.5	17.4	32.1	1.84	
		pH: 5.6	1150	10 R 5/6	3	5.0	12.7	25.2	1.98	
			1200	2.5 YR 4/6	4	7.5	8.0	17.2	2.14	
			1250	-	-	Melted	-	-	-	
TCC-15	4.6	Water plasticity: 27.7%	1000	5 YR 7/6	2	2.5	27.3	42.9	1.57	Marginal for structural clay products
		Color: tan	1050	2.5 YR 6/8	2	2.5	25.4	40.8	1.61	
		Drying shrinkage: 0.0%	1100	2.5 YR 5/8	3	2.5	17.6	32.4	1.83	
		pH: 6.4	1150	10 R 5/6	3	7.5	13.3	26.1	1.96	
			1200	2.5 YR 4/6	4	7.5	7.5	16.2	2.16	
			1250	10 YR 4/2	5	10.0	0.0	0.0	2.38	

1/ Tests indicate the following for all samples: Working properties--short; dry strength--fair; no HCl effervescence; preliminary bloating tests--negative.

2/ Abrupt vitrification for all samples below 1250° C.

cannot compete with higher grade flake graphite mainly in foreign deposits (Mexico), or from more easily worked deposits in Alabama and Pennsylvania (Pallister and Thoenen, 1948; Sanford and Lamb, 1949).

Stone--Metasandstone, metagraywacke, and metaconglomerate in the area may be suitable as riprap, railroad ballast, and road material. A small quarry on the south side of Citico Creek. about 1.5 km upstream of the confluence with Doublecamp Creek, removed massively bedded metasandstone and metaconglomerate of unit III, presumably for use as road metal. Stone has only been utilized locally, however, and there is no reason to believe that a wider market exists in the future.

Some units of attractive blue quartz metagraywacke and metaconglomerate also have potential use as dimension stone. They have low porosity and high strength due to recrystallization and commonly are massively bedded. However, in many areas they contain disseminated iron sulfides (pyrite and/or pyrrhotite) which would form unsightly stains upon weathering. The presence of iron sulfides and variable grain size in some beds would considerably restrict use of the stone.

Silica--Thick, relatively pure quartz veins occur in slate and metasiltstone along Doublecamp Creek and near Beehouse Gap. Outcrops of veins as much as 2 m thick were found at several locations, and some float blocks suggest that thicker veins may exist. Quartz veins possibly could be utilized as a source of fluxstone, silica flour, or ferrosilicon. In the past, a small amount of vein quartz from nearby areas has been used as a fluxstone in copper smelting in the Ducktown copper district (Hurst, 1955). However, the costs of working, crushing, and transporting the quartz would not be competitive with that from other sources.

Sand and gravel--Minor amounts of sand and gravel occur as alluvium along a few streams, especially the lower parts of Doublecamp Creek and Citico Creek. Larger and more easily recovered deposits are found in other regions outside the study area, therefore their economic potential is judged to be low.

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