DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1593-B
PAMPHLET

MINERAL RESOURCE POTENTIAL OF THE BRISTOL CLIFFS WILDERNESS, ADDISON COUNTY, VERMONT

By

John F. Slack, U.S. Geological Survey

and

Peter C. Mory, U.S. Bureau of Mines

1983

Studies Related to Wilderness

Under the provisions of the Wilderness Act (Public Law 88-557, 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 Bristol Cliffs Wilderness, Green Mountain National Forest, Addison County, Vt. Bristol Cliffs Wilderness was established by Public Law 93-622, January 3, 1975, and modified by Public Law 94-268, April 16, 1976.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

The Bristol Cliffs Wilderness, Vt., has no identified mineral resources, except for certain non-metallic commodities. Geochemical sampling found slightly anomalous concentrations of copper, chromium, nickel, tin, and zinc in rocks, stream sediments, and panned concentrates, but not in sufficient quantity to indicate a potential resource. The results of the geochemical survey indicate that there is little evidence for the occurrence of metallic-mineral deposits within the study area. The only apparent resources are small deposits of peat and sand and gravel, and abundant rock suitable for construction materials. In the western part of the wilderness there is a low potential for silica-sand resources for glassmaking or chemical products. The area has an unknown potential for oil and natural gas at depth, but this cannot be evaluated by the present study.

INTRODUCTION

The Bristol Cliffs Wilderness comprises 3,775 acres of land in the Green Mountain National Forest in Addison County, Vt. (fig. 1). The area is situated along the western front of the Green Mountains, approximately 1 mi southeast of Bristol and 8 mi northeast of Middlebury; Burlington and Rutland are 25 and 35 air miles to the north and south, respectively (fig. 1). The topography is gentle within the interior, but is precipitous along Bristol Cliffs, which are located along the western boundary of the study area and from which the wilderness obtains its name. Total relief in the study area is 1,805 ft, from lower altitudes of about 520 ft along the New Haven River near Bristol, to a high point of nearly 2,325 ft on the crest of South Mountain in the center of the wilderness. Two small ponds (north and Gilmore Ponds) are located near South Mountain. Several small unnamed streams drain radially away from the wilderness into the New Haven River, ultimately discharging into Lake Champlain to the west. Access is by U.S Route 7 at Middlebury, and by State Highway 17 and 116. Paved and gravel or dirt County and Forest Service roads are also present near the western, southern, and eastern boundaries of the area. A foot trail provides access to near Gilmore Pond from the southern border of the wilderness.

Previous Work

Previous geologic studies in the vicinity of the Bristol Cliffs Wilderness have been limited to reconnaissance mapping by Keith (1923) and Cady (1959), the latter for compilation of the Centennial Geologic Map of Vermont (Doll and others, 1961). Areas adjacent to the wilderness have been examined in more detail, including mapping by Cady (1945) to the west of the study area, by Osberg (1952) to the south and southeast, and by Cady and others (1962) to the east. The most recent geologic work is by Tauvers (1982), who mapped the Lincoln area immediately north and east of the wilderness.

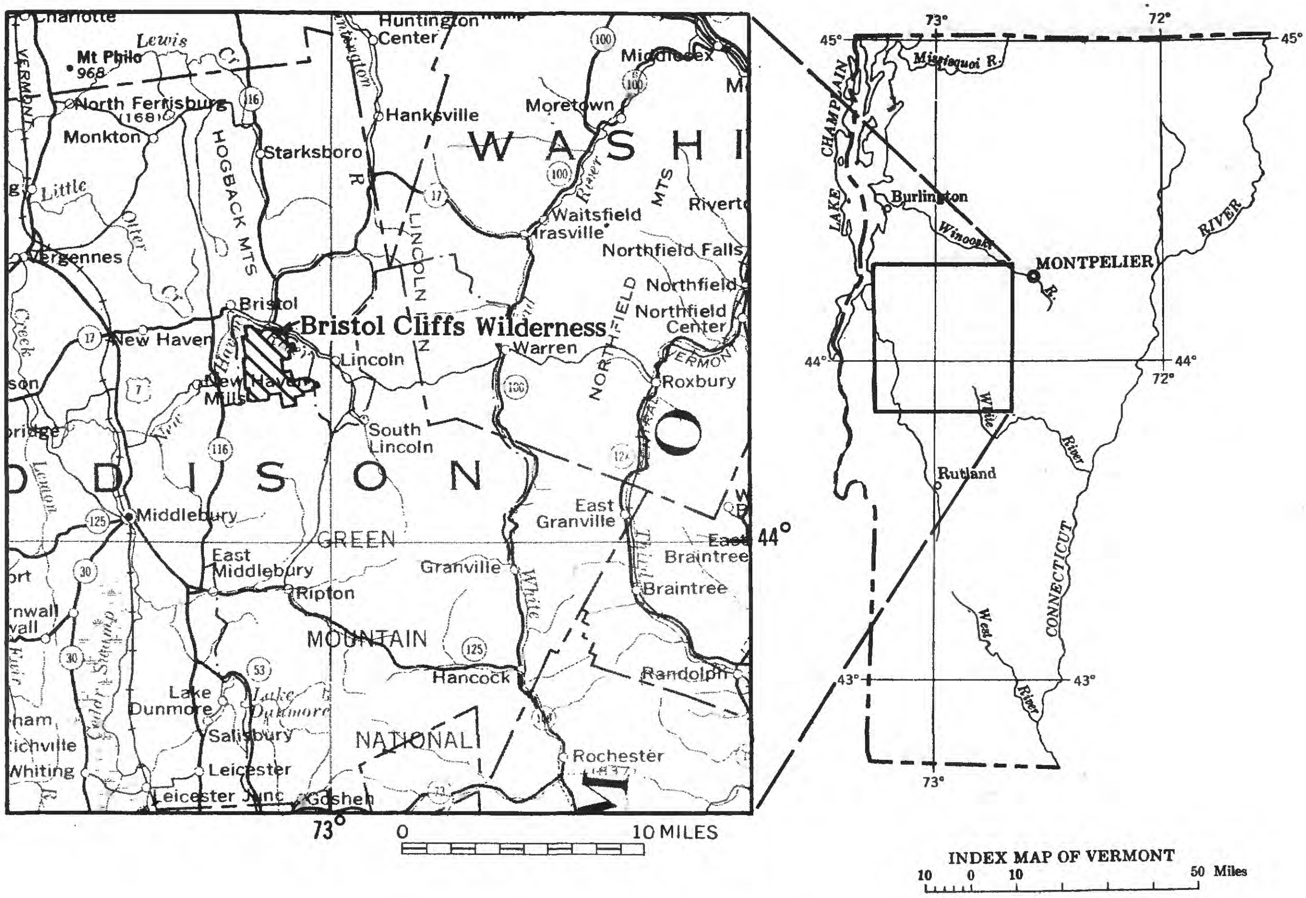


Figure 1.—Index map showing the location of the Bristol Cliffs Wilderness.

Present Work

The present investigation began with field studies by P. C. Mory of the U.S. Bureau of Mines (USBM) in the fall of 1977, who collected 27 rock samples. These rock were analyzed by spectrographic methods for 40 elements by the USBM Metallurgy Research Center, Reno, Nev.; selected samples also were analyzed by neutron-activation, atomic-absorption, fire-assay, and radiometric techniques. J. F. Slack, A. R. Pyke, R. L. Graves, J. T. Hanley, and J. C. Olson, all of the U.S. Geological Survey (USGS), spent one week of reconnaissance geologic mapping and sampling in June 1981. Rock samples collected at that time, together with stream sediments and panned concentrates obtained by A. E. Grosz, were submitted for geochemical analysis. A composite group of 34 rocks, 10 stream sediments, and nine panned concentrates was analyzed by semiquantitative spectrographic methods for 31 elements, and by quantitative atomic absorpotion for two elements (gold and zinc). Selected rock samples also were analyzed for major elements by X-ray fluorescence, and for uranium and thorium by neutron-activation methods.

SURFACE- AND MINERAL-RIGHTS OWNERSHIP

All surface and mineral rights in the Bristol Cliffs Wilderness were purchased by the Federal Government in the 1930's under the authority of the Week's Act of 1911. The only part of the area not under the jurisdiction and administration of the U.S. Forest Service is a small parcel of privately owned land about 12 acres in size in the northeastern corner of the wilderness (fig.2).

GEOLOGY

The Bristol Cliffs Wilderness is underlain by metasedimentary rocks of Proterozoic and early Paleozoic age, mantled locally by glacial and alluvial deposits. Bedrock units consist of the Late Proterozoic and(or) Early Cambrian Pinnacle and Underhill Formations, both part of the Camels Hump Group, and the overlying Cheshire Quartzite of Early Cambrian age. These formations occur along the northwestern flank of the Green Mountain anticlinorium, stratigraphically above basement rocks of the Mount Holly Complex of Grenville (approximately 1 b.y. old) age (Doll and others, 1961). The metasedimentary units belong to a thick cover sequence unconformably overlying the basement, as a part of the western limb of the Lincoln Mountain anticlinorium. West of the wilderness, many folds and thrust faults of the Taconic allochthon (Zen, 1967) involve platform clastic and carbonate rocks of Cambrian and Ordovician age. The platform sequences are only weakly metamorphosed to chlorite grade, giving rise to higher-grade metamorphic rocks to the east. Units within the study area are entirely of lower greenschist facies (chlorite-biotite) metamorphic grade. The garnet isograd lies approximately 2 mi east of the wilderness, near the northernmost exposure of Precambrian basement in the Green Mountains (Cady and others, 1962; Tauvers, 1982). The Pinnacle Formation and the Fairfield Pond Member (Dennis, 1964) of the Underhill Formation occurring in the eastern part of the wilderness, are impure clastic metasediments consisting of thin-bedded, fine-grained quartzose schist and mica-quartz-chlorite phyllite containing locally abundant biotite. Within the study area, the principal exposed unit is the Cheshire Quartzite (fig. 3). It forms the steep slopes of Bristol Cliffs along the western boundary, as well as most of the interior of the wilderness. The Cheshire consists of massive to thin-bedded, fine- to coarse-grained quartzite, micaceous quartzite, and feldspathic quartzite; tourmaline and zircon are common accessory mineral. In other areas (Tauvers, 1982), the Cheshire has been subdivided into a lower argillaceous (or micaceous) and feldspathic quartzite, and an upper unit composed of massive orthoquartzite and quartz arenite. Our reconnaissance mapping has not permitted any lithologic divisions to be confidently made, however. Rocks of the Pinnacle and Underhill Formations dip steeply westward off the Grenvillian basement to the east, and may be part of an overturned anticline (Tauvers, 1982). The structure of the Cheshire Quartzite appears to consist of a series of broad, open folds. These folds are part of a group of north-trending anticlines and synclines common to the western front of the Green Mountain anticlinorium (Doll and others, 1961).

GEOCHEMICAL SURVEY

Geochemical analyses of rocks, stream sediments, and panned concentrates do not reveal any significant metal anomalies in the wilderness. Certain metals have slightly anomalous concentrations, but none are suggestive of important mineralizing processes in the study area. Histograms for metallic elements of particular interest (Slack and others, in press) show some enrichments, especially for panned concentrate samples. Anomalous values were discovered for copper, chromium, nickel, tin, and zinc. Slightly high values obtained for other metals (i.e., barium, boron, cobalt, lead) are interpreted as belonging to normal geochemical distributions and are not considered statistically significant.

It is quite likely that a large fraction of sampled material is derived from glacially transported debris, and that the geochemical data for stream sediments and panned concentrates may not be fully representative of the local bedrock. Certain metal concentrations can thus be judged to be inappropriate for the local geology, particularly chromium, nickel, and tin. Anomalously high concentrations of these elements, chiefly in panned concentrate samples, are interpreted as belonging to glacial materials derived from outside the study area. These glacial materials could be till or ground moraine derived from areas to the north during Pleistocene glaciation, or from outwash deposits formed by post-Pleistocene glacial retreat.

A logical source for the chromium and nickel is the mafic and ultramafic terrane of northern Vermont and southern Quebec. A source for the tin concentrations is more difficult to identify, but may be from cassiterite-bearing pegmatites to the north of the wilderness. A less likely possibility is that these metals were derived from detrital heavy minerals originally present as accessory grains in clastic rocks of the study area. In contrast, the anomalous copper and zinc values conceivably could be indigenous to the geology of the study area. The highest values recorded were in panned concentrate samples, 200 ppm for copper and 300 ppm for zinc. Because these samples were collected from entirely different drainage basins, they appear to have no collective significance.

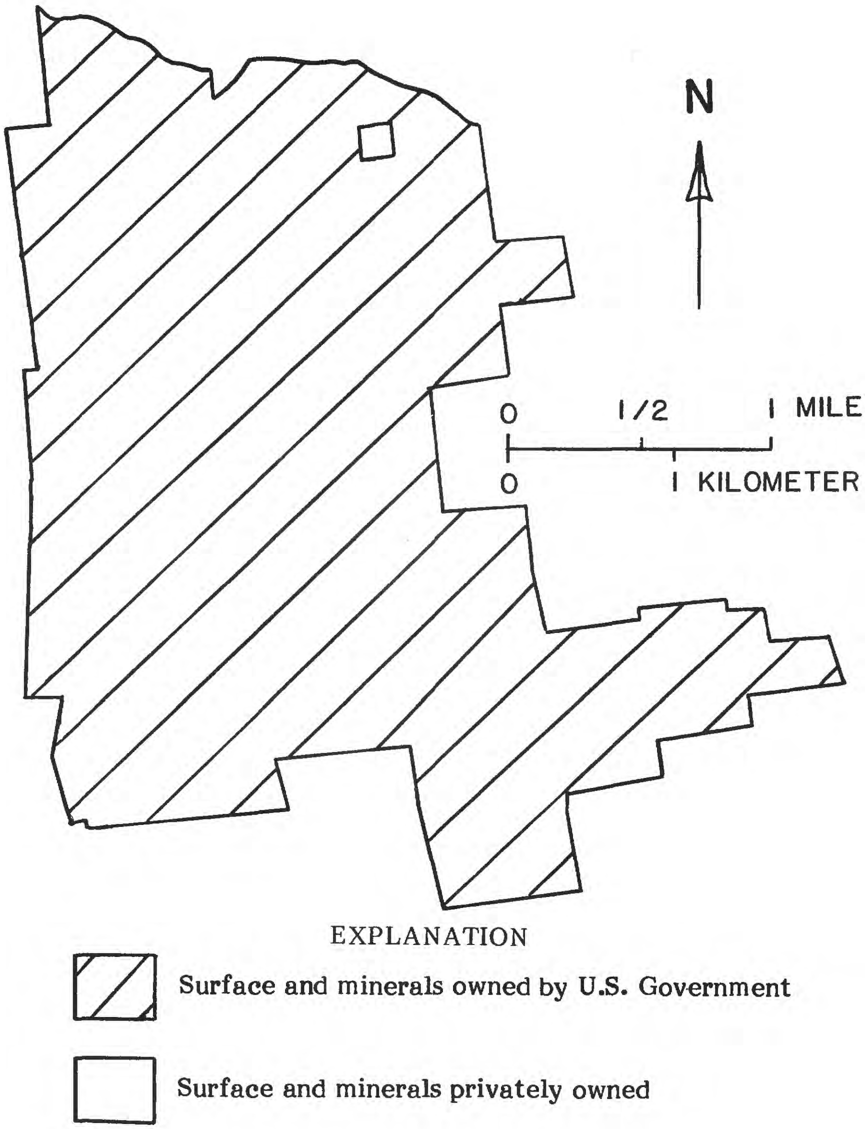
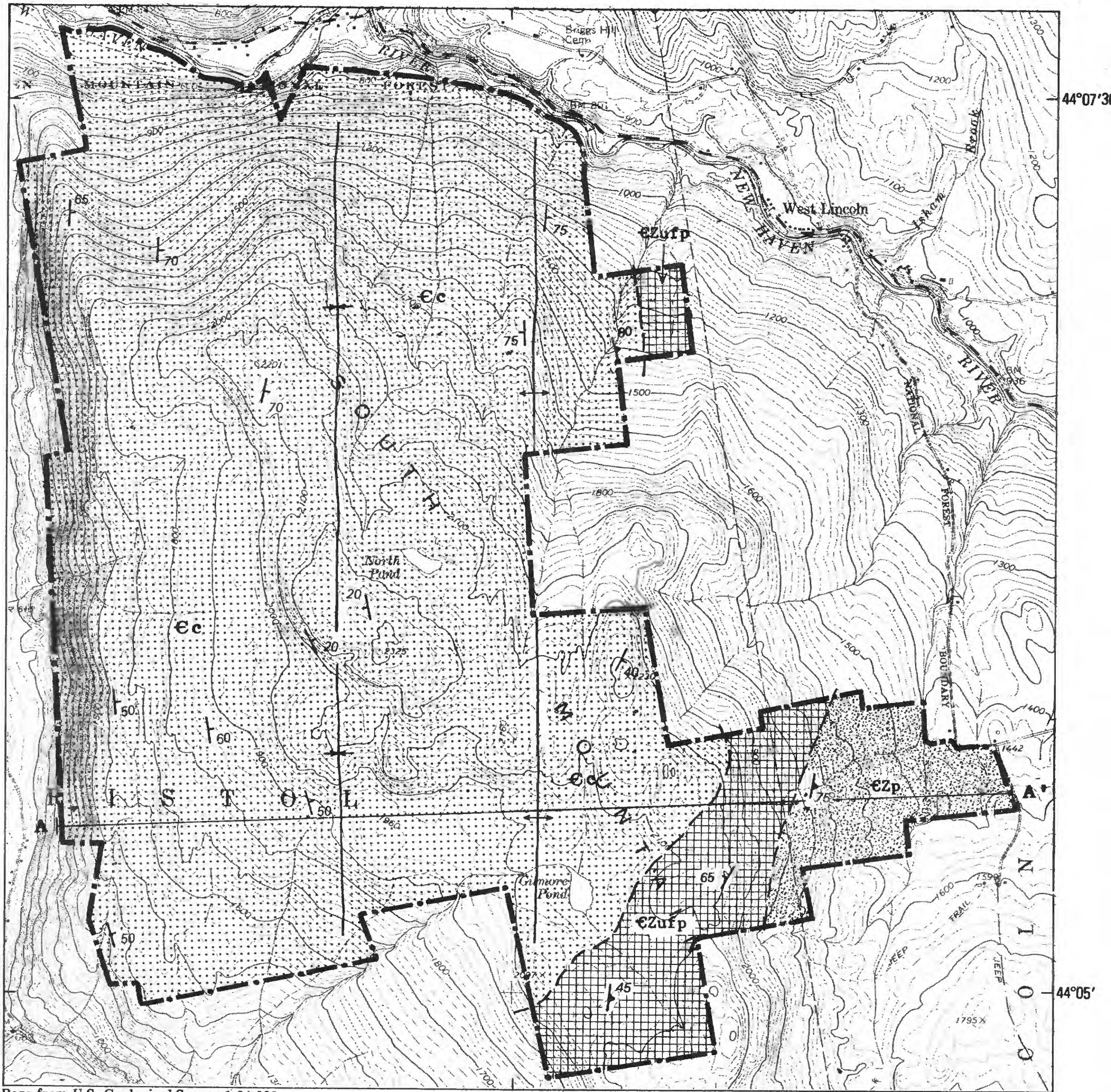


Figure 2.—Surface- and mineral-rights ownership.



Base from U.S. Geological Survey 1:24,000
Bristol and South Mountain, 1963

73°2'30"

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

Geology mapped by J.F. Slack, A.R. Pyke, R.L. Graves, J.T. Hanley, and J.C. Olsen, 1981.

Details of cross section A-A' can be found on MF-1593-A.

DESCRIPTION OF MAP UNITS

€c — Cheshire Quartzite (Early Cambrian) — Massive to thin-bedded, fine- to coarse-grained quartzite, micaceous quartzite, and feldspathic quartzite. Parts of this unit have low potential for the production of high-silica sand

€Zufp — Fairfield Pond Member (Dennis, 1964) of the Underhill Formation (Early Cambrian and (or) Late Proterozoic) — Thin-bedded quartzose schist and schistose quartzite, commonly with abundant muscovite and biotite. Base marked locally by thin unit of dolomitic quartzite

€Zp — Pinnacle Formation (Early Cambrian and (or) Late Proterozoic) — Thin-bedded mica-quartz-chlorite phyllite and schist, typically with abundant biotite and plagioclase

Contact, dashed where approximate

Axial trace of anticline

Axial trace of syncline

70 Strike and dip of inclined bedding

45 Strike and dip of inclined foliation

Figure 3.—Geologic map of the Bristol Cliffs Wilderness.

MINERAL RESOURCE POTENTIAL

The Bristol Cliffs Wilderness has no identified mineral resources, except for certain non-metallic commodities. No mines or prospects are known within the wilderness and no prospecting permits have been issued by the U.S. Bureau of Land Management. The mining of kaolin, iron, and manganese elsewhere in Addison County is related to rock units that are not present in the wilderness. The study area is geologically favorable for containing strata-bound lead deposits, but no evidence of lead mineralization was observed. Locally anomalous concentrations of zinc and copper are not indicative of a potential for the occurrence of resources of these metals. With the exception of silica sand, the non-metallic resources are only of little interest

Strata-Bound Lead Deposits

The geology of the Bristol Cliffs Wilderness is in many respects similar to areas containing major strata-bound lead deposits. These types of deposits characteristically occur in basal quartzitic sandstones above feldspar-rich basement rocks. Comparable geologic settings are found along much of the western front of the Green Mountains, where the Cheshire Quartzite overlies the Mount Holly Complex (Doll and others, 1961). Mineralization in strata-bound lead deposits typically consists of galena and local sphalerite forming the matrix (cement) for quartz-rich sandstones or orthoquartzites. Examples include the large (80 million ton) orebody at Laisvall, northern Sweden (Rickard and others, 1979), and other similar deposits elsewhere in the world (Bjoerlykke and Sangster, 1981). No evidence of lead mineralization was found during geochemical sampling of the wilderness, and concentrations of zinc and copper—which might be pathfinders to the lead—occur in separate drainage basins (Slack and others, in press). Moreover, contents of lead, zinc, and copper are extremely low in all rock samples analyzed. These data therefore are not indicative of a potential for strata-bound lead deposits in the study area.

Silica Sand

Parts of the Cheshire Quartzite in and near the wilderness are potential sources of high-silica (glass) sand. This same formation has been mined in the past for glass sand and refractory quartzite in western Massachusetts (Chute, 1943; Herz, 1958). In the study area, much of the rock making up the Cheshire contains abundant feldspar and muscovite, as well as accessory tourmaline, zircon, rutile, and pyrite (Slack and others, in press). Those parts of the Cheshire containing significant amounts of these minerals would therefore be too impure to be considered as a source of silica-sand for glass manufacture.

Industry specifications for glass sand (Murphy, 1975; Heinrich, 1980) are based on both physical and chemical factors. Physical limitations include grain size and shape, rock frabic, and nature and amount of accessory minerals. Chemical requirements are variable and depend upon the desired composition and color of the final glass product. For nearly all uses, silica contents must exceed 95 weight percent. Major contaminants, such as iron (as Fe_2O_3), should be less than about 0.05 weight percent; lime, magnesia, and alkalis together (as oxides) should be less than about 0.5 weight percent, and titania less than 0.05 weight percent. Specifications for alumina are less restrictive, from 0.1 weight percent Al_2O_3 for optical glass, to as much as 4.0 weight percent for low-qualify glass products. Analyses performed by the USBM (Mory, 1981) and the USGS (Slack and others, in press) indicate that most of the Cheshire Quartzite has excessive chemical impurities and as such has no potential for glass manufacturing. However, two samples analyzed from immediately outside the boundary of the wilderness (Slack and others, in press) are quite pure and qualify as material suitable for silica-sand products. One of these samples, from near the base of the Bristol Cliffs only 500 ft west of the wilderness boundary, has sufficient mineralogic and chemical purity to be considered for use as high-quality flint or sheet glass. Although such pure samples have not been discovered from within the wilderness itself, the geologic setting of the area suggests that some of these pure quartzitic rocks should be found along the western portion of the wilderness. Based on these considerations, there is a low potential in the western parts of the study area for a silica-sand resource. More detailed study would be required to fully evaluate this resource, however, particularly in terms of size, location, accessibility, and competition with other markets.

Crushed Stone

Much of the rock exposed in the Bristol Cliffs Wilderness would be suitable for road aggregate and general construction purposes. The Cheshire Quartzite could be used for crushed stone and possibly for dimension stone. However, the abundance of this formation and similar rock outside of the study area reduces the possibility of development of crushed stone from within the wilderness itself.

Sand and Gravel

A few small deposits of sand and gravel are located along the New Haven River on the northern boundary of the wilderness. However, numerous active sand and gravel pits outside of the study area (e.g., southwest of Bristol) contain large reserves of more accessible material.

Peat

Field reconnaissance by the USBM included the examination of a peat bog at the east end of North Pond. The bog is about 200 ft wide and 400 ft long and contains a large number of dead tree trunks. A test probe located in the center of the deposit revealed about 2 ft of water-saturated sphagnum moss. Because of its small size, inaccessibility, and large amount of contained debris, this peat deposit has low potential as a source of peat.

Oil and Gas

Although rocks exposed at the surface of the wilderness are 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 study area is within the so-called Eastern Overthrust Belt which is currently receiving attention to industry (McCaslin and Sumpter 1981; Bigelow, 1982); recently, large tracts of land in central and western Vermont—including parts of Addison County—have been leased in the anticipation of a search for oil and gas (Oil and Gas Journal, 1982). A hydrocarbon resource may exist in the deeper rocks of the wilderness, but it cannot be evaluated by the present investigation.

REFERENCES CITED

Ando, C. J., Cook, F. A., Oliver, J. E., Brown, L. D., and Kaufman, Sidney, 1982, Crustal geometry of the Appalachian Orogen from seismic reflection studies (abs.): Geological Society of America, Abstracts with Programs, v. 14, nos. 1 & 2, p. 2.

Bigelow, T., 1982, Leasing in overthrust is becoming even more competitive: Northeast Oil Reporter, v. 2, No. 5, p. 94-98.

Bjoerlykke, Arne, and Sangster, D. F., 1981, An overview of sandstone lead deposits and their relation to red-bed copper and carbonate-hosted lead-zinc deposits: *in* Economic Geology, 75th Anniversary Volume, p. 179-213.

Cady, W. M., 1945, Stratigraphy and structure of west-central Vermont: Geological Society of America Bulletin, v. 56, no. 5.

________1959, Unpublished manuscript maps and notes, eastern areas of the Burlington and Middlebury quadrangles: Vermont Geological Survey.

Cady, W. M., Albee, A. L., and Murphy, J. F., 1962, Bedrock geology of the Lincoln Mountain quadrangle, Vermont: U.S. Geological Survey Geologic Quadrangle Map GQ-164, scale 1:62,500.

Chute, N. E., 1943, Cheshire glass sand deposits: Massachusetts Department of Public Works—U.S. Geological Survey Cooperative Open-File Report, 12 p.

Cook, F. A., Albaugh, D. S., Brown, L. D., Kaufman, Sidney, Oliver, J. E., and Hatcher, R. D., Jr., 1979, Thin-skinned tectonics in the crystalline southern Appalachians: COCORP seismic-reflection profiling of the Blue Ridge and Piedmont: Geology, v. 7, no. 12, p. 563-567.

Dennis, J. C., 1964, The geology of the Enosbury area, Vermont: Vermont Geological Survey Bulletin 23, 20 pg.

Doll, C. G., Cady, W. M., Thompson J. B., Jr., and Billings, M. P., 1961, Centennial Geologic Map of Vermont: Vermont Geological Survey, scale 1:250,000.

Heinrich, E. W., 1980, Geological spectrum of glass-sand deposits in eastern Canada and their evaluation, *in* Proceedings of the Fourteenth Annual Forum on the Geology of Industrial Minerals: New York State Museum Bulletin no. 436, p. 106-112.

Herz, Norman, 1958, Bedrock geology of the Cheshire quadrangle, Massachusetts: U.S. Geological Survey Geologic Quadrangle GQ-108, scale 1:31,680.

Keith, Arthur, 1923, Cambrian succession of northwestern Vermont: American Journal of Science, 5th Series, v. 5, p. 97-139.

McCaslin J. C., and Sumpter, Randy, 1981, Eastern overthrust search picks up speed: Oil and Gas Journal, v. 79, no. 21, p. 173-180.

Mory, P. C., 1981, Mineral resources of the Bristol Cliffs Wilderness Area, Addison County, Vermont: U.S. Bureau of Mines Open-File Report 18-81, 15 p.

Murphy, T. D., 1975, Silica and silicon, *in* Industrial Minerals and Rocks: American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 4th Edition, p. 1043-1060.

Oil and Gas Journal, 1982, Newsletter, v. 80, no. 5.

Osberg, P. H., 1952, The Green Mountain anticlinorium in the vicinity of Rochester and East Middlebury, Vermont: Vermont Geological Survey Bulletin 5, 127 p.

Rickard, D. T., Willden, M. Y., Marinder, N. E., and Donnelly, T. H., 1979, Studies on the genesis of the Laisvall sandstone lead-zinc deposit, Sweden: Economic Geology, v. 74, no. 5, p. 1255-1285.

Slack, J. F., Atelsek, P. J., and Grosz, A. E., in press, Geology and geochemistry of the Bristol Cliffs Wilderness, Addison County, Vermont: U.S. Geological Survey Miscellaneous Field Studies Map MF-1593-A.

Tauvers, P. R., 1982, Bedrock geology of the Lincoln area, Vermont: Vermont Geological Survey, Special Bulletin no. 2, scale 1:24,000.

Zen, E-an, 1967, Time and space relationships of the Taconic allochthon and autochthon: Geological Society of America Special Paper 97, 107 p.