UNITED STATES

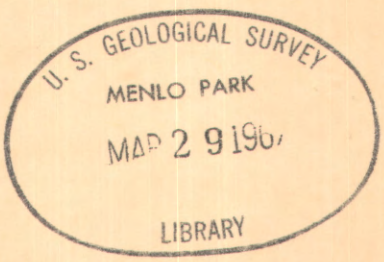
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Mineral Appraisal of the Poker Jim Ridge and Fort Warner Areas of the Hart Mountain National Antelope Refuge, Lake County, Oregon

by

George W. Walker and Donald A. Swanson



Open-file report
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Studies related to Wilderness

The Wilderness Act (Public Law 88-577, Sept. 3, 1964) directs the Secretary of the Interior to review roadless areas of five thousand contiguous acres or more, and every roadless island, within the national wildlife refuges and game ranges under his jurisdiction, and to report on the suitability or nonsuitability of each such area or island for preservation as wilderness. As one aspect of the suitability studies, the Secretary has directed the U. S. Geological Survey and the U. S. Bureau of Mines to make mineral surveys of the wilderness candidate areas. The surveys are concerned principally with the minerals subject to leasing under the mineral leasing laws and are based largely on analysis of existing published or unpublished data.

This bulletin is one of a series of similar reports on lands under the jurisdiction of the Department of the Interior.

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Mineral resources of the Poker Jim Ridge and Fort Warner areas of the Hart Mountain National Antelope Refuge, Lake County, Oregon.

Summary

The Poker Jim Ridge and Fort Warner areas, which are candidate areas for inclusion in the National Wilderness Preservation System, are in the Hart Mountain National Antelope Refuge in east-central Lake County, south-central Oregon. The two areas form part of an upraised and tilted fault block--a structural element that is typical of the northern part of the Great Basin province. Rocks in the two areas are principally volcanic in origin. They have been faulted, uplifted, and tilted eastward, the older rocks having been more strongly deformed than the younger ones.

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No mineral raw materials that are in the category of leaseable minerals[1/] have been produced from either of the two candidate areas,

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[1/] Mineral commodities that are now (1966) being exploited under mining lease laws include gas, oil and oil shale, sulfur, coal and peat, uranium, and sodium and potassium saline minerals. Zeolites and other diagenetic mineral substances are being considered for inclusion in this group of leasable minerals.

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and no mineral commodities known to occur within the two areas can be mined economically at present (1966). Many of the older tuffs and tuffaceous sedimentary rocks of the Fort Warner candidate area are altered to zeolites (principally clinoptilolite) which make up 90-95 percent of some beds. The mineral economics of natural zeolites is not yet clearly established, and large, more accessible deposits of clinoptilolite occur elsewhere in Oregon; hence the future value of the Fort Warner deposits cannot at present be determined.

Small deposits of precious opal (of interest mainly to mineral collectors) and low-grade bentonite occur locally, but are not of commercial importance. The complexly faulted, volcanic area is not favorably for the accumulation of petroleum or for commercial deposits of coal, sulfur, saline minerals, or oil shales.

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Introduction

Purpose and scope

The Poker Jim Ridge and Fort Warner areas of the Hart Mountain Antelope Refuge, Lake County, Oregon (fig. 1), have been proposed

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Figure 1 near here

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for inclusion in the National Wilderness Preservation System. The mineral resources of the two candidate areas have been studied by the Geological Survey, paying special attention to the potential of the areas for gas, oil and oil shale, coal and peat, potassium and sodium saline deposits, sulfur, zeolites, deposits of metallic minerals, bentonite, diatomite, and geothermal power.

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Figure 1.--Location of the Poker Jim Ridge and the Fort Warner candidate areas of the Hart Mountain National Antelope Refuge, Oregon.

In order to evaluate the mineral resources, reconnaissance geologic maps were prepared of the two candidate areas (figs. 2A and 3B). These maps are based on reconnaissance and photogeologic mapping done during July 1961 by G. W. Walker, C. A. Repenning, and D. H. Lindsley (Walker and Repenning, 1965) as part of project to prepare a geologic map of Oregon. Some of the earlier reconnaissance geologic work in the region, by Russell (1884) and subsequent workers, is summarized in a report by Fuller and Waters (1929) on the structure of southeast Oregon. The most recent and detailed study of the area that contains both Hart Mountain and Poker Jim Ridge is an unpublished Ph.D. thesis by E. E. Larson, submitted in 1965 to the Department of Geology, University of Colorado.

Many rock and mineral samples collected in 1961 were examined in the laboratories of the Geological Survey. In October 1966, G. W. Walker and D. A. Swanson revisited the area briefly to collect samples of altered tuff and tuffaceous sedimentary rock exposed on the west side of Hart Mountain. Earlier laboratory work indicated that these rocks probably contain zeolites and possibly also bentonite and diatomite. Samples of tuff and tuffaceous sedimentary rocks were analyzed by means of X-ray diffraction techniques to determine their mineral content.

Because of the absence of mineral production, the U. S. Bureau of Mines has not had occasion to examine the candidate areas, but the Bureau has been informed of the findings and recommendations of the Geological Survey and concurs in them.

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Location and geography

Both the Poker Jim Ridge and Fort Warner candidate areas are in the Hart Mountain National Antelope Refuge in east-central Lake County, Oregon, about 40 miles by air and 65 miles by road northeast of Lakeview. Access to the refuge is by graded gravel roads either from the hamlet of Plush, about 10-15 miles southwest of the candidate areas, or from the road intersection on U.S. Highway 395 several miles northeast of Lake Abert and about 30 miles northwest of the areas. The refuge can also be reached over a poorly maintained desert road from Frenchglen, a small community about 60 miles south of Burns, Oregon, via State Highway 205.

The outlines and relative positions of the Poker Jim Ridge and Fort Warner candidate areas are shown on figure 1 and the outlines of the individual areas also are shown on the geologic maps (fig. 2, A and B). Several small pieces of privately owned land within the candidate areas are not shown on the figures.

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The Poker Jim Ridge candidate area (fig. 2) is about 8 miles

Figure 2 near here

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long and from 3 to 6 miles wide; it covers 18,500 acres. Included within the area is a major part of the prominent physiographic feature known as Poker Jim Ridge or, to some local inhabitants, as Blue-joint Rim. The ridge is asymmetric, with an 1,800-foot precipitous scarp on the west and northwest and a gentler east-facing back slope; the western boundary of the candidate area closely follows the base of the precipitous scarp.

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Figure 2.--Reconnaissance geologic map of the Poker Jim Ridge area.

The Fort Warner candidate area, a short distance southwest of Poker Jim Ridge, covers about 22,500 acres; it is about 15 miles long, and ranges in width from less than a mile at its northern end to a maximum of about 4 miles to the south (fig. 3). The Fort

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Figure 3 near here

Warner area includes most of Hart Mountain--one of the best defined fault-block mountains in the world and a prominent physiographic feature of the region rising to a maximum elevation of 8,065 feet at Mount Warner. Warner Valley, west of Poker Jim Ridge and Hart Mountain, is a flat desert valley dotted with a number of ephemeral lakes and having an average elevation of about 4,400 feet. Parts of the steep west-facing fault scarp of Hart Mountain are over 3,000 feet above Warner Valley locally consisting of unassailable crags and sheer cliffs. The eastern scarp is neither as precipitous nor as high. In several places jeep roads lead to the elevated tableland on the south and north ends of the mountain.

Upper parts of De Garmo Canyon and adjacent Mount Warner show erosional features indicative of minor valley glaciation during the Pleistocene Era.

The vegetation of both candidate areas is typical of the high desert regions of southeast Oregon and includes a few groves of aspen and yellow pine, widely distributed western juniper, sage and rabbitbrush, and several varieties of grasses and flowering plants.

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Figure 3.--Reconnaissance geologic map of the Fort Warner area.

Geology

Hart Mountain and Poker Jim Ridge form part of a large complex uplifted fault block--a structure typical of the northern Great Basin. All of the rocks in the refuge are of Cenozoic age, and include many flows of basalt and andesite, some rhyolite flows, flow breccias, and tuffaceous sedimentary rocks, a few partly welded ash-flow tuffs, and some comparatively young surficial deposits. In addition, several areas of silicic vent rocks are present, chiefly in or near the major faults that bound the large fault block or horst.

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Consolidated rocks

Stratigraphic rocks

The oldest rocks in the Fort Warner and Poker Jim Ridge areas include gently dipping, moderately to well-lithified, commonly altered tuffs, tuffaceous sedimentary rocks, and andesite flows and flow breccias. These are exposed along the west side of Hart Mountain, particularly south of De Garmo Canyon. The precise age of the rocks is not known, but their stratigraphic position beneath rocks dated as middle and late Miocene, and the degree and type of their alteration suggest that they may in part be correlative in age with the John Day Formation of central Oregon (late Oligocene and early Miocene). However, the upper part of the sequence is thought to be somewhat younger than the typical John Day Formation and perhaps as young as middle Miocene.

Southwest of Mount Warner, the oldest rocks consist of a thick continuous unit of altered tuffs and tuffaceous sedimentary rocks (fig. 3B). The rocks are composed chiefly of pumice lapilli and glass shards or their alteration products. They are localized on the flanks of a large silicic volcanic pile, most of which was erupted from vents a few miles northeast of Mount Warner. These clastic rocks contain zeolites of possible commercial importance, and are of three types: well-sorted tuffs, many of which formed directly from falls of ash on land; poorly sorted volcanic sandstones and siltstones of probable slurry-flood origin; and pumice lapilli tuffs and tuff breccias, which were deposited by nuées ardentes or by mudflows.

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The well-sorted tuffs occur in beds less than a foot thick. They are laminated in places, fine to medium grained, and consist mainly of ash and small pumice lapilli. The well-sorted tuffs comprise only a small part of the section in the area west-southwest of Mount Warner. In these tuffs the glass is completely altered to clinoptilolite and mixed-layer montmorillonitic (bentonitic) clays, with some mordenite, phillipsite, calcite, and celadonite. A few pure vitric tuffs are now 90-95 percent clinoptilolite. Rocks with small amounts of clay but abundant zeolites are yellow brown, whereas those rich in clay but poorer in zeolites are shades of green.

Farther south the well-sorted tuffs are more abundant and tend to be finer grained and less altered than those to the north. All of the glass shards are finely devitrified to alkali feldspar and silica minerals, and contain minor amounts of clay minerals, sodic plagioclase, clinoptolilite, and mordenite.

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Poorly sorted volcaniclastic sedimentary rocks are interbedded with the well-sorted tuffs, commonly along erosional contacts. These rocks form a large part of the section west-southwest of Mount Warner, but a very much smaller part farther south. They consist largely of coarse-ash- to fine-lapilli-size volcanic rock fragments in a matrix of fine- to medium-size vitric ash and detrital clay--the matrix making up more than half of some rocks. The volcaniclastic sedimentary deposits occur in beds several inches to a few feet thick that are lenticular and commonly channeled.

The greater proportion of well-sorted tuffs to the south, and their generally finer grain size, suggest a greater distance from the source vents than the tuffs farther north. The poor sorting, channeling, and erosional lenticularity suggest that the rocks are products of slurry floods or overloaded streams that periodically scoured loose debris from hill slopes and carried it in a muddy suspension far out into adjacent lowlands.

Alteration of the poorly sorted volcanic sandstones and siltstones is similar to that affecting the well-sorted tuffs. Zeolites are less abundant, however, inasmuch as vitric ash, the material most susceptible to zeolitization, is less plentiful than in the air-fall tuffs.

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Nuées ardentes and mudflow deposits about 10-50 feet thick make up most of the upper half of the stratigraphic section west-southwest of Mount Warner, but they form less than a quarter of the unit farther south. These chaotic lapilli tuffs and tuff breccias are interlayered with slurry flood deposits and air-fall tuffs. Commonly, the underlying rocks show evidence of having been gouged and scoured along the contact, and ripped-up fragments of tuff and volcaniclastic sediments are dispersed throughout the lower parts of some of the lapilli tuffs and tuff breccias. The lithology and relationships to interbedded rocks suggest that the unsorted lapilli tuffs and tuff breccias are products of near-vent nuées ardentes or, possibly, thick mudflows carrying newly erupted ash, pumice, and lithic fragments away from the vent areas.

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The lapilli tuffs and tuff breccias are altered to zeolites and clays similar to those in the interlayered rocks.

Silicic flow and intrusive rocks, principally rhyolite or dacite but including some soda rhyolite (Walker, 1961), occur near the top of the sequence of tuffs and tuffaceous sedimentary rocks. Some of these silicic rocks are delineated on figure 3 as intrusive rocks (map unit Trd); most of them, however, are included either in the rhyolitic vent rocks (unit Tvr) near Mount Warner, or in the upper part of the older flows, breccias, and tuffs (unit Tar) that are essentially conformable with other layered rocks outside the vent area.

A regional unconformity, with hundreds and perhaps several thousand feet of relief, separates this older sequence of clastic and silicic rocks from the overlying basaltic flow rocks that are partly correlative with the Steens Basalt (Steens Mountain Basalt of Fuller, 1931, p. 101-113) of middle(?) and late Miocene age (Walker and Repenning, 1965; Evernden and others, 1964). These flows and associated scoria and breccia more than 1,800 feet in thickness form most of the scarp on Poker Jim Ridge, but they thin southward and lap out on Hart Mountain several miles north of De Garmo Canyon. The basalts reappear a few miles south of Mount Warner and thicken to several hundred feet at the south end of Hart Mountain.

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The basaltic flow rocks are overlain by a discontinuous but widespread unit of poorly bedded, moderately well-sorted, tuffaceous sedimentary rocks composed largely of vitric ash and detrital clay. Sparse vertebrate fossils, found in several places in the northern part of the Fort Warner candidate area (Walker, 1960), indicate approximate age equivalence with the Beatty Butte (Wallace, 1946), Mascall (Downs, 1956), and Virgin Valley (Merriam, 1910) faunas of late middle or late Miocene age. In contrast to the older tuffaceous sedimentary rocks of Oligocene or early Miocene age, most of the vitric ash is fresh or only slightly altered, and no zeolites were recognized in any samples tested.

A thin unit of basalt overlies the tuffaceous sedimentary rocks. It is not precisely dated, but is either of late Miocene or early Pliocene age. In places the flows rest directly on the Miocene basaltic flow rocks and elsewhere on the intervening fossiliferous Miocene tuffaceous sedimentary rocks. In adjoining parts of the region it is possible that the tuffaceous sedimentary rocks interfinger with both the overlying and underlying basalt flows.

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A thin discontinuous sheet of pumice lapilli welded tuff crops out in some of the flatter parts of the refuge--mostly north and east of the two candidate areas. Several small patches of the tuff occur along the eastern boundary of the Poker Jim Ridge candidate area, and more extensive outcrops are present near the headquarters of the refuge between the two candidate areas. The tuff is about 15 feet thick in the northern part of the refuge but thins southwestward. The ashflow tuff in areas several miles to the east and north has been determined to be of early or middle Pliocene age, both by potassium-argon isotopic methods and by vertebrate fossils collected from adjacent sedimentary beds. The tuff, moderately to poorly welded, is light gray and pale yellowish to pinkish brown. It is composed dominantly of pumice fragments and glass shards that locally are converted to secondary alkali feldspar and cristobalite or quartz through vapor-phase alteration.

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Vent rocks

Intrusive vent rocks and extrusive near-vent rocks of several different kinds have been recognized near Mount Warner and in several places along the major faults at the west base of Hart Mountain. Only the larger masses of these rocks are shown on figure 3.

Minor amounts of red, cindery, near-vent scoriaceous andesite and several small dikes and sills are associated with the older andesite flows and flow breccias of map unit Tar. The scoria and intrusive rocks probably represent in part the source of the flows and breccias. Most of the vent rocks in the refuge, however, are flow-banded, locally brecciated, porphyritic rhyolite or dacite, in the form of intrusive or exogenous domes and closely associated flows. Several of the intrusive masses and related near-vent flows are soda rhyolite characterized by phenocrysts of anorthoclase and microlites of anorthoclase, riebeckite(?), acmite, and aenigmatite-rhonite(?) (Walker, 1961). The largest accumulation of silicic vent rocks lies east of Hart Mountain, with parts extending into the Fort Warner candidate area near Mount Warner.

All of the vent rocks are Oligocene or Miocene in age and none exhibits evidence of associated metallic mineralization or strong alteration.

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Surficial deposits

Unconsolidated surficial deposits within the Hart Mountain National Antelope Refuge include landslide debris, pluvial lake sediments, alluvium, and playa deposits, most of which are of late Pleistocene or Recent age, although some may be latest Pliocene.

Several of the large landslides that originated on the precipitous west side of Hart Mountain slid laterally into the large pluvial lake that occupied Warner Valley during the Pleistocene. Apparently, the mobility of these landslides was greatly increased as they mixed with the lake waters, permitting completely unsorted material, including blocks of basalt up to 4-5 feet in diameter, to advance far across the nearly flat lake floor. In places these landslide lobes extend for more than a mile from the base of Hart Mountain.

The alluvium consists mostly of sedimentary deposits that are fine grained and well sorted along gentler stream channels but are very coarse and poorly sorted in the large alluvial fans at the west base of Hart Mountain and Poker Jim Ridge. Some talus and fluvio-glacial deposits are also included in the alluvium, and in Warner Valley the near-surface alluvium locally contains minor amounts of peat mixed with clastic debris.

During periods of drought, small amounts of saline minerals form surface crusts in playas and in the shallow basins of the transient lakes of Warner Valley.

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Structure

The two candidate areas are parts of a major structural feature consisting of a great complex horst on the south, forming Hart Mountain, and a large faulted monoclinal warp on the north, at Poker Jim Ridge. Structural elements transitional from the monoclinal warp to the horst are present in and between the candidate areas.

Both of the candidate areas are separated from Warner Valley--a very large and complex graben on the west and southwest--by an arcuate zone of north-trending normal faults whose aggregate displacement is more than 2,000 feet. The east side of Poker Jim Ridge is essentially a dip slope of basalt and is only locally broken and faulted. The east side and north end of Hart Mountain, however, are bounded by low and less precipitous scarps in a zone of normal faults having an aggregate displacement of about 1,000 feet. Tilted fault blocks on the east face of Hart Mountain in places represent the broken parts of the original monoclinal structure that now characterizes Poker Jim Ridge and once extended to Hart Mountain. The Hart Mountain fault block, which is nearly flat topped and about 14 miles long and 2 miles wide, is cut by several normal faults with displacements of several tens of feet and, in places, is intruded by masses of rhyolite, dacite, and andesite or basalt. The largest pile of rhyolite and dacite, in the east central part of Hart Mountain, must have been a volcanic mountain in middle to late Miocene time, because the middle(?) and late Miocene basalt flows lap out against these rocks.

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Some aspects of the origin of the huge fault-block structures in southeast Oregon, including Hart Mountain and Poker Jim Ridge, have been described by Fuller and Waters (1929).

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Mineral resources

Regional features

Some metallic and nonmetallic mineral deposits have been exploited on a small scale in the region that includes the Hart Mountain National Antelope Refuge. Within the refuge, however, there is no past record of mining or quarrying and only a few minor occurrences of potentially valuable minerals have been reported.

Brooks (1963, p. 171-179) notes the presence of several commercial mercury deposits, including one with small production in the Coyote Hills about 10 miles west of Hart Mountain, and lists one minor occurrence on Hart Mountain with no recorded production. Deposits of uranium, locally associated with some molybdenum and minor antimony, mercury, and lead, have been discovered several tens of miles east and west of the refuge (Matthews, 1955; Peterson, 1959a), although recorded production of uranium ores from south-central Oregon has come only from the deposits northwest of Lakeview. Nearly all of these metallic mineral deposits are either in silicic intrusive rocks or in the adjacent wall rocks and are probably of hydrothermal origin closely related genetically to the intrusive rocks.

Deposits of low-grade diatomite and bentonite and several perlite deposits have been located in parts of the region (Moore, 1937; Peterson, 1961). Although some of these deposits have been explored in a limited way, mostly by bulldozer trenching, none have been of sufficiently high grade or close enough to potential markets to warrant commercial exploitation.

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Several of the large desert basins of the general region have been explored for saline minerals, notably potash salts and borates (Phalen, 1917; Libbey, 1960; Ore Bin, 1960). Some borax was produced from Alvord Valley, in southern Harney County, about 1900 (Struthers, 1904, p. 894). A minor and noncommercial occurrence of ulexite was discovered on the shore of Flagstaff Lake (R. S. Mason, written communication, 1952), a few miles northwest of Hart Mountain. Also, precious fire opal has been collected in the Virgin Valley area of northern Nevada and in minor amounts from several areas on the west face of Hart Mountain, where it occurs as detrital fragments and as vesicle and fracture fillings in basalt flows (Dake, 1954).

Sporadic interest in the petroleum and gas potential of the region has centered either in the Lakeview area, 40 to 50 miles to the west, or in areas at even greater distances from Hart Mountain to the northeast. The most recent petroleum activity in the region, during the late 1950's and early 1960's, culminated in the drilling of two deep test wells, one 20 to 25 miles northwest of Lakeview and other several miles south of Lakeview, in a volcanic terrane geologically similar to that on the refuge. The tests were negative, and interest in the area subsequently waned.

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Mineral potential of candidate areas

The Fort Warner and Poker Jim Ridge candidate areas contain few, if any, resources of metallic minerals and no apparent potential for the commercial production of saline minerals, petroleum, sulfur, coal, oil shale, or peat. Small amounts of precious opal occur on Hart Mountain and are of interest to mineral collectors. Both areas contain noncommercial bentonitic (montmorillonitic) tuffaceous sedimentary rocks. The Fort Warner area contains the potentially valuable mineral commodity clinoptilolite, a potassium-sodium-calcium zeolite.

Thin-section and X-ray analyses of many samples collected throughout both candidate areas indicate that several different zeolites are present--principally clinoptilolite, mordenite, and phillipsite, with minor heulandite(?). These zeolites are concentrated in the older, late Oligocene or early Miocene tuffs and tuffaceous sedimentary rocks on the west face of Hart Mountain in the Fort Warner candidate area. Most of these rocks contain only minor amounts of zeolites, but some of the thin-bedded fine-grained tuffs in the sequence, originally nearly pure vitric ash, are now composed of 90-95 percent clinoptilolite. Mordenite, phillipsite, and heulandite(?) are much less abundant, constituting less than 10 percent of any of the rocks tested. Neither the samples collected during the reconnaissance mapping in 1961 nor those collected since are adequate to establish the precise distribution, volume, or grade of zeolitized tuffs.

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The value and mineral economics of naturally occurring zeolites, including clinoptilolite, are not yet clearly established, although some aspects of their use as absorbants of radioactive or other waste products are briefly described by Brown (1962). The interest in natural zeolites is increasing, however, and certain deposits in the western United States, including some in central and southern Malheur County in southeast Oregon, are being explored at present (1966) by private industry.

Natural zeolites have been found in large amounts in areas more accessible than the Fort Warner candidate area, including some extensive deposits of clinoptilolite in the John Day Formation of central Oregon (Hay, 1962; Fisher, 1962). Under conditions existing in 1966, the potential value of the deposits of clinoptilolite within the Fort Warner candidate area is difficult, if not impossible, to estimate.

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Potential for geothermal power

Several thermal springs in the Hart Mountain National Antelope Refuge (Stearns, Stearns, and Waring, 1937, p. 175) and along the eastern edge of Warner Valley, about 10 miles southwest of Hart Mountain (Peterson, 1959b), suggest that an as yet undetermined potential for thermal power may exist in the area (Groh, 1966). All of the thermal springs are small, however, and the few recorded surface temperatures of the hot water are about 94°C or less--temperatures well below those currently used for the generation of power (White, 1965, table 1; Bodvarsson, 1966). Nevertheless, the presence of these springs in an area characterized by relatively young (middle to late Cenozoic) volcanism and intense faulting suggests that higher temperatures probably occur at depth, particularly adjacent to major faults and in large intrusive bodies. However, there is no way to determine, without physical exploration, whether temperatures adequate for thermal power exist at depth in the candidate areas.

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Conclusions and recommendations

Neither the Fort Warner nor the Poker Jim Ridge candidate areas in the Hart Mountain National Antelope Refuge contain deposits of mineral fuels, metallic minerals, or, with one exception, nonmetallic minerals that may be considered as potential mineral resources. The Fort Warner candidate area contains some high-grade deposits of the zeolite clinoptilolite. A growing demand for zeolites is evident but readily accessible deposits are widely available in central Oregon, as well as in many other states.

Insofar as mineral content is a determining factor, the Poker Jim Ridge area is well suited for inclusion in the wilderness system. However, In weighing the values of wilderness as against other values of the Fort Warner area, it is recommended that consideration be given to the zeolite potential of this area.

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References cited

Bodvarsson, Gunnar, 1966, Energy and power of geothermal resources: Ore Bin, v. 28, no. 7, p. 117-124.

Brown, R. E., 1962, The use of clinoptilolite: Ore Bin, v. 24, no. 12, p. 193-197.

Brooks, H. C., 1963, Quicksilver in Oregon: Oregon Dept. Geology and Mineral Industries Bull. 55, 223 p.

Dake, H. C., 1954, Opal in Oregon: Mineralogist, v. 22, no. 2, p. 68, 70.

Downs, Theodore, 1956, The Mascall fauna from the Miocene of Oregon: California Univ. Pubs. Geol. Sci., v. 31, no. 5, p. 199-354.

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964, Potassium-argon dates and the Cenozoic mammalian chronology of North America: Am. Jour. Sci., v. 262, no. 2, p. 145-198.

Fisher, R. V., 1962, Clinoptilolite tuff from the John Day Formation, eastern Oregon: Ore Bin, v. 24, no. 12, p. 197-203.

Fuller, R. E., 1931, The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon: Washington Univ. Geology Pub., v. 3, no. 1, p. 1-130.

Fuller, R. E., and Waters, A. C., 1929, The nature and origin of the horst and graben structure of southern Oregon: Jour. Geology, v. 37, no. 3, p. 204-238.

Groh, E. A., 1966, Geothermal energy potential in Oregon: Ore Bin, v. 28, no. 7, p. 125-135.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

Hay, R. L., 1962, Origin and diagenetic alteration of the lower part of the John Day Formation near Mitchell, Oregon in Petrologic studies: Geol. Soc. America, Buddington Volume, p. 191-216.

Larson, E. E., 1965, The structure, stratigraphy, and paleomagnetics of the Plush area, southeastern Lake County, Oregon: Colorado Univ., Ph.D. thesis.

Libbey, F. W., 1960, Boron in Alvord Valley, Harney County, Oregon: Ore Bin, v. 22, no. 10, p. 97-105.

Matthews, T. C., 1955, Oregon radioactive discoveries in 1954 and 1955: Ore Bin, v. 17, no. 12, p. 87-91.

Merriam, J. C., 1910, Tertiary mammal beds of Virgin Valley and Thousand Creek in northwestern Nevada. Pt. 1, Geologic history: California Univ., Dept. Geology Bull., v. 6, no. 2, p. 21-53.

Moore, B. N., 1937, Nonmetallic mineral resources of eastern Oregon: U.S. Geol. Survey Bull. 875, 180 p.

Ore Bin, 1960, Active mines and mills in Oregon in 1960: Ore Bin, v. 22, no. 9, p. 85-88.

Peterson, N. V., 1959a, Preliminary geology of the Lakeview Uranium Area, Oregon: Ore Bin, v. 21, no. 2, p. 11-16.

_____1959b, Lake County's new continuous geyser [Oregon]: Ore Bin, v. 21, no. 9, p. 83-88.

_____1961, Perlite occurrences in southeastern Klamath and southwestern Lake Counties, Oregon: Ore Bin, v. 23, no. 7, p. 65-70.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

Phalen, W. C., 1917, Potash salts, including Simple tests for potash, by W. B. Hicks: U.S. Geol. Survey Mineral Resources United States, 1915, Pt. 2-l., Nonmetals, p. 95-133.

Russell, I. C., 1884, A geological reconnaissance in southern Oregon: U.S. Geol. Survey Ann. Rept. 4, p. 431-464.

Stearns, N. D., Stearns, H. T., and Waring, G. A., 1937, Thermal springs in the United States: U.S. Geol. Survey Water-Supply Paper 679-B, 59-206 p.

Struthers, Joseph, 1904, Borax: U.S. Geol. Survey Mineral Resources United States, Calendar Year 1902, aa, p. 891-896.

Walker, G. W., 1960, Age and correlation of some unnamed volcanic rocks in south-central Oregon, in Geological Survey Research 1960: U.S. Geol. Survey Prof. Paper 400-B, p. B298-B300.

_____1961, Soda rhyolite (pantellerite?) from Lake County, Oregon: U.S. Geol. Survey Prof. Paper 424C, p. C142-C145.

Walker, G. W., and Repenning, C. A., 1965, Reconnaissance geologic map of the Adel quadrangle, Lake, Harney, and Malheur Counties, Oregon: U.S. Geol. Survey Misc. Geol. Inv. Map I-446, scale 1:250,000.

Wallace, R. E., 1946, A Miocene mammalian fauna from Beatty Buttes, Oregon: Carnegie Inst. Washington Pub. 551, p. 113-134.

White, D. E., 1965, Geothermal Energy: U.S. Geol. Survey Circ. 519, 17 p.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171

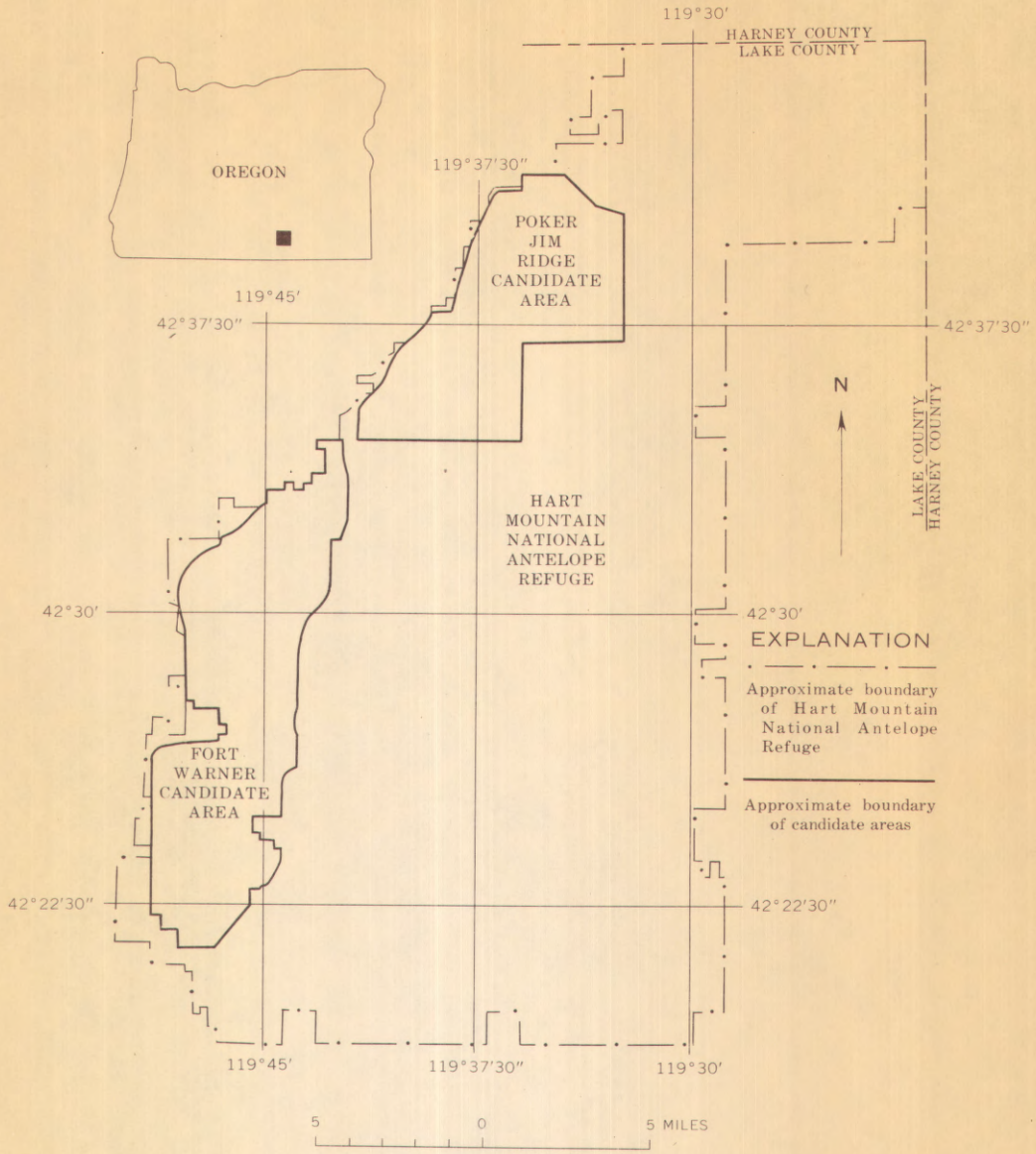
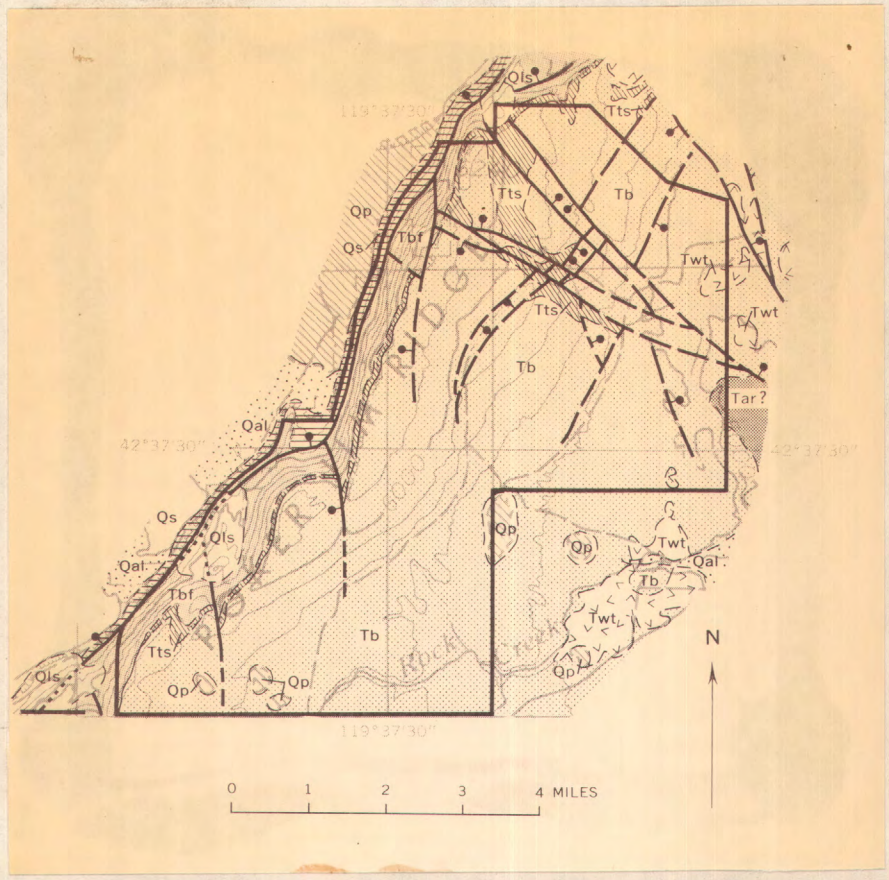


Figure 1.--Location of the Poker Jim Ridge and the Fort Warner candidate areas of the Hart Mountain National Antelope Refuge, Oregon.

3a (4 follows)



EXPLANATION

SURFICIAL DEPOSITS

Recent

Qp — Playa deposits

Qal — Alluvium

Pleistocene

Qs — Sedimentary deposits

Qls — Landslide deposits

QUATERNARY

CONSOLIDATED ROCKS

Pliocene

Twt — Welded tuff

Miocene or Pliocene

Tb — Basalt

TERTIARY

Miocene

Tts — Tuffaceous sedimentary rocks

Tbf — Basaltic flow rocks

Oligocene or Miocene

Tar — Andesite and rhyolite flows and breccias

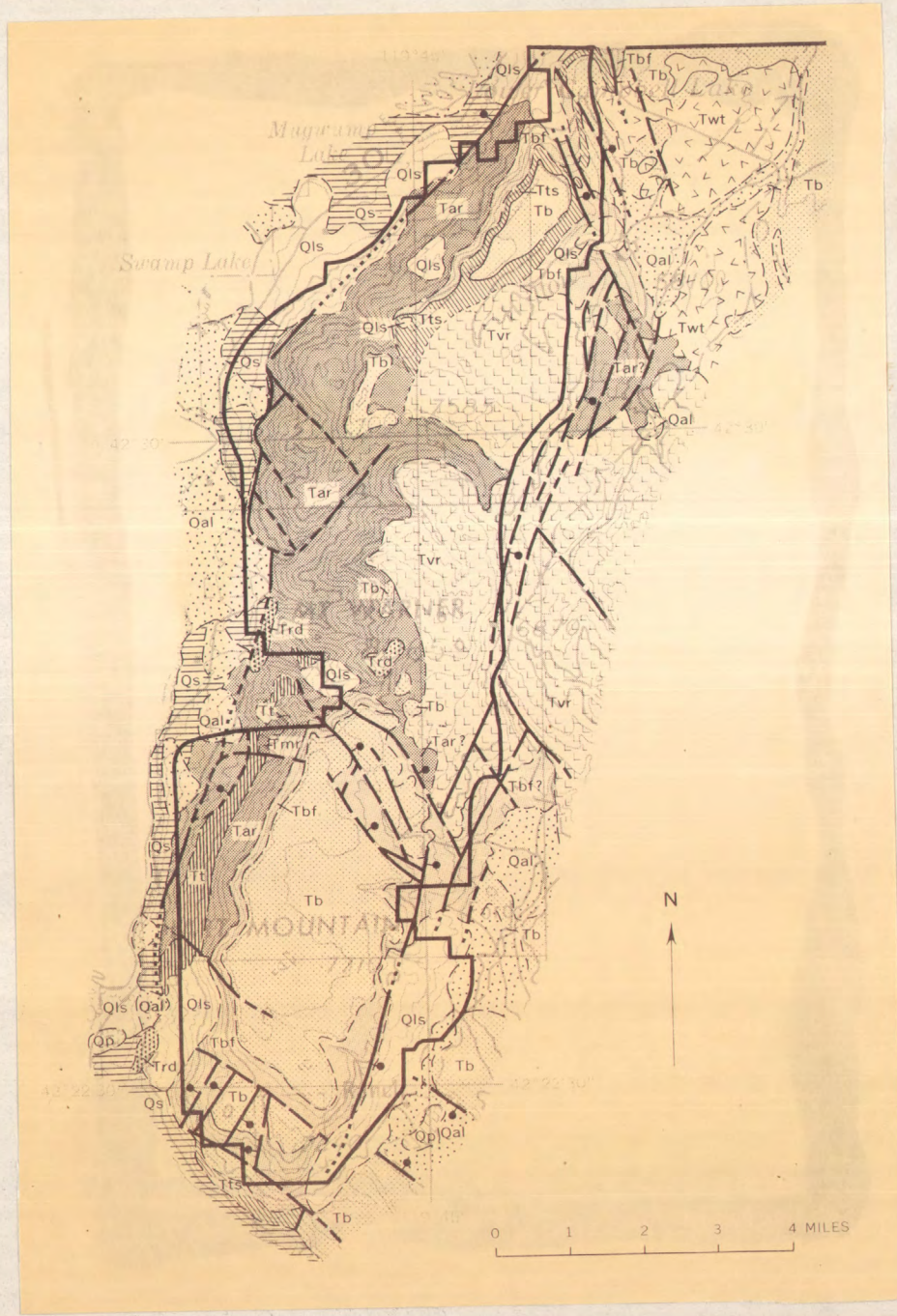
TERTIARY

Contact
Dashed where inferred

Fault
Dashed where approximate, dotted where concealed. Bar and ball on downthrown side

Approximate boundary of candidate area

Figure 2.--Reconnaissance geologic map of the Poker Jim Ridge area.



EXPLANATION

SURFICIAL DEPOSITS

Recent

Qp — Playa deposits

Qal — Alluvium

Pleistocene

Qs — Sedimentary deposits

Qls — Landslide deposits

QUATERNARY

CONSOLIDATED ROCKS

Pliocene

Twt — Welded tuff

Miocene or Pliocene

Tb — Basalt

Miocene

Tts — Tuffaceous sedimentary rocks

Tbf — Basaltic flow rocks

TERTIARY

Miocene

Trd, Tmr — Intrusive rocks
Trd, *rhyolite or dacite*
Tmr, *mafic rocks*

Oligocene or Miocene

Tvr — Rhyolite vent rocks and near-vent flows

Tar, Tt — Flows, breccia, tuff, and sedimentary rocks
Tar, *andesite and rhyolite flows and flow breccia*
Tt, *altered tuffs and tuffaceous sedimentary rocks*

TERTIARY

Contact
Dashed where inferred; dotted where concealed

Fault
Long dashed where approximate. Short dashed where inferred; dotted where concealed. Bar and ball on downthrown side

Approximate boundary of candidate area

Figure 3.--Reconnaissance geologic map of the Fort Warner area.

7a (8 follows)