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MINERAL RESOURCE POTENTIAL OF THE PIEDRA WILDERNESS STUDY AREA, ARCHULETA AND HINSDALE COUNTIES, COLORADO

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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 being studied at present. 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 Piedra Wilderness Study Area, San Juan National Forest, Archuleta and Hinsdale Counties, Colorado. The area was established as a wilderness study area by Public Law 96-560, known as the Colorado Wilderness Act of 1980.

MINERAL RESOURCE POTENTIAL SUMMARY STATEMENT

The mineral resource potential of the Piedra Wilderness Study Area is low. No occurrences of metallic minerals, of valuable industrial rocks and minerals, or of useful concentrations of organic fuels are known in the study area. However, a noneconomic occurrence of gypsum in the Jurassic Wanakah Formation lies a few hundred feet west of the WSA boundary, is believed to extend into the WSA, and has a low resource potential. Particular attention was paid to the possible occurrence of organic fuels in the Pennsylvanian Hermosa Formation, of uranium and vanadium in the Jurassic Entrada Sandstone and Morrison Formation, and of coal in the Cretaceous Dakota Sandstone. Thin coaly beds in the Dakota have a low resource potential. Extensive sampling of stream sediments, limited sampling of rock outcrops and springs, and a number of scintillometer traverses failed to pinpoint significant anomalies that might be clues to mineral deposits.

INTRODUCTION

The Piedra Wilderness Study Area encompasses 41,500 acres in Archuleta and Hinsdale Counties in southwestern Colorado. The area is southwest of the Continental Divide in the southern foothills of the San Juan Mountains, about equidistant between Durango and Pagosa Springs, Colorado. Access to the southern part of the Wilderness Study Area (WSA) is from U.S. Highway 160, via a U.S. Forest Service road to the junction of the Piedra River and First Fork (see fig. 1). The eastern, northern, and northwestern parts of the WSA are accessible from another U.S. Forest Service Road.

The Piedra Wilderness Study Area is along the northern border of the San Juan Basin, at the juncture of the Colorado Plateau and Southern Rocky Mountains physiographic provinces. Altitudes range from just under 6,800 ft at the junction of Indian Creek and the Piedra River to 10,474 ft at Bear Mountain. The WSA is dominated by the steep-walled valleys of the Piedra River, which is the master through-going stream, and of the several major tributaries, notably First Fork, Mosca, Coldwater, Sand, Indian and Sheep Creeks. The valleys constitute three-quarters or more of the area; upland surfaces, generally south sloping, make up the remaining one-quarter. The topography is very similar to the mesa and canyon country of the Colorado Plateau farther west and southwest, differing mainly in the markedly sloping mesa surfaces and the dense cover of vegetation. The vegetative cover is a mix of conifers (about 70 percent of the area) and deciduous trees (about 25 percent of the area) (U.S. Department of Agriculture, 1982). A dense undergrowth of scrub oak occupies more than one-third of the area. The conifers are mostly Douglas fir, with some spruce fir

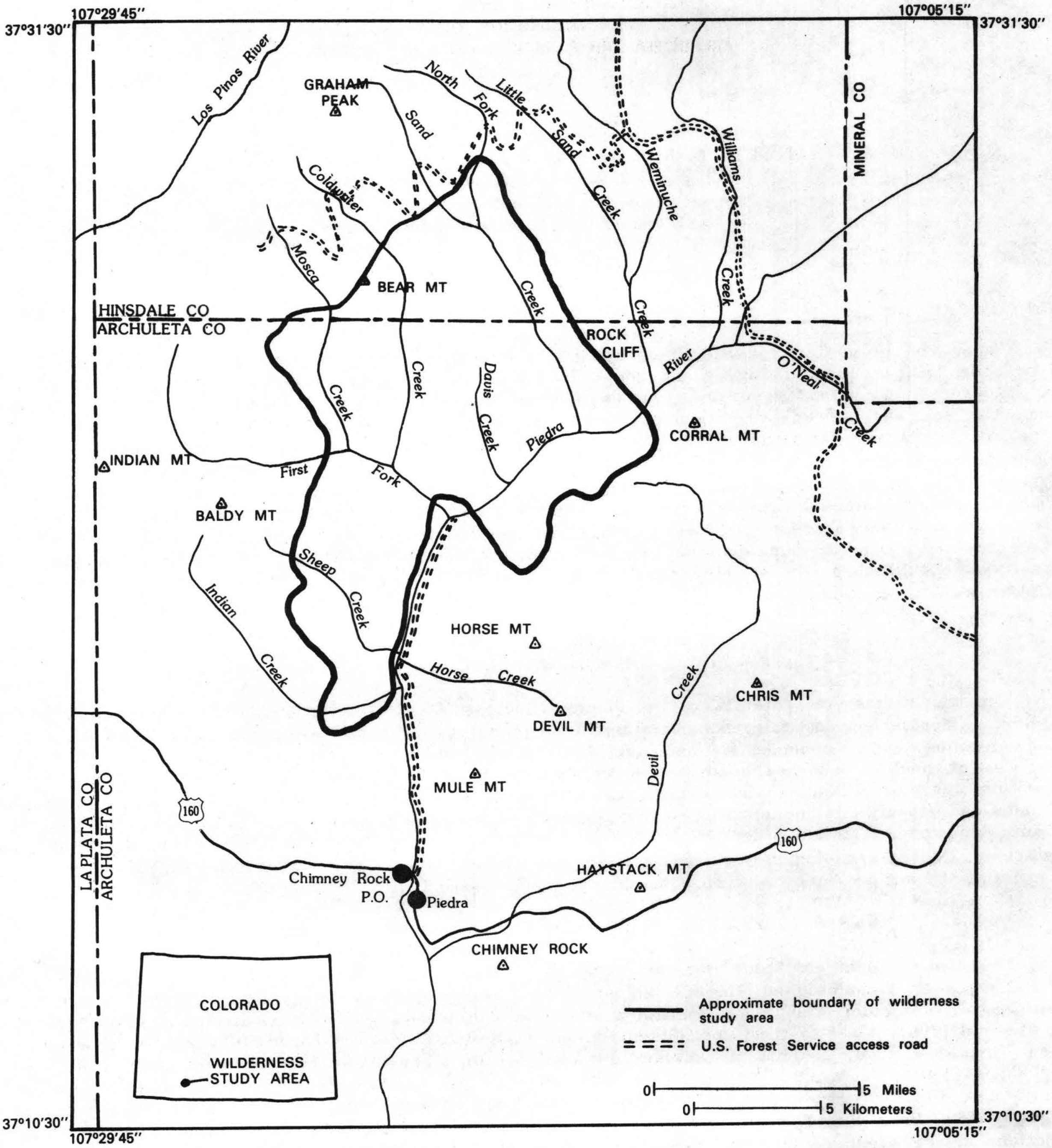

Figure 1.--Index map showing location of the Piedra Wilderness Study Area, Archuleta and Hinsdale Counties, Colorado.

and a small amount of Ponderosa pine at the lower altitudes; deciduous trees are mostly scattered stands of aspen. Soils generally are thin, but forest litter is abundant, and outcrops are sparse, scattered, and usually disclose only a small part of a formation's thickness. At two places along the Piedra River, resistant Precambrian rocks in the cores of anticlines have been eroded into deep, steep-walled canyons (First Box and Second Box); there, exposures are excellent though access is difficult. Of all the younger rocks, the Dakota Sandstone (Cretaceous) is most likely to be exposed as steep cliffs at the mesa edges; the Hermosa Formation (Pennsylvanian) makes numerous ledges throughout the area, but the outcrops tend to be discontinuous, isolated, and only a few feet to a few tens of feet thick.

Summertime cattle grazing was the only commercial use that was made of the WSA at the time of this study. Fishing, hunting, and backpacking are the major recreational uses—bear and deer are numerous, and elk also are present.

GEOLOGY

The rocks of the Piedra Wilderness Study Area range in age from Precambrian to Late Cretaceous and aggregate more than 11,000 ft in thickness, of which some 7,000 ft is assignable to the oldest unit, the layered metamorphic rocks of the Uncompahgre Formation. Stratigraphy and structure in the WSA are discussed by Condon and others (in press).

The Uncompahgre crops out in the cores of two anticlines where they have been breached by the Piedra River at the First Box and Second Box Canyons and in a broad dome at the mouth of Weminuche Creek. Two facies are present, a quartzite sequence that occurs in both the First Box and the Second Box Canyons, and a slate-phyllite-schist assemblage that crops out at Weminuche Creek and extends to barely within the eastern boundary of the WSA. The relations between the two facies are not known, but the 1,460-m.y.-old Eolus Granite (Barker, 1969, p. 25-27) cuts the quartzite facies along the Piedra River and the slate facies along Weminuche Creek outside the WSA boundary. The base of the Uncompahgre is not exposed in or near the Piedra Wilderness Study Area, but the formation in the Needle Mountains, about 15-20 mi to the northwest, is considered to be younger than a number of granitic rocks that have ages of about 1,720 to 1,760 m.y. (Barker, 1969, p. 3, 16-22). Accordingly, the Uncompahgre Formation here, as elsewhere, is considered to be Proterozoic Y and X in age.

Paleozoic rocks older than the Pennsylvanian total only about 200 ft in thickness. The marine Ignacio Quartzite (Upper Cambrian) is unconformable on the Uncompahgre Formation and reaches a maximum known thickness of 28 ft. The shallow marine Upper Devonian Elbert Formation is unconformable on the Ignacio, is composed of sandstone, siltstone, and dolomite, and has a maximum thickness of 25 ft. The Upper Devonian Ouray Limestone is conformable on the Elbert and is composed mostly of limestone, calcareous shale, and calcareous sandstone, but also contains some quartzitic sandstone. The maximum thickness is about 45 ft. The Lower Mississippian Leadville Limestone overlies the Ouray with apparent conformity, and the contact may be gradational. The Leadville consists of about 100 ft of thin- to medium-bedded, coarsely crystalline and oolitic limestone and, like the underlying Elbert and Ouray, was deposited in a shallow marine and tidal flat environment. During subsequent regional uplift, karst topography was developed in places on the Leadville. These lower Paleozoic rocks crop out only along the Piedra River, near First and Second Box Canyons and the mouth of Weminuche Creek.

The upper Paleozoic is represented by Pennsylvanian and Permian rocks that aggregate about 2,000 ft in thickness and crop out mostly in the southern part of the WSA. The continental Molas Formation (Lower and Middle Pennsylvanian) consists of basal breccia, siliceous shale and siltstone, limestone, limestone-pebble conglomerate, and quartzose sandstone; it is probably a regolith. The Molas is disconformable on the Leadville, and the basal breccia fills the cavernous, irregular, and spottily developed karst surface on the Leadville. The Molas reaches about 125 ft in thickness. The Upper Pennsylvanian marine Hermosa Formation is conformable on the Molas, and the contact between them is a transitional one. The Hermosa comprises a succession of shales (some calcareous), limestones, mudstones, arkosic sandstones, and conglomerates that aggregates about 1,000 ft in thickness and that increases in clastic content northeastward along the Piedra River (Read and others, 1949), and presumably similarly throughout the WSA. The Rico Formation (Upper Pennsylvanian and Lower Permian) conformably overlies and intertongues with the Hermosa and marks a return to continental sedimentation, an environment that persisted through the remainder of the Permian and much of the Mesozoic. The Rico is a fan delta, transitional unit between the Hermosa and the Cutler; it has interbedded limestone, sandstone (crinoidal and arkosic), and shale (gray and red) and is as much as 185 ft thick. The contact with the overlying Permian Cutler Formation is gradational and is characterized by the gradual disappearance of limestone and crinoidal sandstone and the increasing proportion of red beds. In places, the Rico is not a distinguishable unit, and rocks mapped as Cutler lie directly on rocks mapped as Hermosa; the exact relationship is not known. The Cutler is an alluvial fan complex of arkosic conglomerate, arkosic sandstone, shale, and siltstone that reaches a thickness of about 850 ft. It thins northward and northeastward through the WSA as a result of erosion at the end of the Paleozoic and during the Early and Middle Triassic, and in the central part of the WSA it is cut out by the regional unconformity at the base of the Upper Triassic.

The Mesozoic rocks begin with the Upper Triassic Dolores Formation, which overlies the regional unconformity with very slight angular discordance. The Dolores is a fluvial red-bed sequence that is less arkosic than the underlying Cutler. It is composed of interbedded shale and sandstone and has some units of limestone-pebble conglomerate that are not found in the Cutler. The Dolores is bevelled by a widespread erosion surface on which the Middle Jurassic Entrada Sandstone was deposited so that the Dolores ranges in thickness from 350 ft to an erosional pinchout along a line that runs about north-south through the WSA. This erosion surface cuts across all the Paleozoic rocks and extends down to the slate-phyllite-schist facies of the Proterozoic Y and X Uncompahgre Formation at the eastern boundary of the WSA at the Piedra River. About 1 mi northeast of this point, at the junction of Weminuche Creek and the Piedra River, a section of red beds about 10 ft thick rests on the Precambrian rocks. W. J. Hail, Jr. (unpub. mapping, 1965-66) has tentatively correlated these rocks with the Dolores Formation.

Middle and Upper Jurassic rocks are at the surface over more than half (perhaps as much as two-thirds) of the WSA. The Entrada Sandstone is the oldest of these rocks, a mostly eolian unit 200-350 ft thick, that is characterized by large-scale trough crossbeds in thick sets, interbedded with planar laminated beds in thin sets. The Entrada is overlain conformably by the tripartite Wanakah Formation and may intertongue with the lower unit of the Wanakah, the Pony Express Limestone Member (Read and others, 1949). The member has a lower, laminated bituminous limestone and, in places, an upper unit of limestone breccia and gypsum; total thickness ranges from 3 to 20 ft. Viscous bitumens coat joints in the limestone, suggesting that the Pony Express may have been a source rock for oil or gas. This member was deposited either in a restricted marine basin or in a lake. The middle unit of the Wanakah is an unnamed sequence of light- to dark-red limy shale, siltstone, and lenticular sandstone that is about 75-80 ft thick just south of the study area. The Junction Creek Sandstone Member at the top of the Wanakah ranges in thickness from about 120 ft just south of the WSA to about 25 ft just northeast of the mouth of Weminuche Creek. The unit is an even-grained, crossbedded sandstone, probably mostly of eolian origin. The Middle and Upper Jurassic Morrison Formation, composed of the Salt Wash Sandstone Member below and the Brushy Basin Shale Member above, conformably overlies the Wanakah. The Salt Wash is a complex of intertonguing, lenticular, fluvial sandstones and conglomeratic sandstones that contain plant fragments and that are interbedded with claystones and mudstones. The Brushy Basin is dominantly a variegated mudstone unit, interbedded with mostly thin, blocky sandstones and occasional lenticular conglomeratic sandstones. Poor exposures in the WSA prevent an accurate measurement of thickness, both for the individual members and for the entire formation, but a total thickness of 550 ft was determined a short distance south of the WSA.

The Cretaceous sedimentary rocks overlie the Morrison disconformably. The Lower Cretaceous Burro Canyon Formation is a dominantly fluvial unit; its thickness ranges from a few tens of feet to about a hundred feet, reflecting the relief on the underlying unconformity. Another erosional unconformity lies between the Burro Canyon and the Lower and Upper Cretaceous Dakota Sandstone, but the relief on the unconformity is subdued and probably does not exceed a few tens of feet. Fluvial sandstones and conglomerates make up the lower 40-60 ft of the Dakota, and they may resemble closely the underlying Burro Canyon Formation; however, the Burro Canyon contains green and gray claystone, in contrast to the dark-gray to black organic shales of the Dakota. The upper part of the Dakota consists of carbonaceous shales, thin coaly beds, and thin, blocky sandstones that may aggregate several hundred feet in thickness.

Although several thousand feet of Upper Cretaceous and Tertiary rocks are present 10-20 mi south of the Piedra WSA, none of these rocks occur in the WSA, and presumably they were removed by erosion during the Tertiary and Quaternary. The only observed Tertiary rocks within the area are possibly sill-like small masses of andesite on the east side of the Piedra River across from Davis Creek and downslope from Rock Cliff along Sand Creek. They are very likely related to the Oligocene and Miocene intrusive and volcanic igneous activity of the nearby San Juan volcanic field (Lipman and others, 1970) but evidence for more precise dating is lacking. Landslide debris comprises the only significant Quaternary depostis in the WSA.

The long homoclinal southward dip of the sedimentary rocks into the San Juan Basin is interrupted by two pairs of northwest-trending anticlines and synclines and is broken by a number of dominantly northwest-trending, steep, normal faults, which occur mostly in the southern half of the WSA. These structures probably developed during the Laramide orogeny at about the end of the Cretaceous for they are similar in style and intensity to structures elsewhere that are more accurately dated on firmer evidence. This association of folds and faults suggest that they resulted from movement on deep-seated faults that bounded blocks in the basement rocks. Earlier uplift north and northeast of the WSA at the end of the Paleozoic and in the Triassic and Jurassic apparently was on a broader scale, resulting both in facies changes and erosional pinchout of the rocks.

GEOCHEMISTRY AND GEOPHYSICS

Clues to the occurrence of mineral deposits in the Piedra WSA were sought in a sampling program that resulted in 189 stream-sediment samples, 18 rock samples, and 2 water samples. Statistical analysis of the stream-sediment sample data indicated a number of samples with anomalously high concentrations of one or more metallic elements. Although minor geographic concentrations of these anomalous metal values were found, all appear to be explainable either as derived from normal concentrations in the sedimentary and metamorphic rocks in and near the WSA, or as derived from rocks that occur only outside the WSA but whose detritus has been introduced along through-going streams that cross the WSA. Details of the occurrence of these anomalies have been discussed by Franczyk and others (in press).

Rock samples located two apparent uranium anomalies, although there are too few samples to establish the anomalous character statistically. A sample of the Entrada Sandstone along the left bank of Sand Creek about three-quarters of a mile northwest of the WSA contains 14 ppm uranium, and correlates with a scintillometer survey reading of about 5X background. Another sample of a vein cutting a probable andesite sill in the Hermosa Formation along the left bank of Sand Creek about 2 mi from its mouth contains 18 ppm uranium, but no anomalous

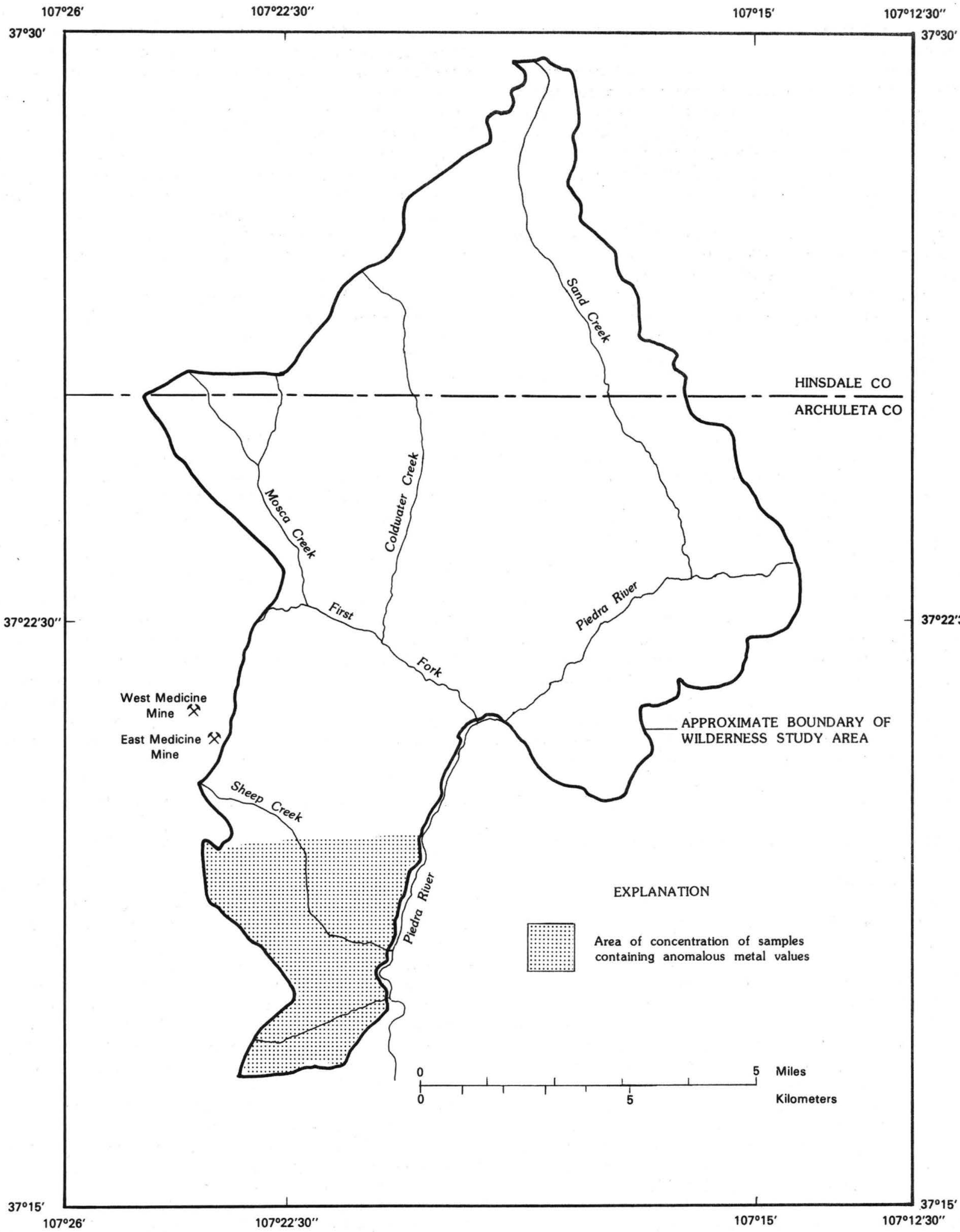

Figure 2.--Map of the Piedra Wilderness Study Area showing area of largest concentration of samples with anomalous metal values.

radioactivity was detected by a scintillometer survey along the creek.

Although there are no strong indications of possible areas of potential mineral resources, more anomalous metal values are found in the southern third of the WSA than elsewhere (see fig. 2). Most of these are attributable to heavy and(or) resistant minerals in the Cutler Formation that contribute zirconium, nickel, strontium, and beryllium to the stream sediments.

Scintillometer traverses conducted during the present survey commonly showed a slight elevation in background near the Entrada-Pony Express contact, very seldom more than 2X. Except for the anomaly along Sand Creek mentioned above, the scintillometer traverses failed to indicate any areas of unusually high radioactivity.

The only published and available geophysical data that apply directly to the Piedra Wilderness Study Area are in the report on an airborne radioactivity and magnetic survey for the Durango $1^{o}x2^{o}$ quadrangle (Western Geophysical Company of America, 1979). At the scale of the survey (published at 1:500,000) no anomalies suggestive of mineral deposits were discerned within the WSA. In the Dudley Creek-Coffee Creek area just east of the WSA, a weak uranium anomaly was suggested by the data from the aeroradioactivity survey but was not identified by a scintillometer traverse during the present survey. However, a survey by the U.S. Bureau of Mines of a prospect pit about midway between Dudley Creek and First Fork on the east side of the Piedra River reports a small uranium occurrence (Brown, 1983). Possibly this is the source of the anomaly plotted to the south by the airborne survey. In addition, the anomalous uranium content in the rock sample from Sand Creek, northwest of the WSA (mentioned above) possibly may be identified as a small blip on the survey done by the Western Geophysical Company of America (1979).

MINING DISTRICTS AND MINERALIZED AREAS

A comprehensive search for information on mines and mineralized areas in the Piedra Wilderness Study Area identified large blocks of unpatented mining claims in and around the study area but located no mining districts in or near the study area. In addition to the unpatented mining claims, one patented claim borders the western boundary of the study area at the East Medicine Mine. The area of investigation extended to about 1 mi beyond the boundary of the study area. No mines, prospects, or mineralized areas were found within the study area, but near the boundary, on the west side of the study area, the East and West Medicine Mines consist of several small pits (Brown, 1983); the closest is about 400 ft outside the study area boundary. Two surface cuts are about 1 mi outside the southeast boundary of the study area. No other prospects were observed within 1 mi of the Piedra Wilderness Study Area boundary.

At both the East and West Medicine Mines (Brown, 1983), several small pits expose beds of gypsum in the Jurassic Wanakah Formation. A small amount of the gypsum has been mined for medicinal purposes (William Lyons, claim owner, College Place, WA, oral commun., June 15, 1982). Assay results of three Bureau of Mines samples taken at the Medicine Mines do not show any unusual concentrations of metals; the favorable substance for medicinal purposes in the gypsum is unknown. The extent of the gypsum could not be determined due to the thick overburden; thicknesses as much as 15 ft were exposed in the pits. Beds of gypsum are common in the Wanakah Formation which extends into the study area; however, because of the small size of the gypsum beds and the inaccessibility of the occurrence, the gypsum here is not a resource for industrial purposes.

About 1 mi south of the central part of the study area, two open cuts expose interbedded limestone, shale, and sandstone of Pennsylvanian age. Several small blebs of pyrite were seen in one of the cuts, along with sulfur and iron stains (Brown, 1983). A sample from the other cut assayed 13 ppm U_3O_8; the uranium mineralization occurs throughout a 3-ft width in massive limestone, and this zone was traced with a scintillometer for 30 ft along strike (Brown, 1983). The limits of the uraniferous zone were exposed within the cut, and the uranium occurrence appears to be small and isolated, with no extension into the WSA. The same Pennsylvanian Hermosa Formation rocks are present inside the WSA, but other uranium occurrences are unknown.

In addition to the rock samples, pan concentrates of sediments were taken from all major streams in the Piedra Wilderness Study Area, in search of heavy-metal concentrations (Brown, 1983). Nothing of significance was seen in any of these samples.

Oil and gas lease applications were pending on about 2 mi^2 in the Piedra Wilderness Study Area in September 1981. No oil and gas activity was observed in the WSA during the field investigation. No coal leases are present in the WSA, and no coal deposits are known inside the area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

The mineral resource potential of the Piedra Wilderness Study Area is low in all categories of materials: metals, nonmetals, and organic fuels. There are no known occurrences of valuable metals within the WSA, and no significant anomalous concentrations of metallic elements were disclosed by the stream-sediment and rock-sampling program.

Specific attention was paid to the possible occurrence of vanadium and uranium in the Entrada Sandstone, for there are deposits in the Placerville, Barlow Creek-Hermosa Creek, and Lightner Creek areas some 35-50 mi to the west and northwest. At all these deposits, the Entrada is overlain by the Pony Express Limestone Member of the Wanakah Formation, and this relationshp may be an essential factor in the localization of the deposits. Such a relationship indeed is present in the Piedra WSA but no evidence of vanadium-uranium mineralization was found. Attention was also focussed on the possible occurrence of uranium and vanadium in the Morrison Formation, particularly in its Salt Wash Sandstone Member, which is productive over a wide area in southwestern Colorado and southeastern Utah. Scintillometer traverses and analyses of stream sediments derived primarily from Morrison outcrop areas gave no hint of possible uranium-vanadium occurrences.

The association of lead-zinc-silver-barite-copper (massive sulfide) deposits with Paleozoic marine limestones and shales is well known. The outcrop area of the most likely host rock, the Leadville Limestone, is small and confined to the inner valley of the Piedra River, First and Second Box Canyons, and a small area downstream from the mouth of Weminuche Creek. In these outcrops evidence of massive-sulfide deposits is lacking and anomalous concentrations of metallic elements in stream-sediment samples seem as likely to be derived from rocks upstream from the WSA as from within the WSA. There appears to be no basis for the assignment of any mineral potential for these deposits types.

Occurrences of industrial rocks and nonmetallic minerals are lacking in the WSA except for beds of gypsum in the upper part of the Pony Express Limestone Member of the Wanakah Formation. These beds are variable in both thickness and extent and are not well exposed anywhere in the WSA. Brown (1983) located the only prospected occurrences at the East and West Medicine Mines, both of which lie very close to, but west of, the WSA boundary (fig. 2). The gypsum reaches an exposed thickness of about 15 ft. The resource potential of the occurrences is low, however, for the deposits are far from major markets, are of variable thickness, and would be difficult to mine by open-pit methods.

Carbonaceous shales and thin coaly beds occur in the middle and upper parts of the Dakota Sandstone, but the carbon content of the shales is low, and the coal is low rank and only about 1 ft thick (George E. Claypool, written commun., Nov. 8, 1981; Franczyk and others, in press). The mineral resource potential is low.

In various parts of the San Juan Basin the Hermosa Formation has yielded both oil and gas, but the potential for the occurrence of oil and gas resources in the WSA appears to be low. The full thickness of the formation has been breached by the Piedra River and its tributaries, possible structural traps like the First Fork and Second Box anticlines have been breached by erosion and cut by deep-seated faults, and the homoclinally dipping rocks of the southern third of the area also are faulted. The effect of faulting on possible reservoir rocks is ambiguous; in places it may have created trap conditions, elsewhere it may have provided escape channelways for oil or gas. No evidence of dead oil was found at the outcrop of the Hermosa rocks, although some of the limestones have a fetid odor. It would appear that whatever organic materials were contained previously in the formation have had ample opportunity to escape.

A warm spring, unlocated during the present survey, has been reported by word-of-mouth to exist near river level on the east side of the Piedra River in the Coffee Creek-Dudley Creek area, and a steep fault is present in the area. A second warm spring, also unlocated, has been reported similarly to exist near the mouth of Davis Creek, on the west side of the river; the nearest known fault is about a mile from the mouth. Possibly the springs are related to unmapped faults associated with and(or) parallel to the known faults. On the basis of the knowledge available at the time of the survey, the springs are intriguing features but are not believed to indicate a significant geothermal resource in this area.

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