DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1625-A
PAMPHLET

MINERAL RESOURCE POTENTIAL MAP OF THE BREAD LOAF ROADLESS AREA, ADDISON AND WASHINGTON COUNTIES, VERMONT

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1983

Studies Related to Wilderness

Under the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and related acts, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. 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. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Bread Loaf Roadless Area, Green Mountain National Forest, Addison and Washington Counties, Vt. The Bread Loaf Roadless Area (09-081) was classified as a further planning area during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

In 1980 and 1981, a mineral resource survey was made of the Bread Loaf Roadless Area, Vermont. Geochemical sampling programs identified significant concentrations of copper, lead, zinc, and barium in rocks, soils, and drainage samples (stream sediments and panned concentrates), particularly in the northern part of the roadless area. Anomalous amounts of arsenic, cobalt, boron, and manganese were also detected in some samples. The geologic setting and geochemical anomalies suggest a low to moderate potential for volcanogenic massive sulfide deposits of copper, lead, and zinc, in the Mount Abraham Schist and the Hazens Notch Formation. The geochemically most anomalous samples are from the Hazens Notch Formation, near its contact with the easternmost part of the Mount Abraham Schist.

Nonmetallic commodities in the Bread Loaf Roadless Area include minor deposits of sand and gravel, and abundant rock suitable for crushing. However, large amounts of these materials are available in more accessible locations in the surrounding region. Oil and natural gas at great depth may also exist, but this cannot be evaluated by the present investigation.

INTRODUCTION

The Bread Loaf Roadless Area comprises 19,850 acres in the Green Mountain National Forest in Addison and Washington Counties, central Vermont (fig. 1). The area is extremely rugged and contains some of the highest peaks in the State, including Bread Loaf Mountain (3835 ft), Mt. Wilson (3785 ft), Mt. Roosevelt (3528 ft), Mt. Cleveland (3482 ft), and Mt. Grant (3623 ft). Total relief is nearly 2600 ft, from a low elevation of 1240 ft at the southeast corner to a high point of 3835 ft on the southern crest of Bread Loaf Mountain. The nearest towns are Warren and Hancock, each a few miles to the northeast and southeast, respectively. The villages of Granville, South Lincoln, and Ripton are nearby. The well-known Bread Loaf Writers' School is about 2 mi from the southwestern boundary of the roadless area; the Middlebury College Ski Bowl is adjacent to the southern border at Middlebury Gap (fig. 3). Principal access is provided by State Route 100 along the eastern side of the area, and by State Route 125 which forms the southern border; U.S. Forest Service Roads 54 and 59 are near the western boundary. Old logging roads and several foot trails (including the Long Trail) allow entry into the interior, and access to most of the high peaks. The north-south topographic divide provided by these peaks has developed many sizeable streams draining east and west from the divide. These streams, which include the headwaters of the New Haven, White, Middlebury, and Mad Rivers, ultimately discharge either west into Lake Champlain, or east

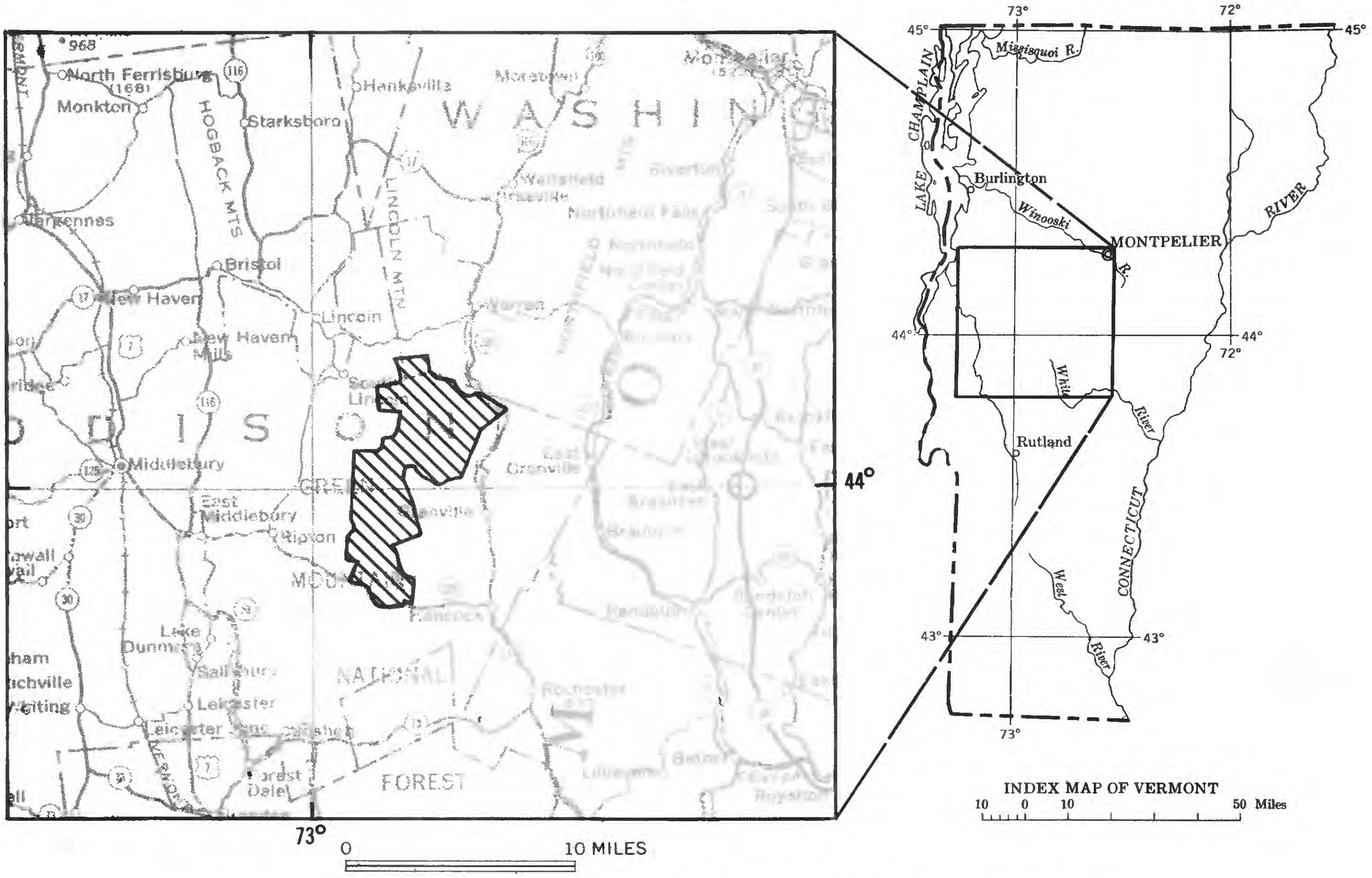


Figure 1.—Index map showing location of the Bread Loaf Roadless Area.

into the Connecticut River.

Previous and present investigations

The Bread Loaf Roadless Area has been the focus of several previous geologic investigations. Parts of the area (hereinafter also termed Bread Loaf area or study area) were briefly described in the early reports of Seely (1910), Foye (1918), and Gordon (1927). The first geologic mapping by Osberg (1952) covered the southern part of the roadless area. More recent work by Cady and others (1962) presented a revised stratigraphy and thorough description of the geology of the northern part of the study area. Geochemical and isotopic studies have also been carried out on samples from a location west of Mt. Grant (Albee, 1965; Taylor and others, 1963).

The present investigation began in the fall of 1980 with work by both the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Field studies by the USBM, carried out by R. F. Bitar and M. K. Armstrong, included ground radiometric surveys and the collection of 53 rock samples for geochemical analysis. The samples were analyzed by semiquantitative spectrographic techniques for 42 elements and by atomic absorption methods (quantitative) for iron, copper, and titanium. Selected samples were also analyzed for silica (by wet chemistry) and uranium (by fluorometry).

Work by the USGS included geologic, geochemical, and geophysical studies. Reconnaissance geologic mapping and sampling was carried out by J. F. Slack and R. A. Ayuso in 1980 (and briefly in 1981), with the assistance of A. R. Pyke, R. L. Graves, P. J. Loferski, and M. P. Foose. A. E. Grosz, USGS, concurrently collected samples of stream sediment and panned concentrate. A total of 176 rocks, 208 soils, 72 stream sediments, and 18 panned concentrates was collected and analyzed semiquantitatively for 31 elements (by spectrographic methods) and quantitatively for gold and zinc (by atomic absorption); the geochemical data for these samples are presented in Erickson and others (1984). Selected rock samples from the study area were also analyzed for uranium and thorium by neutron activation methods. The geophysical surveys of the area, which include airborne magnetic and radiometric coverage, are described by Slack and others (in press).

SURFACE- AND MINERAL-RIGHTS OWNERSHIP

Surface and mineral rights in the Bread Loaf Roadless Area are owned entirely by the Federal Government. More than half of the roadless area, however, is currently under lease application for oil and gas exploration. The applications cover about 10,067 acres, mainly in the western part of the area (fig. 2).

GEOLOGIC SETTING

The geology of the Bread Loaf Roadless Area is dominated by a series of typically schistose rocks of Late Proterozoic and(or) Early Cambrian age. Pleistocene glacial deposits are also present locally, particularly at lower elevations where till and outwash are common. The bedrock in the area forms part of an extensive cover sequence unconformably overlying the Middle Proterozoic (Grenville) basement terrane of the Mount Holly Complex to the west (Doll and others, 1961; Cady and others, 1962). The cover rocks (fig. 3) have been assigned by Cady and others (1962) to several formal stratigraphic units, including (from oldest to youngest): 1) the Hoosac Formation, 2) the Underhill Formation, 3) the Mount Abraham Schist, 4) the Hazens Notch Formation, 5) the Pinney Hollow Formation, and 6) the Ottauquechee Formation. Major lithologies within these units are carbonaceous and noncarbonaceous quartz-muscovite schist, quartz-albite-mica schist, quartz-mica-chlorite schist, and schistose impure quartzite. These rocks are interpreted to be mixtures of metamorphosed shale, graywacke, and volcaniclastic sediment. Thin conformable layers of fine-grained greenstone occur locally in the Hazens Notch and Pinney Hollow Formations (fig. 3) and are believed to be basaltic metatuffs. A more unusual lithology represented by the Mount Abraham Schist consists of white mica (chiefly paragonite), quartz, chlorite, and chloritoid. The presence of abundant paragonite throughout this unit (Albee, 1965) suggests a highly aluminous bulk composition. The occurrence of chloritoid is also of interest, as it is in general restricted to rocks having high iron/magnesium ratios (Halferdahl, 1961; Miyashiro, 1973). The protolith of the Mount Abraham Schist is not known, but may have in part developed during submarine hydrothermal alteration (Slack and others, in press).

Many of the rocks in the Bread Loaf area contain sulfide minerals. Pyrrhotite and pyrite are the principal sulfides, occurring mainly in the Hazens Notch Formation and the Mount Abraham Schist. In the Hazens Notch, pyrrhotite occurs as disseminations in noncarbonaceous albite schist; in places, the pyrrhotite constitutes as much as 10 percent of the rock volume. The highly carbonaceous quartz-muscovite schist of the Hazens Notch typically contains euhedral cubes of pyrite (or molds) up to 1 in. in diameter. Pyrite is also common in aggregates of fine-grained crystals in the Mount Abraham Schist, particularly near its eastern contact with the Hazens Notch Formation. Chalcopyrite has been observed in several areas as very small grains intergrown with pyrrhotite (in albitic schist), and as thin films smeared out in the plane of the schistosity of the carbonaceous schist. Minor amounts of malachite have been noted as stains on several outcrops in the northern and central parts of the study area; malachite has also been reported from west of Mt. Grant by Albee (1965, p. 252). Presumably, the malachite—a secondary copper mineral—is derived from chalcopyrite in nearby rocks.

The structural geology of the Bread Loaf area has been outlined by Osberg (1952) and by Cady and others (1962). In general, the structure can be viewed as an eastward-dipping homoclinal succession, in which the youngest rocks occur along the eastern boundary of the study area. In places, however, this simple interpretation may be incorrect, as evidenced by some lithologic contacts and by the multiple generations of folds observed in many outcrops. Previously, Cady and others (1962) mapped highly irregular contacts between the Mount Abraham Schist and the Hazens Notch Formation in the western part of the area, and interpreted them as primary facies changes. The nature of the contacts might also reflect other processes, though, such as polyphase deformation or complex thrust faulting. The available field data do

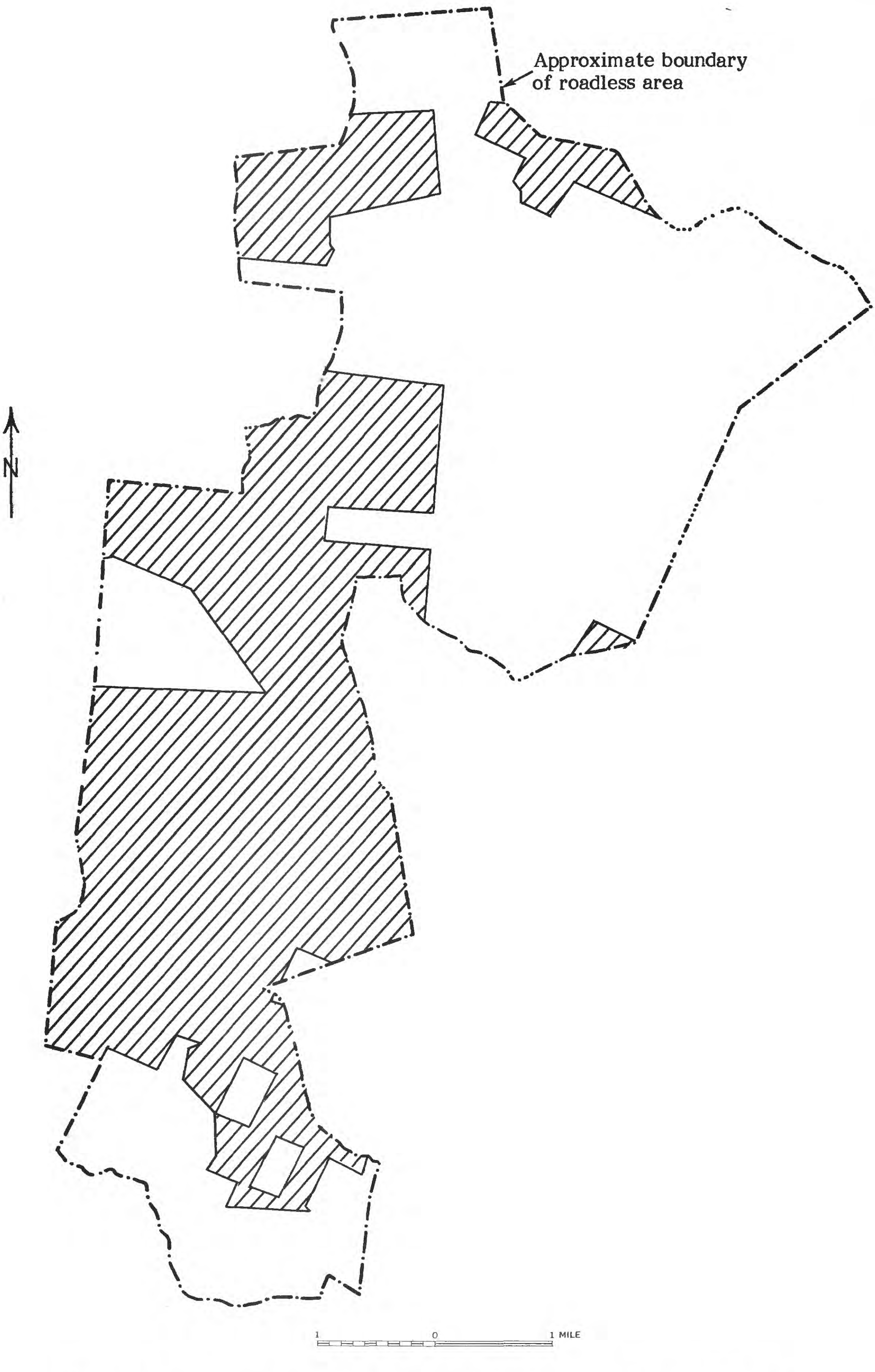


Figure 2.—Areas under application for oil and gas leases (hachured) in the Bread Loaf Roadless Area.

not discriminate among these possibilities, and more detailed work is needed for a thorough understanding of the local structure.

Field and laboratory studies of rocks in the roadless area have recognized mineral assemblages characteristic of both the greenschist and amphibolite facies of regional metamorphism. The geologic work of Osberg (1952) and Cady and others (1962) identified garnet-grade rocks in the western part of the study area, and biotite-grade rocks systematically to the east; the garnet isograd trends north-northeast, near the topographic divide. Kyanite also has been reported from the area, but appears to be restricted to chloritoid-bearing assemblages in the Mount Abraham Schist (Osberg, 1952; Cady and others, 1962; Albee, 1965). Minor amounts of staurolite have been identified in some of these rocks as well. The staurolite has a very limited distribution, however, and may have been stabilized at anomalously low pressure and temperature conditions in the Bread Loaf area by an unusual zinc-rich bulk composition (Albee, 1968, 1972).

GEOPHYSICAL SURVEYS

Geophysical surveys of the Bread Loaf area were made by means of magnetic and radiometric methods (Slack and others, in press). The magnetic data were acquired by an airborne survey at an altitude of approximately 500 ft, for flight lines spaced 0.5 mi apart. Maps of contoured aeromagnetic data show many small anomalies. The largest, at approximately 350 gammas, closely correlates with a body of metagabbro in the eastern part of the study area (fig. 3, ЄZhnm). Other anomalies in this eastern belt range from about 300 to nearly 350 gammas, and appear to reflect the presence of small lenses of greenstone. In the western part of the Bread Loaf area, several magnetic anomalies of 100 to 200 gammas occur, but they are located in the Hazens Notch Formation and the Mount Abraham Schist, where no major bodies of mafic rock are known. The occurrences of disseminated pyrrhotite in places in the Hazens Notch Formation and of porphyroblastic magnetite locally in the Mount Abraham Schist are the most likely cause of these magnetic anomalies.

Radiometric coverage was obtained by both airborne and ground surveys. Maps of contoured airborne total-count data show that a few anomalies are located in the southern part of the study area where underlain by the Underhill Formation and the Mount Abraham Schist. Ground surveys, however, failed to locate any highly radioactive outcrops in these rock units. The low magnitude of the anomalies and the lack of ground verification suggests no major concentration of uranium- or thorium-bearing minerals in the study area. The most probable cause of the anomalies is abundant feldspar in the metasedimentary units.

GEOCHEMICAL SURVEY

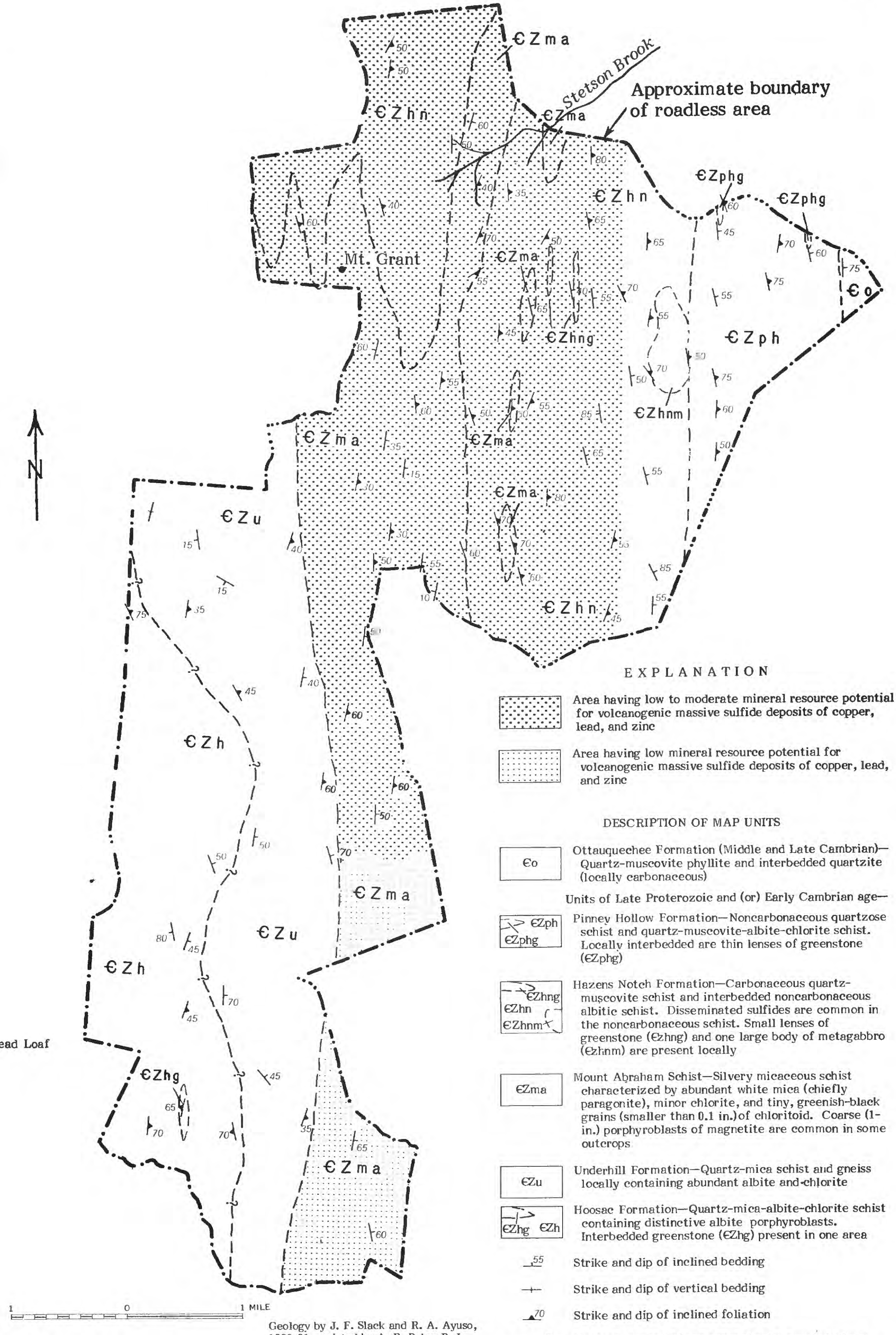
Geochemical analyses of nearly 500 rocks, soils, and drainage samples (stream sediments and panned concentrates) show concentrations of a suite of elements including arsenic, copper, zinc, cobalt, lead, barium, boron, and manganese. In all cases, these elements were identified in anomalously high amounts in bedrock samples, thus precluding a distant (glacial) source. The geochemical survey also detected minor quantities of silver, gold, nickel, and chromium, but the distribution of these metals appears to be unrelated to that of the anomalous suite. Local concentrations of molybdenum, tin, and thorium discovered in certain drainage samples have not been verified in the bedrock of the study area, and may have been glacially derived from a source to the north.

Geochemical data for 176 rock samples show anomalously high values for arsenic, copper, lead, zinc, cobalt, barium, boron, and manganese, especially in samples from the northern part of the study area (fig. 4). Samples of micaceous schist contain as much as 200 parts per million (ppm) arsenic, 300 ppm copper, 300 ppm zinc, 5000 ppm barium, 1000 ppm boron, and more than 5000 ppm manganese. Rock samples containing abundant quartz (quartzite, granofels) have up to 700 ppm copper, 200 ppm lead, 1300 ppm zinc, 100 ppm cobalt, 2000 ppm barium, 1000 ppm boron, and 5000 ppm manganese; bismuth and cadmium were also detected (10-20 ppm) in one sample. Histograms for this suite of elements (Slack and Atelsek, in press) show the highest values to be statistically anomalous when compared with data for lithologically similar rocks. Most of these anomalous samples were collected from a linear belt that conforms, in general, to the western part of the Hazens Notch Formation. Some of the anomalous samples are also from the Mount Abraham Schist, but only for locations close to the contact with the Hazens Notch Formation.

Geochemical analyses of 208 soil samples reveal high-background values that show a general correlation with the anomalous suite of metals identified in rocks. The soil samples were in most cases taken on steep slopes where glacial till was absent or very thin. As a result, the soil geochemical data are believed to closely reflect the composition of the underlying bedrock. Although no statistically anomalous metal concentrations are evident, histograms suggest that high-background values for copper, lead, zinc, cobalt, barium, and manganese are present in several samples (Slack and Atelsek, in press). The distribution of these samples (fig. 4) is broadly coincident with the linear belt containing the anomalous rock values, in the Hazens Notch Formation near its contact with the easternmost part of the Mount Abraham Schist.

Geochemical data for 72 stream-sediment samples show only a few anomalous metal values. Histograms compiled for a suite of elements (Slack and Atelsek, in press) display characteristic normal distributions, except for barium and cobalt. The distribution of data for barium includes anomalously high (1500-2000 ppm) values for several samples; one sample also contains 200 ppm cobalt. The barium-rich samples all were collected from small stream basins within drainage area 411, in the northernmost part of the study area (fig. 5; see also Slack and Atelsek, in press). Although not statistically anomalous, many of the highest values for copper, lead, and zinc were obtained from stream-sediment samples from these same basins, and from geologically related basins along strike to the south.

A detailed study of the geochemistry of 18 panned-concentrate samples indicates that copper, lead, zinc, and barium are largely concentrated in drainages in the northern part of the study area. Data for standard magnetic and non-magnetic heavy-mineral fractions lack statistically based metal



EXPLANATION

Area having low to moderate mineral resource potential for volcanogenic massive sulfide deposits of copper, lead, and zinc

Area having low mineral resource potential for volcanogenic massive sulfide deposits of copper, lead, and zinc

DESCRIPTION OF MAP UNITS

€o — Ottauquechee Formation (Middle and Late Cambrian)—Quartz-muscovite phyllite and interbedded quartzite (locally carbonaceous)

Units of Late Proterozoic and (or) Early Cambrian age—

€Zph, €Zphg — Pinney Hollow Formation—Noncarbonaceous quartzose schist and quartz-muscovite-albite-chlorite schist. Locally interbedded are thin lenses of greenstone (€Zphg)

€Zhng, €Zhn, €Zhnm — Hazens Notch Formation—Carbonaceous quartz-muscovite schist and interbedded noncarbonaceous albitic schist. Disseminated sulfides are common in the noncarbonaceous schist. Small lenses of greenstone (€zhng) and one large body of metagabbro (€zhnm) are present locally

€Zma — Mount Abraham Schist—Silvery micaceous schist characterized by abundant white mica (chiefly paragonite), minor chlorite, and tiny, greenish-black grains (smaller than 0.1 in.) of chloritoid. Coarse (1-in.) porphyroblasts of magnetite are common in some outcrops

€Zu — Underhill Formation—Quartz-mica schist and gneiss locally containing abundant albite and chlorite

€Zhg, €Zh — Hoosac Formation—Quartz-mica-albite-chlorite schist containing distinctive albite porphyroblasts. Interbedded greenstone (€Zhg) present in one area

55 — Strike and dip of inclined bedding

Strike and dip of vertical bedding

70 — Strike and dip of inclined foliation

— — —?— Contact, dashed where approximate, queried where uncertain

Figure 3.—Geologic map of the Bread Loaf Roadless Area showing areas of mineral resource potential. Geology modified from Cady and others (1962) and Doll and others (1961). Surficial deposits not shown.

anomalies. However, a more detailed laboratory separation procedure (Grosz and others, in press) yielded fractions having systematic high-background concentrations (fig. 6). These concentrations, identified mainly for copper, lead, zinc, and barium, are broadly coincident with the high values determined for these elements in samples of stream sediment (fig. 5) and bedrock (fig. 4).

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Potential metallic mineral resources in the Bread Loaf Roadless Area include copper, lead, and zinc in volcanogenic massive sulfide deposits. The nonmetallic commodities in the study area are small deposits of sand and gravel and abundant rock suitable for crushing. Oil and natural gas at depth may also exist, but this cannot be evaluated by the present investigation.

Massive sulfides

Massive sulfide deposits typically consist of stratabound and commonly stratiform accumulations of sulfide minerals in sedimentary and(or) volcanic rocks. The chief economically recoverable metals are copper and zinc, although many deposits yield significant amounts of silver and lead as well. The deposits are typically conformable within specific rock layers, and, as a result, tend to form stratigraphic units parallel to the trend of the surrounding strata. Where these strata include volcanic rocks, the deposits are believed to be related to submarine volcanism, and are classified as volcanogenic (Hutchinson, 1973; Franklin and others, 1981).

The geologic setting and geochemical anomalies identified in the Bread Loaf area suggest a potential for massive sulfide deposits in several ways. First, the sequence of metamorphic schists in the study area is interpreted to be a mixture of sedimentary and minor mafic volcanic rocks of Late Proterozoic and(or) Early Cambrian age. Rocks of similar age and lithology throughout the world, including many parts of the Appalachian-Caledonian orogen, are known to contain massive sulfide deposits (Vokes and Zachrisson, 1980). Second, and more significant, are the concentrations of certain elements identified in the rocks of the Bread Loaf area. In addition to detecting the base metals themselves (copper, lead, and zinc), the geochemical survey discovered rocks enriched in barium, manganese, and boron. These elements probably reflect an abundance of barite, spessartine-rich garnet, and tourmaline respectively, which, when concentrated, are considered valuable prospecting guides for massive sulfide deposits (Slack, 1982).

Third, a potential indicator of massive sulfides in the study area is the mineralogy of the Mount Abraham Schist. This unit consists largely of paragonite and minor muscovite, quartz, chlorite, and chloritoid, although in places the chloritoid composes as much as 80 percent of the rock (Albee, 1965). Rocks containing chloritoid typically have high iron/magnesium ratios (Halferdahl, 1961). The presence of abundant paragonite in this unit is also of interest, as evidence of an extremely aluminous bulk composition (Miyashiro, 1973). In an area near Mt. Grant, the Mount Abraham Schist additionally contains manganese-rich garnet and zinc-rich staurolite, the latter having as much as 5.5 weight percent ZnO (Albee, 1972, figs. 5 and 6). Highly aluminous rocks, as well as garnet and staurolite rich in manganese and zinc, respectively, are known to be associated with massive sulfide deposits. Chloritoid may also be related to mineralizing processes, on the basis of its occurrence both in the alteration zone of the Mattabi deposits, Canada (Franklin and others, 1975), and near base-metal and gold deposits in the southeastern United States (Carpenter and Allard, 1982). The unusual mineralogy and mineral chemistry of the Mount Abraham Schist does not appear to be typical of metasedimentary (or metavolcanic) rocks, and may have developed in part through the metamorphism of hydrothermally altered rocks (Slack and others, in press).

The most favorable location for the occurrence of massive sulfide deposits is in the northern to north-central part of the study area. Bedrock samples showing the highest geochemical anomalies were collected from the northernmost drainage basin, southeast of Lincoln Gap. Other significant anomalies are evident nearby to the south and southeast, particularly at the head of Stetson Brook. These areas coincide, in general, with the distribution of the Hazens Notch Formation and the eastern part of the Mount Abraham Schist, and are assigned a low to moderate potential for volcanogenic massive sulfide deposits (fig. 3). Utilizing the criteria of Taylor and Steven (1983), we designate the geochemically most anomalous areas as having a moderate potential for these types of deposits. A low potential is assigned to stratigraphically equivalent rocks along strike to the south, where no bedrock anomalies are known.

Talc and verde antique

Talc and verde antique are important commodities currently being mined at several localities in Vermont. The closest mines, near Rochester, Hancock, and Roxbury, are developed on bodies of ultramafic rock (talc, serpentinite) within the Ottauquechee and Stowe Formations. In northern Vermont, talc is produced from ultramafic bodies in the Hazens Notch Formation. The presence in the study area of both the Ottauquechee and Hazens Notch Formations suggests the possibility of similar ultramafic bodies containing talc or verde antique. Geologic mapping in the Bread Loaf area, however, has not identified any ultramafic rocks (Osberg, 1952; Cady and others, 1962; Slack and others, in press). There is thus no evidence of a potential for deposits of talc or verde antique in the study area.

Crushed stone

Much of the rock exposed in the Bread Loaf area is suitable for use as crushed stone for road aggregate or for general construction purposes. However, abundant accessible rock is available outside the study area closer to most markets.

Sand and gravel

A few small deposits of sand and gravel are in the study area, mainly near its southwestern boundary east and northeast of the writers' school at Bread Loaf. Two of these deposits have been worked in the past in small pits. However, there is an abundance of

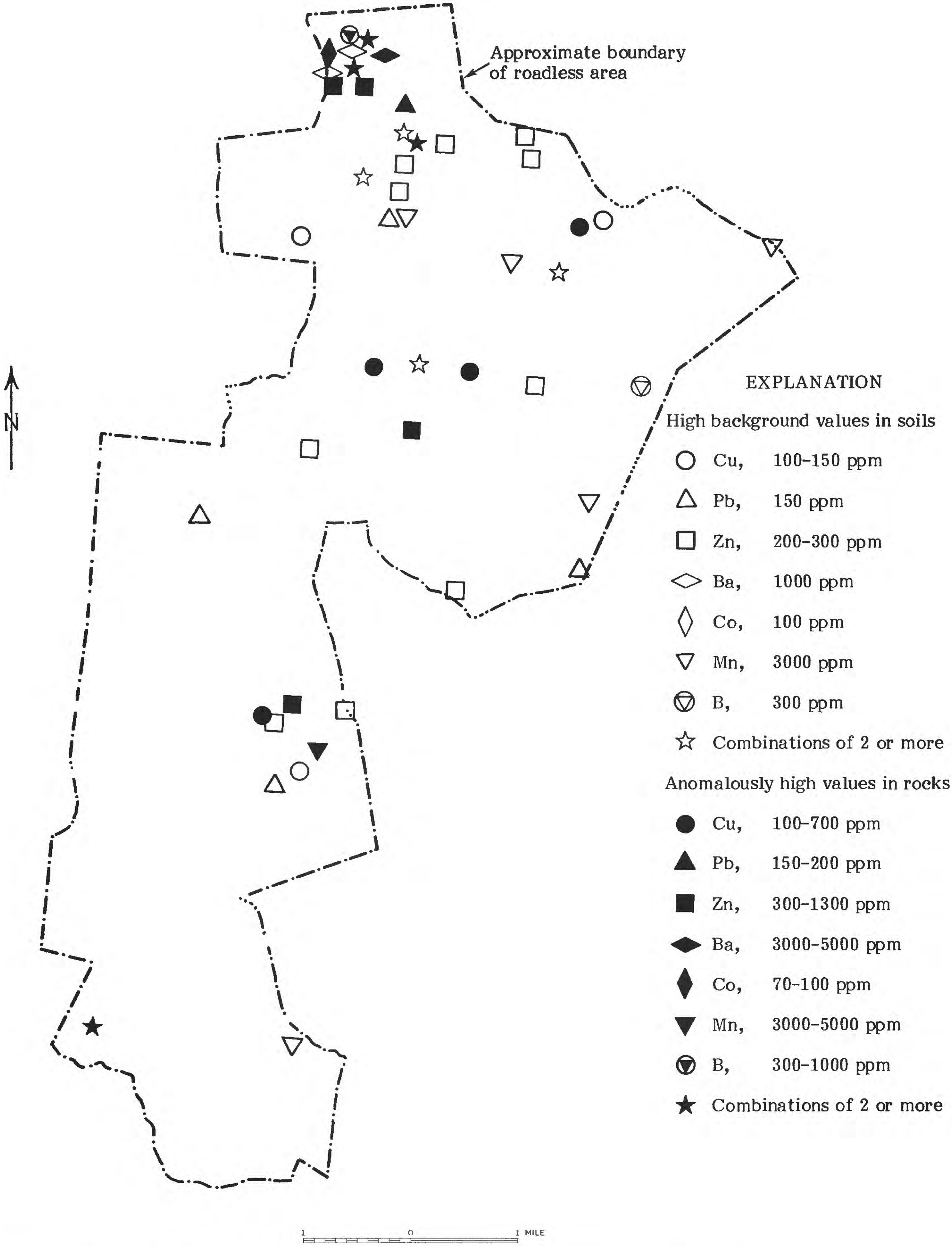


Figure 4.—Distribution of soil samples containing high-background metal values and rock samples containing anomalously high metal values.

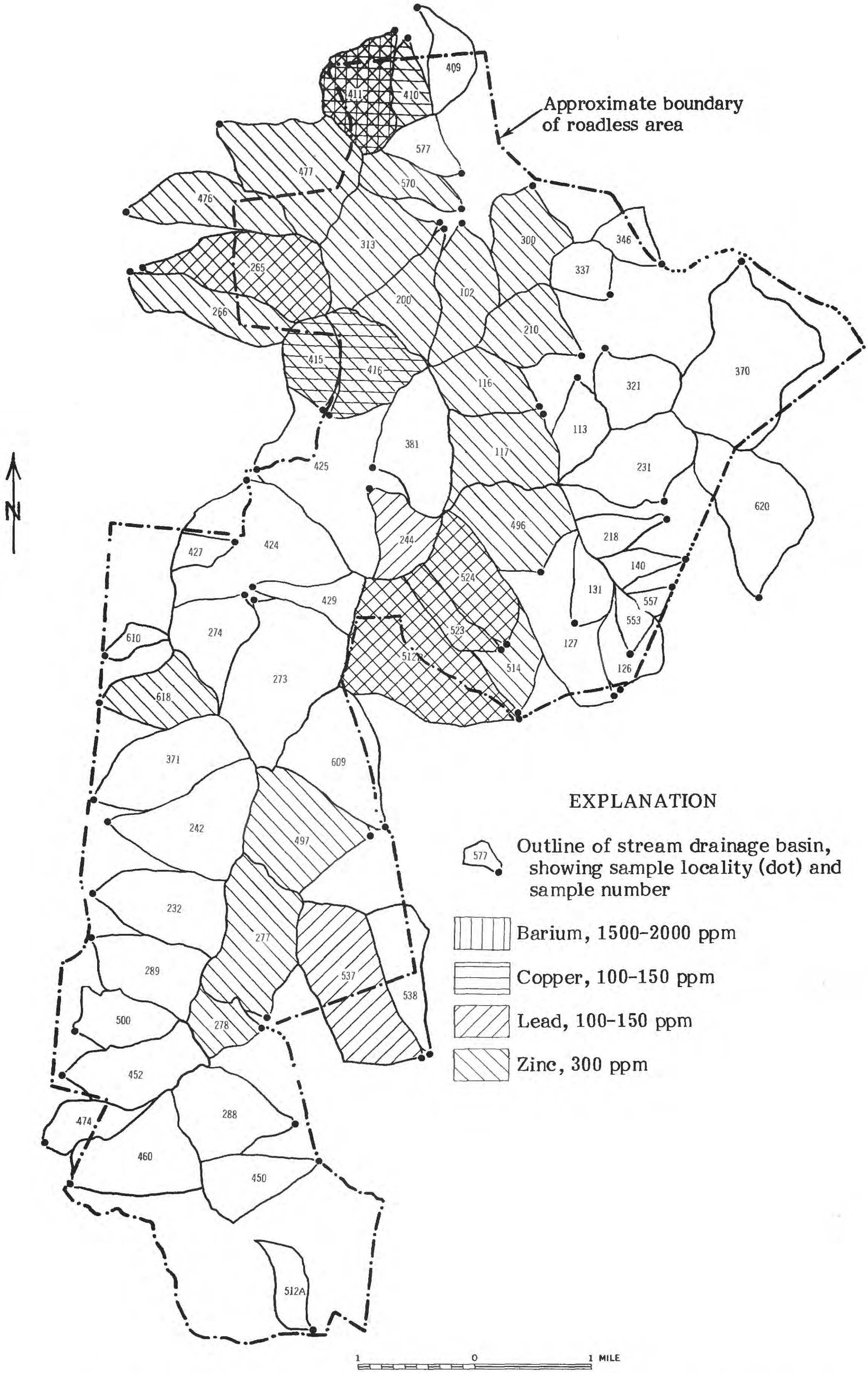


Figure 5.—Map of drainage basins showing distribution of stream-sediment samples containing anomalously high metal values.

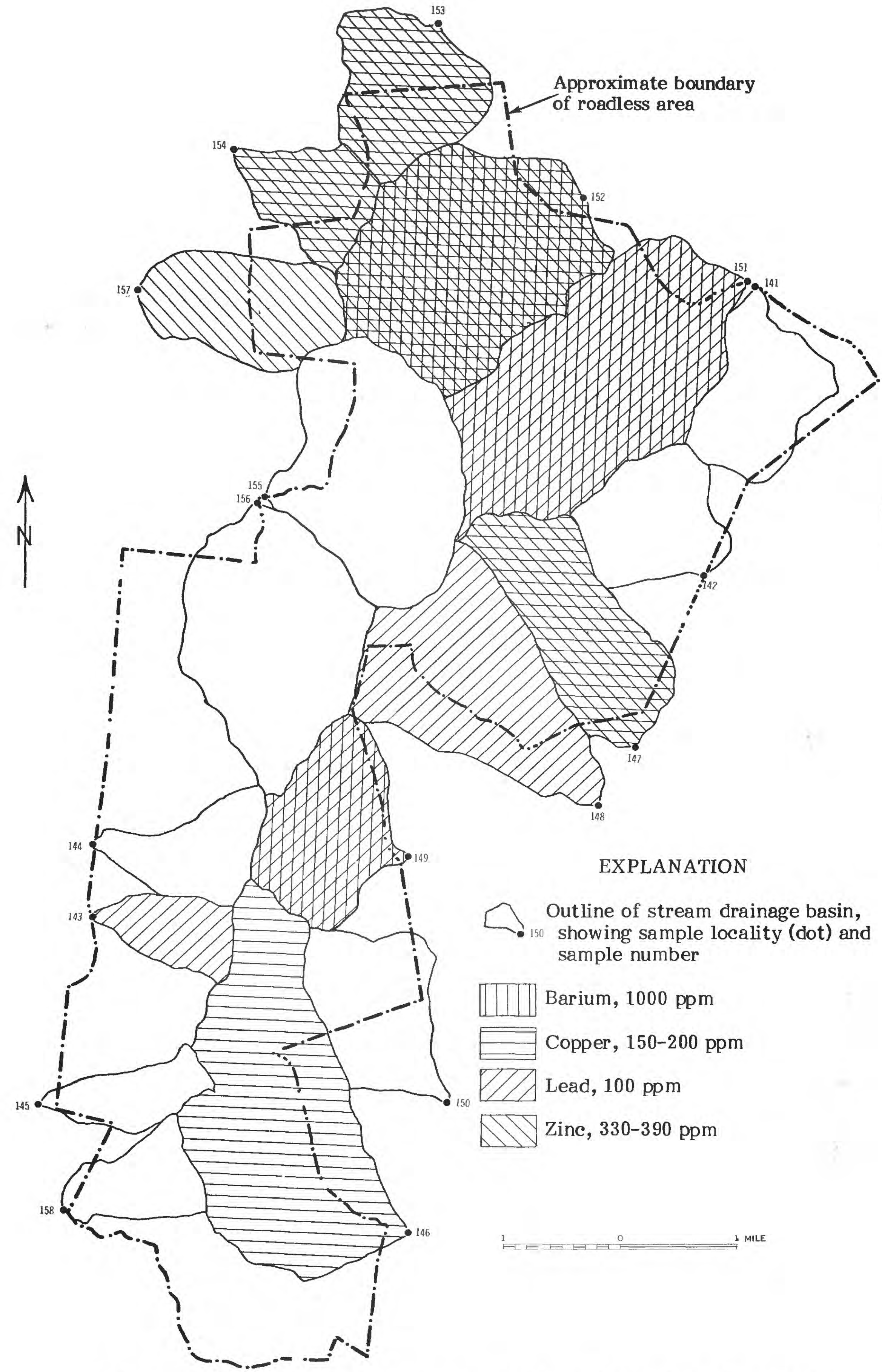


Figure 6.—Map of drainage basins showing distribution of panned-concentrate samples containing high-background metal values. Basins are groupings of smaller drainage areas outlined in figure 5.

much larger resources of sand and gravel in the surrounding region.

Marble

Marble has been mined in the past from several localities near the Bread Loaf Roadless Area. In the vicinity of Hancock and Rochester, quarries have produced marble that was burned for lime (Bitar and Armstrong, 1982). Cady and others (1962) also describe a body of calcite marble in the Hazens Notch Formation north of Waitsfield that was quarried for use as fertilizer. However, no marble is known within the study area.

Oil and gas

Although rocks exposed at the surface in the study area are largely devoid of hydrocarbons, a possibility does exist for oil and natural gas at depth. Recent seismic studies (Cook and others, 1979; Ando and others, 1982) suggest that the older metamorphosed rocks in the Blue Ridge of the southern Appalachians and the Green Mountains of Vermont overlie a thick sequence of young sedimentary rocks favorable for hydrocarbon accumulations. The Bread Loaf area is within the so-called eastern overthrust belt, which is currently receiving attention from industry (McCaslin and Sumpter, 1981; Bigelow, 1982); recently, large tracts of land in central and western Vermont—including parts of Addison and Washington Counties and parts of the roadless area—have been leased in the anticipation of a search for oil and gas (fig. 2). A hydrocarbon resource may exist in the deeper rocks of the study area, but it cannot be evaluated by the present investigation.

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