Base from U.S. Geological Survey, 1:24,000
Anceney, 1949; Cameron, Cliff Lake, 1950;
Crown Butte, 1955; Ennis, 1949; Garnet Mtn.,
1955; Hebgen Dam, 1956; Norris, 1949;
Spanish Peaks, Sphinx Mtn., 1950; Tepee Creek,
1958

SCALE 1:96 000

Geology mapped by R. G. Tysdal
and F. S. Simons, 1980-83

EXPLANATION OF RESOURCE POTENTIAL

Cu-Ag — AREA WITH LOW POTENTIAL FOR COPPER AND SILVER--U.S. Bureau of Mines sample localities 35-39 are in this area

Pb-Ag — AREA WITH LOW POTENTIAL FOR LEAD AND SILVER--U.S. Bureau of Mines sample locality 17

Mo1, Mo2 — AREAS WITH LOW POTENTIAL FOR MOLYBDENUM

U — AREA WITH LOW POTENTIAL FOR URANIUM

SAMPLE LOCALITIES--Mineral commodities at each locality are given in table 1
- 1p - 4p: Phosphate rock sample locality U.S. Bureau of Mines (this report)
- 5 - 10: Swanson (1970, pl. 28C)
- 11 - 14: Condit and others (1928, p. 189-197)
- 15, 3p: Deposit with identified mineral resources--U.S. Bureau of Mines (this report)
- 16 - 26: Other mineral occurrences--U.S. Bureau of Mines (this report)
- 41 - 45: Other mineral occurrences--U.S. Geological Survey (this report)

EXPLANATION OF GEOLOGIC BASE

(Note: The following explanation is for the geologic base map shown in gray)

- Qu — UNCONSOLIDATED DEPOSITS, UNDIVIDED (QUATERNARY)
- QTy — YELLOWSTONE GROUP (PLEISTOCENE AND PLIOCENE)--Volcanic rocks
- Ts — SPINX CONGLOMERATE (TERTIARY)
- Kda — DACITIC INTRUSIVE ROCKS (CRETACEOUS)--Sills and dikes
- Kl — LIVINGSTON GROUP (CRETACEOUS)--Dacitic to basaltic volcaniclastic and volcanic rocks
- Ku — SEDIMENTARY ROCKS, UNDIVIDED (CRETACEOUS)--Dominantly clastic rocks
- JTru — SEDIMENTARY ROCKS, UNDIVIDED (JURASSIC AND TRIASSIC)--Dominantly clastic rocks
- Ps — SHEDHORN SANDSTONE (PERMIAN)
- Pzu — SEDIMENTARY ROCKS, UNDIVIDED (PALEOZOIC)--Dominantly carbonate rocks
- pMm — METAMORPHIC ROCKS (PRECAMBRIAN)--Dominantly feldspar-quartz gneiss and amphibolite

CONTACT

THRUST FAULT--Sawteeth on upper plate; dotted where concealed

NORMAL FAULT--Bar and ball on downthrown side; dashed where approximately located, dotted where concealed

QUATERNARY NORMAL FAULT--Hachures on downthrown side

ANTICLINE--Showing trace of axial plane and direction of plunge

OVERTURNED ANTICLINE--Showing trace of axial plane

SYNCLINE--Showing trace of axial plane and direction of plunge

OVERTURNED SYNCLINE--Showing trace of axial plane and direction of plunge

STRIKE AND DIP OF BEDS
- Inclined
- Overturned

STRIKE AND DIP OF FOLIATION IN METAMORPHIC ROCKS

DRY OIL WELL

AREA UNDER LEASE OR LEASE APPLICATION FOR OIL AND GAS--Shown in brown

APPROXIMATE BOUNDARY OF THE MADISON ROADLESS AREA

STUDIES RELATED TO WILDERNESS

The Wilderness Act (Public Law 88-577, September 3, 1964) and related acts require the U.S. Geological Survey and the U.S. Bureau of Mines to survey certain areas on Federal lands to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of the mineral survey of the Madison Roadless Area, Gallatin and Beaverhead National Forests, Gallatin and Madison Counties, Montana. The Roadless Area comprises Madison RARE II area No. 1949, parts E, J, N, R, and S, which were classified as further planning areas during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January 1979. Parts E, N, and S had been designated in 1977 for evaluation under the Montana Wilderness Study Act (Public Law 95-150). Part J was studied initially in 1978 as an extension of the proposed Spanish Peaks Primitive Area.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

A geological and mineral resource survey of the Madison Roadless Area in the Madison Range of southwestern Montana was made by the U.S. Geological Survey and the U.S. Bureau of Mines at various periods between 1970 and 1980. The area covers approximately 606 mi^2 (388,000 acres) in the Gallatin and Beaverhead National Forests. No minerals except for a possible small tonnage of asbestos have been produced from the area, and only a little prospecting has been done. One exploratory oil well, a dry hole, was drilled in 1949.

Mineral commodities of the area are phosphate rock, asbestos, and sillimanite; construction materials are present, but deposits are small or inaccessible and they are not further considered. Permian Shedhorn Sandstone, containing a large resource of phosphate rock, underlies much of the central and southern part of the area, but most of the beds of phosphorite and phosphatic shale are thin, or low grade, or both, and over most of the area are probably too deeply buried to be presently minable. Two occurrences, Indian Creek and Pulpit Rock, contain 9.0 million tons of phosphate rock with a grade in excess of 18 percent. Asbestos resources of the Karst prospect are estimated to be 83,000 tons of rock averaging 18 percent asbestos. The asbestos is in Precambrian mafic metamorphic rocks and the asbestos mineral is anthophyllite. Other known occurrences of asbestos in the area are small. The Placer Creek deposit has an estimated 93,000 tons of sillimanite-bearing Precambrian gneiss that averages about 04 percent sillimanite and also contains 2 percent rutile. This deposit has a high potential for additional resources of sillimanite. Sillimanite occurs elsewhere in the roadless area, but the deposits appear to be small. Construction materials similar to those in the roadless area are available more easily nearby.

The area lacks the kinds of plutonic igneous rocks and the altered rocks that commonly accompany metalliferous mineral deposits in the Rocky Mountains, and the few apparently altered rocks that were sampled contained only ordinary amounts of any metal. However, an area near the south edge of the roadless area has a low potential for resources of copper and silver, and an area about 1 mi north of the northwest corner of the roadless area has a low potential for resources of silver and lead. Two areas that have a low potential for molybdenum, and one with a low potential for uranium, were outlined by geochemical sampling.

Coal occurs at several places in Cretaceous sedimentary rocks, but known seams are thin, discontinuous, and of low quality.

Some potential oil- and gas-bearing structures may exist west of the leading edge of the Hilgard fault system, but they can be sought and evaluated adequately only by geophysical methods, particularly seismic profiling. No hot springs or potential sources for geothermal energy are known.

INTRODUCTION

The Madison Roadless Area is in southwestern Montana immediately west and northwest of Yellowstone National Park (fig. 1). It extends 50 mi northwestward along the crest of the Madison Range from Hebgen Lake on the Madison River to about 5 mi north of Ennis Lake, and covers an area of approximately 606 mi^2 or 388,000 acres. The west flank of the Madison Range is in the Beaverhead National Forest and the east flank is in the Gallatin National Forest. The area is about equally divided between Madison and Gallatin Counties.

Fieldwork in the Madison Roadless Area was carried out by the U.S. Geological Survey from 1980 to 1982, and a total of 6 months were spent in the field. Fieldwork by the U.S. Bureau of Mines was done in 1970 and from 1978 to 1980 and is described in Lambeth and others (1982). A geologic map of the area at a scale of 1:96,000 appears in Tysdal and Simons (in press) and a geochemical map appears in Simons and others (in press). Mineral resources of the Spanish Peaks Primitive Area were studied by Becraft and others (1966), those of the Jack Creek area by Becraft and others (1970), and those of the Bear Trap Canyon Instant Study Area and vicinity by Pinckney and others (1980); these areas are outlined on the map.

GEOLOGY

The Madison Range of southwestern Montana extends north-northwestward from Hebgen Lake to the vicinity of Norris, a distance of about 55 mi. The Madison Range is geologically part of a Tertiary structural block that also includes the Gallatin Range to the east; the two ranges are separated geographically but not geologically by the Gallatin River. The Madison-Gallatin block consists of a basement of Precambrian metamorphic rocks of Archean ¥ (Late Archean) age (2,500-3,000 m.y. old) overlain by a sequence of dominantly carbonate Paleozoic rocks, 3,000-4,000 ft thick, and a sequence of dominantly clastic Mesozoic sedimentary rocks, mainly Cretaceous, about 5,000-7,000 ft thick. Volcanic and volcaniclastic rocks of Late Cretaceous age, 1,500-2,000 ft thick, and conglomerate of early Tertiary age, 2,000 ft or more thick, occur in the central part of the range. Pliocene and Pleistocene silicic volcanic rocks blanket a few square miles in the southeastern part of the roadless area. Porphyritic dacitic igneous rocks of Late Cretaceous age intrude sedimentary rocks at Lone Mountain and Fan Mountain along the Gallatin River at Snowslide Creek. Bedrock is concealed locally by Holocene glacial deposits, landslide deposits, talus, and alluvium.

Pre-Tertiary rocks of the Madison Range were folded and faulted along northern to northwestern trends during Laramide deformation. The principal structures formed during this deformation are, from north to south, the Spanish Peaks fault, which trends northwest across the range and has a displacement of 10,000-15,000 ft; the Buck Creek fault and its associated folds, which for most of its length trends northwest across the middle of the roadless area and has a displacement of as much as 2,500 ft; the Snowflake fold-fault zone, which trends north in the southeastern part of the area and has a displacement of 2,000 ft or less; and the Hilgard fault system, which trends north-northwest for about 30 mi from Hebgen Lake to the Spanish Peaks fault, has a displacement of many thousands of feet, and in general forms the boundary between Precambrian rocks to the west and younger rocks to the east in the central and southern parts of the Madison Range. In the Gallatin Range to the east, rocks uplifted during Laramide deformation were subsequently arched and in Eocene time were buried by volcanic rocks of the Absaroka volcanic field. Although only a few tiny scattered remnants of these volcanic rocks remain in the Madison Range, probably it too was once covered at least in part by them. Certainly a large part of the present range was later blanketed by rocks of the Pliocene and Pleistocene Yellowstone Group. The Madison-Gallatin block was tilted gently southward during late Cenozoic uplift of the block along a system of normal faults that define the west flank of the Madison Range. The present topography of the range resulted from erosion by water and ice.

GEOCHEMISTRY

Geochemical evaluation of the mineral potential of the Madison Roadless Area is based on the chemical analysis of 898 stream-sediment samples, 280 rock samples, and 14 panned-concentrate samples of stream sediments collected by the U.S. Geological Survey (Simons and others, in press) and 280 stream-sediment samples collected by Los Alamos Scientific Laboratory (Bolivar, 1980a, 1980b; Shannon, 1980). Possible copper-silver-bearing rock samples were collected at 15 localities by the U.S. Bureau of Mines, coal and phosphate rock at five different localities each, sillimanite and mica at three localities each, and asbestos, rare-earth elements, platinum metals, and uranium at one locality each; more than 100 samples were collected and analyzed (Lambeth and others, 1982).

Anomalous amounts of 21 elements were detected in samples collected during the geochemical study, but many elements (beryllium, bismuth, thorium, tin, tungsten, zinc) were found in only very small amounts, and others (barium, boron, chromium, cobalt, copper, lanthanum, lead, manganese, nickel, niobium, silver, vanadium, yttrium) were mostly in low concentrations and in widely scattered samples. No geochemical anomaly considered to be significant was found for any element, but very low level anomalies were recognized for molybdenum in two areas and for uranium in one region.

GEOPHYSICS

Aeromagnetic and gravity surveys of the Madison Roadless Area were made to obtain geophysical information on subsurface lithology and structure that would assist in the evaluation of mineral resource potential. Interpretation of the geophysical data is in progress, but the results are not available at present.

MINING DISTRICTS AND MINERALIZED AREAS

Mineral commodities

Mineral commodities in the Madison Roadless Area are phosphate rock, asbestos, sillimanite, and construction materials. Traces of copper, silver, molybdenum, gold, lead, and zinc were found at several prospects. No oil, gas, or geothermal energy sources are known, and the only exploratory oil well in the area, drilled at Carrot Basin in 1949, was dry. No other mineral deposits are known to exist, nor are there any active mining claims. Locations of deposits of phosphate rock, asbestos, sillimanite, areas that have mineral potential, known prospects or mineral occurrences, and areas under lease or lease application for oil and gas, are shown on the map. Occurrences of construction materials are not shown because they are small or inaccessible, and similar materials are more easily available nearby. Sample localities and the mineral commodities at each locality are listed in table 1.

Mineral resources

Shedhorn Sandstone of Permian age contains beds of phosphorite and phosphatic shale at many places along its outcrop (shown on map). Phosphate rock ranges in thickness from less than 1 in. to more than 6 ft, but most of it is less than 3 ft in thickness. Phosphate deposits of the Madison Range were studied by Swanson (1970, p. 733-739; pl. 28C). He calculated phosphate resources based upon the total area of the Retort Phosphatic Shale Member of the Phosphoria Formation (a tongue of the Shedhorn Sandstone in the area of this report), inferred to underlie the range, and on the average thicknesses and grades based upon measurements made at various places along the outcrop (map, loc. 5-14). Swanson's estimates of resources for the areas that include the potentially phosphate-bearing part of the roadless area are given in table 2. The locations of the four blocks used by Swanson are shown on figure 2; large parts of blocks A and C, and most of block B, are not in the roadless area, so the resource estimates for these blocks are higher than they would be if only the parts within the roadless area were considered. Most of the phosphate rock of the Cedar Creek-Jack Creek block, and much of it in the Indian Creek-Taylor Fork block, is probably too deeply buried to be presently minable, and that of the Beaver Creek-Cabin Creek block is less than 4 ft thick; nevertheless, the roadless area has a substantial resource of phosphate rock.

Phosphate rock was sampled by the U.S. Bureau of Mines at four localities and the resource data are summarized in table 3.

The Placer Creek sillimanite deposit (loc. 15) is a northeast-trending lens of sillimanite-rich gneiss in garnet hornblende gneiss. The lens, 20 ft thick and at least 150 ft long, is estimated to contain about 21,000 tons of indicated resource and 70,000 tons of inferred resource having 04 percent sillimanite and 2 percent rutile. A northeastern-trending, steeply dipping, silicified shear zone about 100 ft northwest of the sillimanite gneiss (loc. 40) is 450 ft long and 3-9 ft wide. The zone, explored by several pits, opencuts, and a shallow shaft, contains massive to laminated quartz, iron oxide, and pyrite. A sample of material from the shaft contained 100 ppm (parts per million) cobalt, 70 ppm copper, 7 ppm molybdenum, and a trace amount of silver. No other samples from the pits or shafts contained significant amounts of valuable metals.

The Karst asbestos prospect (loc. 16) explores veins and replacement bodies of asbestiform anthophyllite in a pod of mafic rocks 90 ft thick. The asbestos occurs where the pod is cut by a steeply dipping north-northwest-striking 24-ft-wide shear zone. The maximum vein thickness is 4 ft. Estimated asbestos resources are 37,000 tons indicated and 46,000 tons inferred with an average grade of 18 percent asbestos.

Areas that have mineral resource potential

Several copper-silver prospects are near the south edge of the roadless area; all but one are just west of Beaver Creek (area C-Ag). The principal prospect is Highland Mary (loc. 37), which has several lenticular quartz veins along a shear zone 1-3 ft wide that trends north-northeast for 400 ft in Precambrian gneiss. The veins dip gently northwest, are as much as 0.5 ft wide, and contain chalcopyrite, pyrite, and oxidized copper minerals. They have been explored by several adits and pits. Five chip samples across 1.4-3 ft of vein material contained 0.29-0.77 percent copper and as much as 0.4 oz silver per ton. Two selected grab samples contained 1.3 and 0.8 percent copper and 0.4 oz silver per ton. A prospect to the north (loc. 36) has several northeast-striking quartz-chalcopyrite-pyrite veins in gneiss. The veins are 10-20 ft long and as much as 2.3 ft wide; a sample of one contained 0.66 percent copper.

The Sunshine prospect (loc. 38) also has small northerly striking quartz-pyrite-chalcopyrite veins enclosed in gneiss. They are explored by several pits. One sample from a pit contained 0.85 percent copper and 0.3 oz silver per ton, and a sample from a stockpile had 0.75 percent copper. Six other samples contained only traces of copper.

The Silver Bell prospect (loc. 39) is on a north-trending shear zone that dips northwest and is 150 ft long. The shear zone contains quartz-pyrite-chalcopyrite veins as much as 1.5 ft wide. Samples from three small pits contained 0.4-0.53 percent copper.

All known mineral deposits in the area are small and low grade, but the number of prospects in the area and the occurrence of traces of silver in a few sediment samples from streams draining the area suggest that it has a low potential for copper and silver resources.

The Hargrove prospect (loc. 17) is about 1 mi north of the northwest corner of the roadless area. It consists of an adit 460 ft long, two shafts 110 ft and 30 ft deep, respectively, and 11 pits and trenches. The area is underlain by dacite porphyry that has abundant inclusions of Precambrian amphibolite and gneiss and is cut by quartz diorite dikes. The rocks contain pods and veins of quartz that have traces of galena, sphalerite, chalcopyrite, and pyrite. A chip sample of an altered dike contained 0.9 percent of lead, 0.3 percent of zinc, and a trace of silver, and a sample from a 300-ton dump contained 2.4 oz silver per ton. The other 27 samples taken contained only traces of silver, lead, zinc, or copper. The prospect has a low potential for resources of silver and lead.

Samples in which molybdenum was detected are mostly of Precambrian rocks or of stream sediments derived from Precambrian rocks. In addition, Pleistocene and Pliocene volcanic rocks commonly contained 5-7 ppm molybdenum, and two samples of volcanic rocks from the Cretaceous Livingston Group contained 3 ppm and 7 ppm molybdenum. None of these occurrences indicates resource potential. However, two areas in which Precambrian rocks are not exposed yielded numerous stream-sediment samples containing traces to 10 ppm molybdenum. One is a large area comprising parts of the headwater basins of Indian, Bear, and Buck Creeks and West Fork Gallatin River (area Mo1); the only rocks in the area known to contain as much as 5 ppm molybdenum are tuff of the Cretaceous Livingston Group, and black shale of the Jurassic Morrison Formation which is exposed in a few places. The second area is around Sage and White Peaks, particularly in upper Cabin Creek (area Mo2); no source rock was recognized, but the Morrison Formation occurs in this area also. Both areas are considered to have a very low potential for molybdenum.

Stream-sediment samples containing more than a few parts per million of uranium come almost entirely from drainages underlain wholly or mainly by Precambrian metamorphic rocks. All streams that drain dominantly Precambrian rocks, except for some in the northwesternmost part of the area, yield sediment samples high in uranium. These data indicate that the background uranium content of Precambrian rocks is high relative to that of other rocks in the area. Samples containing exceptionally high uranium contents--100 ppm or more--are concentrated in the southwest corner of the roadless area around and south of Hilgard Peak (area U). This area is entirely underlain by Precambrian rocks and has 20 of the 25 samples from the roadless area that contain 100 ppm or more uranium. It is likely that these samples too reflect a relatively high background uranium content in the source rocks; that is, the uranium is dispersed in the Precambrian rocks rather than being concentrated into deposits, but because of the large number of uranium-rich samples in the area it is considered to have a low potential for uranium.

Other mineral occurrences

Mineral occurrences, reported mineral occurrences, and prospects not included in previous sections are briefly described here.

Loc. 18: Bear Trap Creek sillimanite prospect. Lenticular pods of sillimanite gneiss that strike northeast. Prospect consists of five small pits and trenches. Highest grade sample among eight collected contained only 6 percent sillimanite and also had 30 percent iron.

Loc. 19: Bear Trap corundum-sillimanite prospect. Explores two layers of corundum-sillimanite gneiss that contain as much as 15 percent corundum and 60 percent sillimanite (Hopkins and Taber, 1947); most samples contain less than one-half these amounts. Exploration consists of a short adit and numerous trenches, the longest is 180 ft.

Loc. 20: Crows Nest prospect. Located for platinum metals. A chalcedony-bearing shear zone in gneiss trends east for 0.5 mi and is 3-6 ft wide. It is explored by five pits and a shallow shaft. None of the 12 samples collected contained platinum or other valuable minerals.

Loc. 21: Occurrence of rare-earth elements, reported from the northwest part of the roadless area by Olson and Adams (1962). Numerous stream-sediment samples from this general area contain anomalous amounts of lanthanum (100 ppm or more) or yttrium (70 ppm or more), or both, as do four samples of hornblende or biotite gneiss. However, amounts in stream sediments are low (maximum 200 ppm lanthanum and 150 ppm yttrium) and probably reflect dispersed rare-earth-bearing minerals in Precambrian rocks. Panned concentrates of stream sediments from three places contained no detectable rare-earth-bearing minerals. The Knudson prospect, a reported occurrence of uranium. Consists of six pits as much as 6 ft deep and six shallow opencuts. Five samples contained only normal background amounts of uranium or thorium.

Loc. 42: Several slightly iron-stained silicified zones as much as 30 ft across, in hornblende-garnet gneiss and biotite gneiss in the northwest part of the area. Some shallow pits. A sample from the largest zone contained only a trace of lead.

Loc. 43: Unprospected occurrence of massive slightly iron-stained quartz near the northwest corner of the roadless area; 200 ft long and 30-50 ft wide, enclosed in garnet amphibolite. Chip sample of the quartz contained 300 ppm vanadium and 70 ppm cobalt.

Loc. 44: A shallow shaft in the northwest part of the area, explores an iron-stained north-trending shear zone in Cambrian Meagher limestone. Shear zone is 2-3 ft wide but could be traced only a short distance from the shaft. Sample of slightly copper-stained rock from the shaft dump contained 2000 ppm copper, 300 ppm molybdenum, 30 ppm tin, and 7 ppm silver (+ 0.2 oz per ton).

Loc. 25: Prospect on the west edge of the roadless area just north of Jack Creek, consists of a pit on a fracture in limestone. Fracture contains a little pyrite, calcite, and iron oxide. A chip sample extending 1 ft in length contained 0.11 percent copper, 0.16 percent lead, and 0.9 oz silver per ton, and a selected sample contained 1.6 oz silver per ton.

Loc. 26: Prospect near the Spanish Peaks fault, has two shallow pits on a small fracture in Paleozoic rocks. Sample with a little pyrite and chalcopyrite contained 0.01 percent copper, 0.20 percent lead, and a trace of gold.

Loc. 27: Another prospect near the Spanish Peaks fault, has two shallow pits and a short adit that explore fractures in Paleozoic rocks, probably Shedhorn Sandstone. A sample from one of the pits had 0.07 oz gold per ton; the other four samples were barren.

Loc. 32: Hurtha prospect, veins of calcite and iron oxide cut shattered Precambrian quartzite. Two pits 5 ft deep. The three samples collected were barren.

Loc. 33: Apex prospect; several adits and pits and a shaft 83 ft deep. Mineral deposit is a north-trending pod of silicified Mississippian Madison Limestone 550 ft long and 3 ft wide that is in contact with Cretaceous dacite porphyry. One selected sample contained 3.4 percent copper and 0.01 oz gold per ton, and another contained 0.13 percent copper. Five other samples were barren. The iron content of the deposit is 3-10 percent.

Loc. 45: Precambrian biotite schist east of White Peak; contains many small pods of gray quartz pegmatite a few feet long and a few inches thick. A composite chip sample of a dozen or so of the pods was barren.

Prospecting for mica has been done at several places but no resources were found. At a prospect in the northwest part of the roadless area (loc. 24) quartz pegmatite lenses in Precambrian gneiss are as much as 30 ft long and 6 ft thick and contain crystals of biotite as much as 7 in. long and 0.8 in. thick. A pit 15 ft long has been dug on one pegmatite. At the Anvil prospect in the southern part of the area (loc. 34), a quartz pegmatite 10 ft across, enclosed in Precambrian gneiss, contains biotite crystals that average 2 in. across by 0.5 in. thick; the biotite crystals make up about 5 percent of the pegmatite.

Coal in Cretaceous sedimentary rocks was sampled at three places. At Mill Creek (loc. 28), coal as much as 2 ft thick and carbonaceous shale are explored by an adit, now caved. The coaly material yielded 6,000 Btu per lb. Just east of Shedhorn Mountain (loc. 29), two seams of impure coal are each about 5 ft thick and are exposed for several tens of feet. Three samples of coal yielded 3,000-4,000 Btu per lb and 65 percent or more ash. In upper Cache Creek (loc. 30) several seams of coal 1-2 ft thick are explored by an adit and many small trenches. Individual coal beds can be traced for as much as 500 ft. The best quality coal yielded 12,000 Btu per lb and had 11 percent ash; the other five samples were of much lower grade.

At Coal Canyon, 2 mi outside the roadless area (loc. 40), coal seams 1-4 ft thick are in slumped blocks of Jurassic rocks. The best quality coal produced 11,000 Btu per lb and had 12 percent ash. Two samples from a trench in pyritic welded tuff overlying the Jurassic beds contained no valuable minerals.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

Mineral commodities of the Madison Roadless Area comprise phosphate rock, asbestos, and sillimanite. Except possibly for a small amount of asbestos, no mineral production is known from the area.

Resources of phosphate rock in the Permian Shedhorn Sandstone are substantial, but large parts of the beds of phosphate rock are thin and (or) of low grade and much of the resource is probably too deeply buried to be minable. The Indian Creek locality (1p) has 4.7 million tons of phosphate rock containing more than 18 percent of P_2O_5, and the Pulpit Rock locality (3p) has 4.3 million tons of similar grade.

Asbestos resources are mainly in the Karst deposit (loc. 16) and are estimated at about 83,000 tons containing 18 percent asbestos. Other occurrences are small, and their potential is low.

Sillimanite resources are mostly in the Placer Creek deposit (loc. 15), which is estimated to contain about 93,000 tons of material averaging 04 percent sillimanite and 2 percent rutile. The deposit has a high potential for additional resources of sillimanite.

The roadless area lacks the kinds of plutonic igneous rocks and the altered rocks that commonly are associated with metalliferous mineral deposits in the Rocky Mountains, and the overall potential of the area for these resources is very low. However, five areas are considered to have some potential. An area near the south edge of the roadless area has several small copper-silver prospects, and traces of silver occur in sediment samples from streams in the area; it is considered to have a low potential for copper and silver resources. A small area about 1 mi north of the northwest corner of the roadless area contains the Hargrove prospect and has a low potential for silver and lead resources. Low-level geochemical anomalies for molybdenum and uranium in two places (loc. Mo_1, Mo_2) by geochemical sampling, and a low-level anomaly for uranium was recognized in the southwest part of the area (loc. U). The resource potential of these areas is low. No other geochemical anomalies of consequence were found.

Known beds of coal are thin, discontinuous, and of low quality, and the potential for minable coal resources is low.

The only oil exploration well drilled in the area, at Carrot Basin in 1949, was a dry hole. Potential oil- and gas-bearing structures in the area east of the leading edge of the Hilgard fault system are small, deeply eroded, and intruded locally by igneous rocks. The best structural setting for entrapment of hydrocarbons lies west of the leading edge and can be sought and evaluated adequately only by geophysical investigations, particularly seismic profiling.

No hot springs or potential sources for geothermal energy are known in the roadless area. The nearest hot spring is Bozeman Hot Springs, about 7 mi west of Bozeman and 14 mi north of the roadless area; this spring is reported by Waring (1965, p. 32) to have a temperature of 137°F and a flow of 250 gallons per minute. The area around Bozeman Hot Springs is considered by Sammel (1979, p. 112-113) to be favorable for the discovery and development of local sources of low-temperature geothermal water.

REFERENCES CITED

Becraft, G. E., Calkins, J. A., Pattee, E. C., Weldin, R. D., and Hoche, J. M., 1966, Mineral resources of the Spanish Peaks primitive area, Montana: U.S. Geological Survey Bulletin 1230-B, 45 p.
Becraft, G. E., Klitsgaard, T. M., and Van Noy, R. M., 1970, Mineral resources of the Jack Creek basin, Madison County, Montana: U.S. Geological Survey Bulletin 1319-B, 24 p.
Bolivar, S. L., 1980a, Uranium hydrogeochemical and stream sediment reconnaissance of the Bozeman NTMS quadrangle, Montana, including concentrations of forty-two additional elements: Los Alamos Scientific Laboratory Informal Report LA-7504-MS Supplement, 169 p.
_____1980b, Uranium hydrogeochemical and stream sediment reconnaissance data listing release for the Three Forks Basin, Spanish Peaks, and Boulder River area in the Bozeman NTMS quadrangle, Montana, including concentrations of forty-six additional elements: Los Alamos Scientific Laboratory Informal Report LA-8406-MS, 131 p.
Condit, D. D., Finch, E. H., and Pardee, J. T., 1928, Phosphate rock in the Three Forks-Yellowstone Park region, Montana: U.S. Geological Survey Bulletin 795-G, p. 147-209.
Hopkins, A. B., and Taber, John, 1947, Bear Trap corundum deposit, Madison County, Montana: U.S. Bureau of Mines Report of Investigation 4039, 6 p.
Lambeth, R. H., Schmauch, S. W., Mayerle, R. T., and Hamilton, M. M., 1982, Mineral investigations of the Madison RARE II areas (No. 1549, parts E, J, N, R, and S), Beaverhead and Gallatin National Forests, Madison and Gallatin Counties, Montana: U.S. Bureau of Mines Open-File Report MLA 81-82, 31 p.
Olson, J. C., and Adams, J. W., 1962, Thorium and rare earths in the United States, exclusive of Alaska and Hawaii: U.S. Geological Survey Mineral Investigations Resource Map MR-28, scale 1:3,168,000.
Pinckney, D. M., Hanna, W. F., Kaufmann, H. E., and Larson, C. E., 1980, Resource potential of the Bear Trap Canyon Instant Study Area, Madison County, Montana: U.S. Geological Survey Open-File Report 80-835, 32 p.
Sammel, E. A., 1979, Occurrence of low-temperature geothermal waters in the United States, in Muffler, L.J.P., ed., Assessment of geothermal resources of the United States--1978: U.S. Geological Survey Circular 790, p. 86-131.
Shannon, S. S., Jr., 1980, Uranium hydrogeochemical and stream sediment reconnaissance data release for the Ashton NTMS quadrangle, Idaho/Montana/Wyoming, including concentrations of forty-two additional elements: Los Alamos Scientific Laboratory Informal Report LA-8009-MS, 168 p.
Simons, F. S., Van Loenen, R. E., and Tysdal, R. G., in press, Geochemical map of the Madison Roadless Area, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1605-C.
Swanson, R. W., 1970, Mineral resources in Permian rocks of southwest Montana: U.S. Geological Survey Professional Paper 313-E, p. 661-777.
Tysdal, R. G., and Simons, F. S., in press, Geologic map of the Madison Roadless Area, Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-1605-B.
Waring, G. A., 1965, Thermal springs of the United States and other countries of the world--A summary, revised by R. R. Blankenship and Ray Bentall: U.S. Geological Survey Professional Paper 492, 383 p.

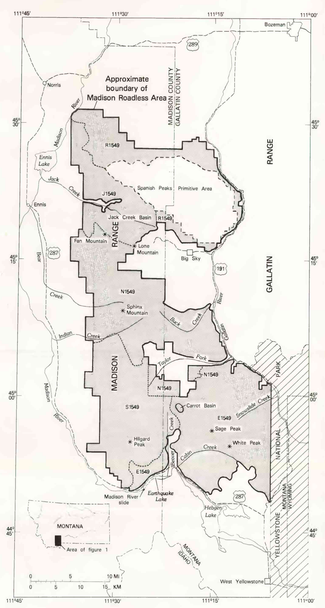

Figure 1.--Index map of Madison Roadless Area and vicinity. Heavy solid line, approximate boundary of roadless area; heavy dashed line, boundary of Spanish Peaks Primitive Area; dotted lines, boundaries of the five Further Planning Areas (No. 1549, parts E, J, N, R, and S) that together make up the roadless area.

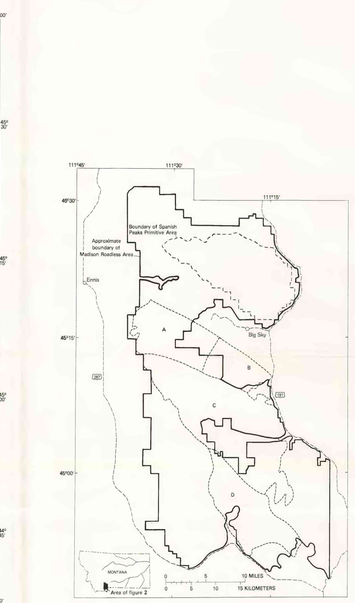

Figure 2.--Index map of Madison Roadless Area showing blocks used for calculation of phosphate rock resources (after Swanson, 1970, p. 736, fig. 180). A, Cedar Creek-Jack Creek block; B, West Fork Gallatin River block; C, Indian Creek-Taylor Fork block; D, Beaver Creek-Cabin Creek block. Resources of each block are given in table 2.

Table 1.--Sample localities shown on mineral resource potential map and mineral commodities at each locality

Phosphate rock sample localities in Permian Shedhorn Sandstone	
Sample localities of U.S. Bureau of Mines (this report)	
1p	Indian Creek
2p	Shedhorn Mountain
3p	Pulpit Rock
4p	Taylor Falls
Sample localities of Swanson (1970, plate 28C)	
5	Jack Creek (lot 1218)
6	Cedar Creek (lot 1215)
7	Shell Creek (lot 1214)
8	West Fork Gallatin River (lot 1216)
9	Indian Creek (lot 1362)
10	Pulpit Rock (lot 1479)
Sample localities of Condit others (1928, p. 189-197)	
11	Buck Creek
12	Cinnamon Creek
13	Sage Creek
14	Cabin Creek
Deposits with identified mineral resources (U.S. Bureau of Mines, this report)	
15	Placer Creek (sillimanite)
16	Karst (asbestos)
Other mineral occurrences	
Sample localities of U.S. Bureau of Mines (this report)	
17	Hargrove (lead, silver)
18	Bear Trap Creek (sillimanite)
19	Bear Trap (corundum-sillimanite)
20	Crows Nest (reported platinum metals)
21	Unnamed (reported rare earths)
22	Unnamed (no valuable minerals)
23	Knudson (reported uranium)
24	Unnamed (mica)
25	Unnamed (silver)
26	Unnamed (copper)
27	Unnamed (no valuable minerals)
28	Mill Creek (coal)
29	Unnamed (coal)
30	Cache Creek (2 localities) (coal)
31	Lightning Creek (coal)
32	Martha (no valuable minerals)
33	Apex (copper, iron)
34	Anvil (mica)
35	Unnamed (copper)
36	Unnamed (copper)
37	Highland Mary (copper, silver)
38	Sunshine (copper, silver)
39	Silver Bell (copper)
40	Coal Canyon (coal)
Sample localities of U.S. Geological Survey (this report)	
41	Placer Creek (copper, molybdenum, silver, cobalt)
42	Unnamed (no valuable minerals)
43	Unnamed (vanadium, cobalt)
44	Unnamed (copper, molybdenum, silver, tin)
45	Unnamed (no valuable minerals)

Table 2.--Estimates of resources of phosphate rock in the Madison Range, Montana (after Swanson, 1970, p. 737, table 7)

[Amounts in millions of short tons; grades in percent of P_2O_5. Letters in parentheses refer to resource blocks shown on fig. 2; leaders (---), not determined]

Resource block	Rock containing >24 percent P_2O_5	Grade	Rock containing >18 percent P_2O_5	Grade
Cedar Creek-Jack Creek (A)-----	350	25.9	550	24.6
West Fork Gallatin River (B)---	250	24.8	400	19.3
Indian Creek-Taylor Fork (C)---	500	26.0	1,500	19.1
Beaver Creek-Cabin Creek (D)---	---	---	150	19.7

Table 3.--Data on phosphate rock resources, Madison Roadless Area (U.S. Bureau of Mines)

Locality	Thickness (feet)	Grade (percent P_2O_5)	Estimated resource (millions of tons)
Indian Creek (sample locality 1p)-----	6.1	18-31 31 or more	3.7 .5
Shedhorn Mountain (sample locality 2p)-----	3.5-6.2	0.14-12	Not estimated
Pulpit Rock (sample locality 3p)	1.7	24-31	4.8
Taylor Falls (sample locality 4p)-----	2.6	7.3	Not estimated

MINERAL RESOURCE POTENTIAL MAP OF THE MADISON ROADLESS AREA, GALLATIN AND MADISON COUNTIES, MONTANA

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