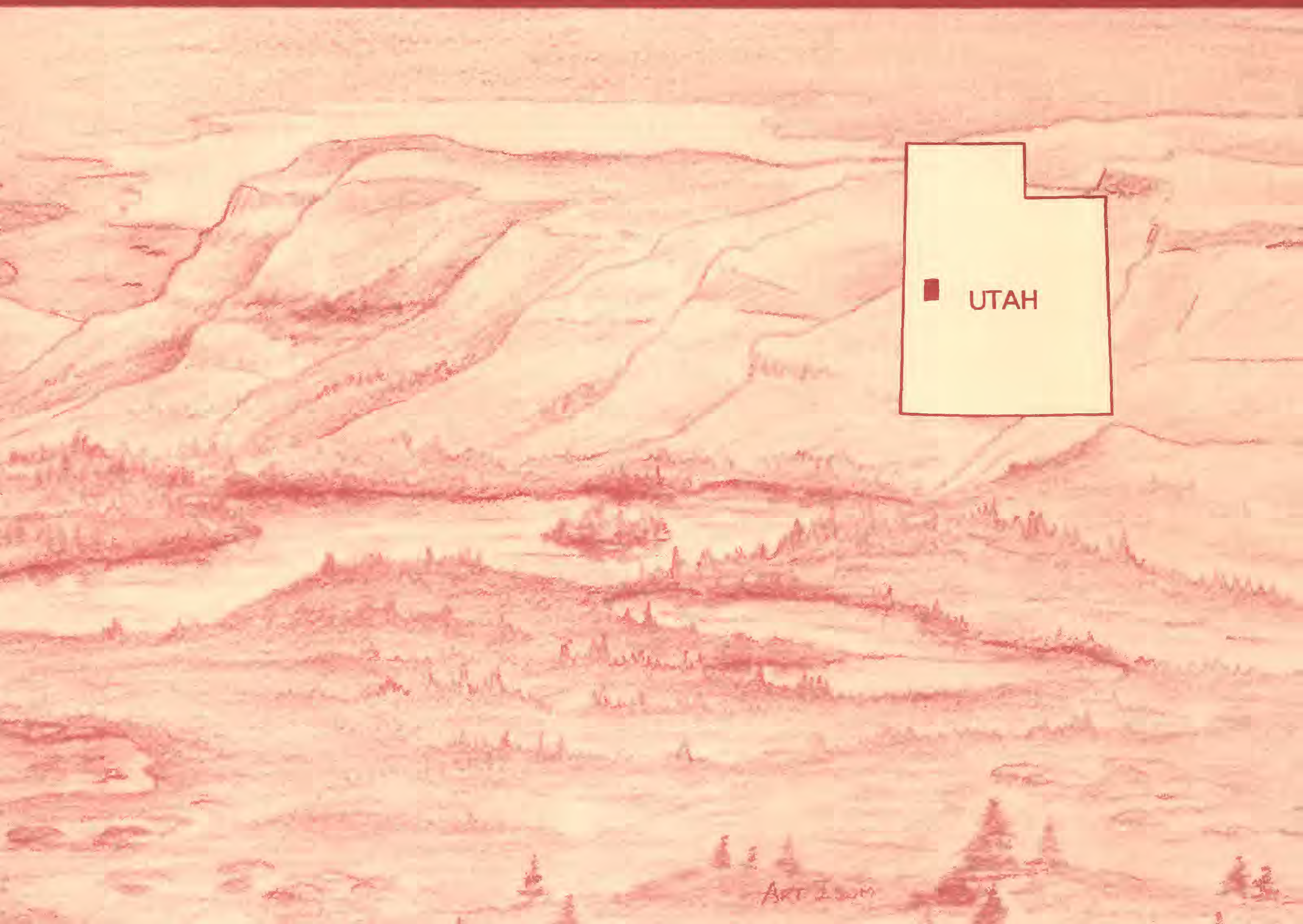
Mineral Resources of the Swasey Mountain and Howell Peak Wilderness Study Areas, Millard County, Utah

U.S. DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF MINES

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT

U.S. GEOLOGICAL SURVEY BULLETIN 1749–A



Chapter A

Mineral Resources of the Swasey Mountain and Howell Peak Wilderness Study Areas, Millard County, Utah

By DAVID A. LINDSEY, DAVID R. ZIMBELMAN, DAVID L. CAMPBELL, JOSEPH S. DUVAL, KENNETH L. COOK, MELVIN H. PODWYSOCKI, DAVID W. BRICKEY, and ROBERT A. YAMBRICK
U.S. Geological Survey

STEVEN E. TUFTIN
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1749

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—WEST-CENTRAL UTAH

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U. S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE: 1989

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Mineral resources of the Swasey Mountain and Howell Peak wilderness study areas, Millard County, Utah.

(Mineral resources of wilderness study areas—West-central Utah ; ch. A)
(U.S. Geological Survey bulletin ; 1749–A)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1749–A
1. Mines and mineral resources—Utah—Swasey Mountain Wilderness. 2. Mines and mineral resources—Utah—Howell Peak Wilderness. 3. Swasey Mountain Wilderness (Utah) 4. Howell Peak Wilderness (Utah) I. Lindsey, David A. II. Series. III. Series: Geological Survey bulletin ; 1749–A.
QE75.B9 no. 1749–A 557.3 s [553'.09792'45] 88–600472
[TN24.U8]

STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Swasey Mountain (UT–050–061) and Howell Peak (UT–050–077) Wilderness Study Areas, Millard County, Utah.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

TABLES

Mineral Resources of the Swasey Mountain and Howell Peak Wilderness Study Areas, Millard County, Utah

By David A. Lindsey, David R. Zimbelman, David L. Campbell, Joseph S. Duval, Kenneth L. Cook, Melvin H. Podwysocki, David W. Brickey, *and* Robert A. Yambrick
U.S. Geological Survey

Steven E. Tuftin
U.S. Bureau of Mines

ABSTRACT

The Swasey Mountain (UT–050–061) and Howell Peak (UT–050–077) Wilderness Study Areas are in the northern House Range, Millard County, Utah. The Swasey Mountain Wilderness Study Area includes 34,376 acres, and the Howell Peak Wilderness Study Area includes 14,800 acres that were evaluated for this report. The House Range is about 40 mi (miles) west of the city of Delta (fig. 1). A mineral resource study of the areas was completed in 1987 by the U.S. Geological Survey and U.S. Bureau of Mines. No mineral production has been recorded for either the Swasey Mountain or the Howell Peak Wilderness Study Areas. Oil and gas leases cover most of both study areas. Inferred subeconomic resources in both study areas are high-purity limestone, quartzite, and sand and gravel. Fossils, especially trilobites, of interest to collectors are also present in both areas. The northern part of the Swasey Mountain Wilderness Study Area has moderate potential for undiscovered resources of lead, zinc, copper, molybdenum, silver, and gold, including disseminated gold deposits. The southwestern part of the Swasey Mountain Wilderness Study Area and the western part of the Howell Peak Wilderness Study Area have moderate potential for resources of these metals. Potential for undiscovered deposits of high-purity limestone and dolomite and for oil and gas is moderate for both study areas. The potential for undiscovered resources of geothermal energy is low in both areas. There is no potential for undiscovered resources of coal.

Manuscript approved for publication, October 28, 1988.

SUMMARY

The Swasey Mountain and Howell Peak Wilderness Study Areas are accessible from the Dome Canyon road, which passes between the study areas in the House Range (fig. 2). The Howell Peak Wilderness Study Area is also accessible from the Marjum Pass road, which passes south of the study area. Dirt roads and jeep trails extend along the foot of the House Range in Tule Valley on the western side and Whirlwind Valley on the eastern side of the study areas. On the western sides of the study areas, picturesque cliffs rise from the floor of Tule Valley. Long slopes covered by piñon and juniper dip gently east to meet Whirlwind Valley. In the study areas, most of the crest of the House Range reaches 7,500–8,500 ft (feet) in elevation. Swasey Peak is the highest point at 9,669 ft in elevation; Howell Peak is 8,348 ft in elevation.

The Swasey Mountain and Howell Peak Wilderness Study Areas are composed mostly of Cambrian (see geologic time chart in Appendix) sedimentary rocks. These rocks are tilted east by a major range-bounding fault that extends along the western side of the House Range. No comparable fault is evident on the eastern side of the range. The entire section of Paleozoic rocks in the House Range, and perhaps a thick section of Precambrian sedimentary rocks in the subsurface, rests on low-angle faults as

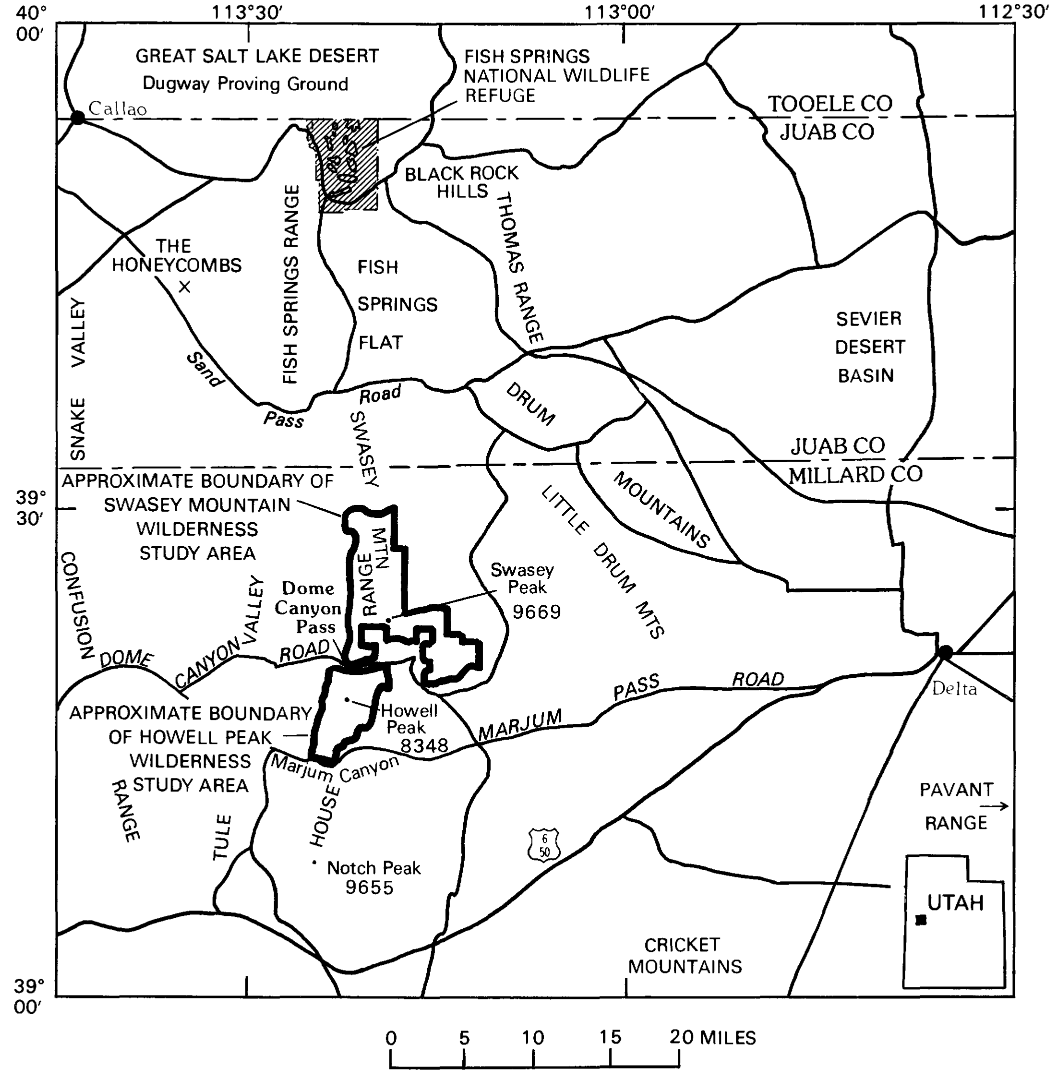


Figure 1. Index map showing location of the Swasey Mountain and Howell Peak Wilderness Study Areas, Utah.

interpreted from a deep seismic profile of western Utah. The faults are interpreted tentatively as having moved as thrusts during Mesozoic mountain-building, and as low-angle extensional faults during Cenozoic basin-range faulting. The low-angle faults and the rocks overlying them form a gentle arch beneath the study areas.

The bottom of the exposed Cambrian section consists of about 2,000 ft of quartzite. The quartzite is overlain by shale and thick beds of carbonate rock famous for their well-preserved trilobite fossils. Small plugs and dikes of igneous rock intrude faults northwest of the Swasey Mountain Wilderness Study Area, but no intrusive igneous rocks have been identified within either study area. The plugs and dikes crop out east of the position of an aeromagnetic anomaly interpreted to be caused by a buried intrusion; they may represent apophyses of the intrusion. These features are all outside the northern boundary of the Swasey Mountain Wilderness Study Area. All of the igneous rocks were altered by hydrothermal fluids that also invaded and altered carbonate rocks. Some areas of altered, silicified rock extend immediately northwest of the Swasey Mountain Wilderness Study Area. Conglomerate and tuffaceous sandstone of Oligocene or younger age crop out along the eastern side of the Swasey Mountain Wilderness Study Area and east of the Howell Peak Wilderness Study Area.

There are approximately 1,900 acres of placer claims and 1,400 acres of lode claims in the Swasey Mountain Wilderness Study Area; no mines or prospect pits were observed. Assays by the U.S. Bureau of Mines showed anomalously high concentrations of arsenic, mercury, antimony, and thallium in jasperoids northwest of the Swasey Mountain Wilderness Study Area; no resources could be identified with only surface sampling data.

Approximately 1,000 acres of placer claims and 500 acres of lode claims are in the Howell Peak Wilderness Study Area. Quartz veins and fault zones in the northern and southern parts of this study area have been explored by five prospect pits and a shaft. Assays of samples from these veins and structures by the U.S. Bureau of Mines did not reveal any notable metal concentrations, and no metallic resources were identified.

High-purity limestone, quartzite, and sand and gravel resources occur in both study areas. All of these materials have a low unit value, and they are available in abundance closer to marketing centers. These commodities are inferred subeconomic resources and are not likely to be developed in the study areas because of their remote location. Potential for undiscovered resources of high-purity limestone and dolomite is moderate in both wilderness study areas.

Cambrian sedimentary rocks throughout the House Range (which includes both study areas) contain fossils of some of the earliest life forms on Earth. These fossils, especially trilobites, are collected by both amateur and professional paleontologists for reference and study collections and by entrepreneurs for sale to the public.

The northern part of the Swasey Mountain Wilderness Study Area has moderate potential for undiscovered resources of lead, zinc, copper, molybdenum, silver, and gold (fig. 2). This area contains faults and geochemical anomalies and adjoins the Sand Pass mineralized area, which has been extensively explored for gold by drilling and geochemical surveys. A large area of moderate potential for resources of these metals encompasses the southwestern part of the Swasey Mountain Wilderness Study Area and the western part of the Howell Peak Wilderness Study Area. The area contains numerous faults, solution breccia zones, and geochemical anomalies.

Both study areas have moderate potential for oil and gas. Most of the two study areas are covered by oil and gas leases and lease applications, but there has been no drilling in either study area. Oil and gas would most likely be found beneath the House Range detachment at a depth of at least 2.5 mi, but drilling is needed to verify the existence of favorable rocks and structures there. The rating of moderate potential carries a low degree of certainty because of the difficulty in projecting correlative rocks and structures from other areas onto seismic-reflection profiles of the House Range.

Both study areas have low potential for resources of geothermal energy. Coal is not present in either study area, and there is no energy resource potential for coal.

INTRODUCTION

The U.S. Geological Survey and the U.S. Bureau of Mines studied 34,376 acres of the Swasey Mountain (UT–050–061) Wilderness Study Area and 14,800 acres of the Howell Peak (UT–050–077) Wilderness Study Area. The study of this acreage was requested by the U.S. Bureau of Land Management. In this report, the studied areas are called "wilderness study areas" or simply the "study areas." An additional 3,000 acres, north of the boundary of the Swasey Mountain Wilderness Study Area shown on plate 1, was studied, based on preliminary maps provided by the U.S. Bureau of Land Management.

The Swasey Mountain Wilderness Study Area is in the House Range south of the gravel road through Sand Pass and north of the gravel road through Dome Canyon, 40 mi west of Delta, Utah (figs. 1, 2). The Howell Peak Wilderness Study Area is in the House Range south of Dome Canyon and north of Marjum Pass. Access to both study areas is by foot from the Dome Canyon road and by dirt roads and jeep trails on the eastern and western sides of the range. Access to the Howell Peak Wilderness Study Area is also by foot from the Marjum Pass road.

Swasey Peak, the highest point in the Swasey Mountain Wilderness Study Area, rises to 9,669 ft in elevation, but most of the crest of the study area is about 7,500–8,500 ft in elevation. Howell Peak, the highest point in the Howell Peak Wilderness Study Area, rises to an elevation of 8,348 ft. On the western sides of both study areas, picturesque cliffs rise from the floor of Tule Valley (elevation 4,400 ft). Long slopes covered by piñon and juniper dip gently east to meet Whirlwind Valley (below 5,600 ft elevation), which lies east of the study areas.

The Dome Canyon road divides the cliffs of Swasey Peak from those of Howell Peak to the south. The road passes alongside the classic trilobite-collecting locality of Wheeler Amphitheater at the southeastern corner of the Swasey Mountain Wilderness Study Area.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines and the U.S. Geological Survey. Identified resources are classified according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources are studied by the U.S. Bureau of Mines. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and is shown in the Appendix. Undiscovered resources are studied by the U.S. Geological Survey.

Investigations by the U.S. Bureau of Mines

Prior to field work, Bureau of Mines personnel conducted a literature search for minerals information pertinent to the study areas. U.S. Bureau of Land Management records were checked for current mining claims and oil and gas leases and lease applications. Two U.S. Bureau of Mines geologists conducted a 13-day field examination of the study areas.

Thirty-nine samples were taken from outcrops in and near the Swasey Mountain Wilderness Study Area,

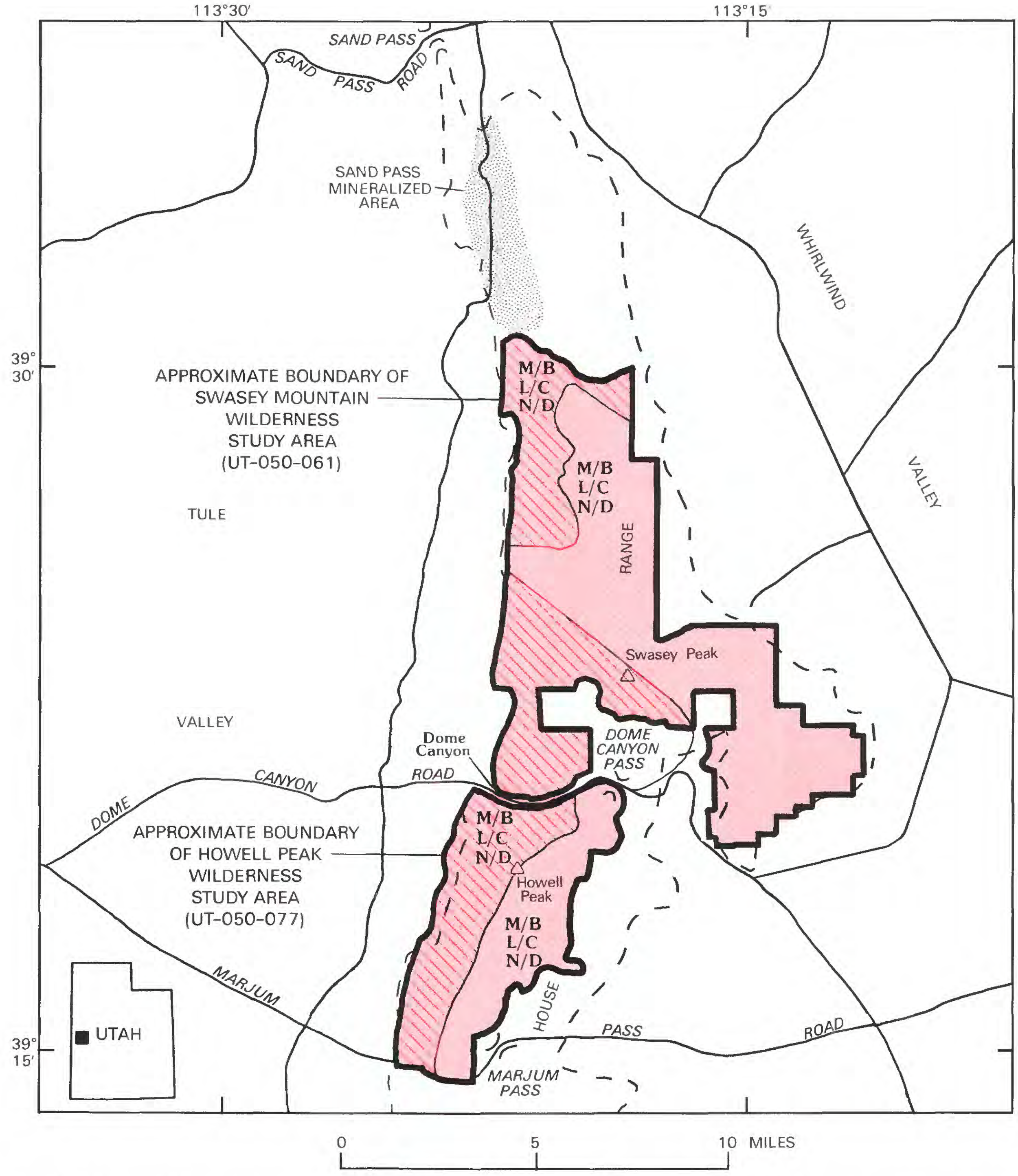


Figure 2 (above and facing page). Map showing mineral resource potential of the Swasey Mountain and Howell Peak Wilderness Study Areas, Utah.

and 29 samples were taken from prospects and outcrops in and near the Howell Peak Wilderness Study Area. Twenty-six samples from quartz veins and fault zones were analyzed by fire assay for gold and silver. Six samples from placer gravel were analyzed for gold. Thirty-three samples from jasperoids and adjacent altered rocks were analyzed for antimony, arsenic, gold, mercury, silver, and thallium. Gold concentrations were determined by fire-assay atomic absorption; silver and thallium by atomic absorption; arsenic by colorimetric analysis; mercury by cold-vapor atomic absorption, and antimony by X-ray fluorescence. Three samples were

EXPLANATION

[Both study areas contain inferred subeconomic resources of high-purity limestone (Howell Limestone), quartzite (Prospect Mountain Quartzite), sand and gravel (in washes and along flanks), and fossils (in the Wheeler Shale and the Marjum Formation). Both study areas have moderate mineral resource potential for high-purity limestone and dolomite, with certainty level B, except for the Prospect Mountain Quartzite, the Howell Limestone, and units of Tertiary and Quaternary age]

M/B	Geologic terrane having moderate mineral resource potential for lead, zinc, copper, molybdenum, silver, and gold, with certainty level B
M/B	Geologic terrane having moderate mineral resource potential for oil and gas, with certainty level B—Applies to entire study areas
L/C	Geologic terrane having low resource potential for geothermal energy, with certainty level C—Applies to entire study areas
N/D	Geologic terrane having no resource potential for coal, with certainty level D—Applies to entire study areas
	Levels of certainty
B	Data indicate geologic environment and suggest level of mineral resource potential
C	Data indicate geologic environment, give good indication of level of resource potential, but do not establish activity of resource-forming processes
———	Road
(dashed outline)	Boundary of House Range

analyzed for calcium carbonate, iron oxide, silicon dioxide, and magnesium oxide to test for high-purity limestone; these were determined by multi-acid extraction and direct-current plasma emission spectroscopy. Eleven samples from outcrops and prospects were tested for 40 elements by semiquantitative optical emission spectrographic analysis. Assay data and analytical results were summarized by Tuftin (1987) and are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, Colo.

Investigations by the U.S. Geological Survey

A geologic map (pl. 1) of the Swasey Mountain and Howell Peak Wilderness Study Areas was compiled by R.A. Yambrick from 1:24,000-scale maps of the Sand Pass (Hintze, 1980a), Sand Pass SE (Hintze, 1980b), Swasey Peak and Swasey Peak NW (Hintze, 1981a), Whirlwind Valley NW (Hintze, 1981b), and Marjum Pass and Swasey Peak SW quadrangles (Hintze, 1981c). No new mapping was done, but geologic features of the study areas were examined in 1986 and 1987 to prepare this report. Sampling for a stream-sediment geochemical survey was done in 1986 and 1987 by D.R. Zimbelman, H.A. Whitney, and T.A. Delaney. Altered rocks were sampled by D.R. Zimbelman, H.A. Whitney, T.A. Delaney, R.A. Yambrick, and D.L. Kelley for geochemical analysis.

Aeromagnetic and radiometric data were collected in 1976–78 along east-west flight lines spaced 2–3 mi apart as part of the National Uranium Resource Evaluation (NURE) program of the U.S. Department of Energy (Texas Instruments, Inc., 1977, 1979). These data were gridded and contoured at the U.S. Geological Survey by R.P. Kucks and interpreted by D.L. Campbell. Aeromagnetic data from an earlier survey by the U.S. Geological Survey in 1972 were also examined. Gravity data were compiled in 1986–87 by K.L. Cook and Viki Bankey. A seismic study done in 1982 for the Consortium for Continental Reflection Profiling (COCORP) was reviewed, as was an electrical study done near the wilderness study areas by the U.S. Geological Survey. These geophysical data were evaluated by D.L. Campbell. The radiometric data were processed and evaluated by J.S. Duval. Remote-sensing data were collected by Landsat Thematic Mapper satellite and were processed and evaluated by M.H. Podwysocki and D.W. Brickey.

Acknowledgments.—We thank Gerald Dalton, Kaysville, Utah, for information about mineral exploration in the area south of Sand Pass. Employees of the U.S. Bureau of Land Management in Salt Lake City, Fillmore, and Delta, Utah, provided information about mineral exploration and space for equipment storage. We thank L.F. Hintze of the Utah Geological and Mineral Survey for additional information on the geology of the study area.

APPRAISAL OF IDENTIFIED RESOURCES

By Steven E. Tuftin
U.S. Bureau of Mines

Mining and Leasing Activity

There is no record of mineral production from either wilderness study area. There are approximately 1,900 acres of placer claims and 1,400 acres of lode claims in the Swasey Mountain Wilderness Study Area, and approximately 1,000 acres of placer claims and 500 acres of lode claims in the Howell Peak Wilderness Study Area (Tuftin, 1987, pls. 1 and 2).

Lode claims northwest of the Swasey Mountain Wilderness Study Area are on jasperoid outcrops that have been extensively sampled by private companies and by the claim owner, Gerald Dalton, of Kaysville, Utah. Several holes are reported to have been drilled in these claims since the U.S. Bureau of Mines field examination of the area. Company drilling and sampling results were not available for this report. No mines or prospect pits were observed in the lode-claim group or in the placer claims in the southern part of the Swasey Mountain Wilderness Study Area.

In the northern and northwestern parts of the Howell Peak Wilderness Study Area, fault zones and quartz veins in quartzite have been explored by four prospect pits; the prospects are on and near two unpatented lode-claim groups. Placer claims and lode claims extend into the northeastern part of the study area from the Swasey Mountain Wilderness Study Area. A shaft and a prospect pit in the southwestern corner of the Howell Peak Wilderness Study Area are on a fault-vein system in the Middle Cambrian Howell Limestone. Two lode claims, one inside and one outside the boundary, are at the southern end of the study area; however, no prospects were observed on these claims. On the eastern side of the study area, a lode-claim block includes part of the Howell Peak Wilderness Study Area, but no prospects were noted within the study area.

The Middle Cambrian Wheeler Shale is quarried for a variety of fossil specimens at three sites in the Wheeler Amphitheater, less than 1 mi south of the Swasey Mountain Wilderness Study Area. The Wheeler Shale is particularly noted for its trilobites (an extinct group of marine arthropods).

Oil and Gas

Most of the Swasey Mountain and Howell Peak Wilderness Study Areas are covered by oil and gas leases and lease applications (fig. 3), but there has been no drilling in either study area.

Appraisal of Sites Examined

Jasperoid Occurrence

Jasperoid crops out as irregular bodies in Middle Cambrian limestone north of the Swasey Mountain Wilderness Study Area. The jasperoid bodies in this area are irregularly distributed; many of them form resistant caps on unaltered limestone. The jasperoid formed when hydrothermal fluids traveled along numerous faults, fractures, and bedding planes and replaced carbonate rock with silica, minor iron, and other metals. Contacts between unaltered carbonate rock and jasperoid are sharp to gradational.

Anomalously high concentrations of arsenic, mercury, antimony, and thallium were found in samples of jasperoid and some adjacent altered rocks northwest of the Swasey Mountain Wilderness Study Area. Silver and gold values were very low to nil. Arsenic, mercury, antimony, and thallium are trace elements that commonly form a halo around and over a low-grade gold deposit at depth. Seven of the 36 samples taken in this area contained gold at or above the detection limit of 5 parts per billion (Tuftin, 1987, table 1).

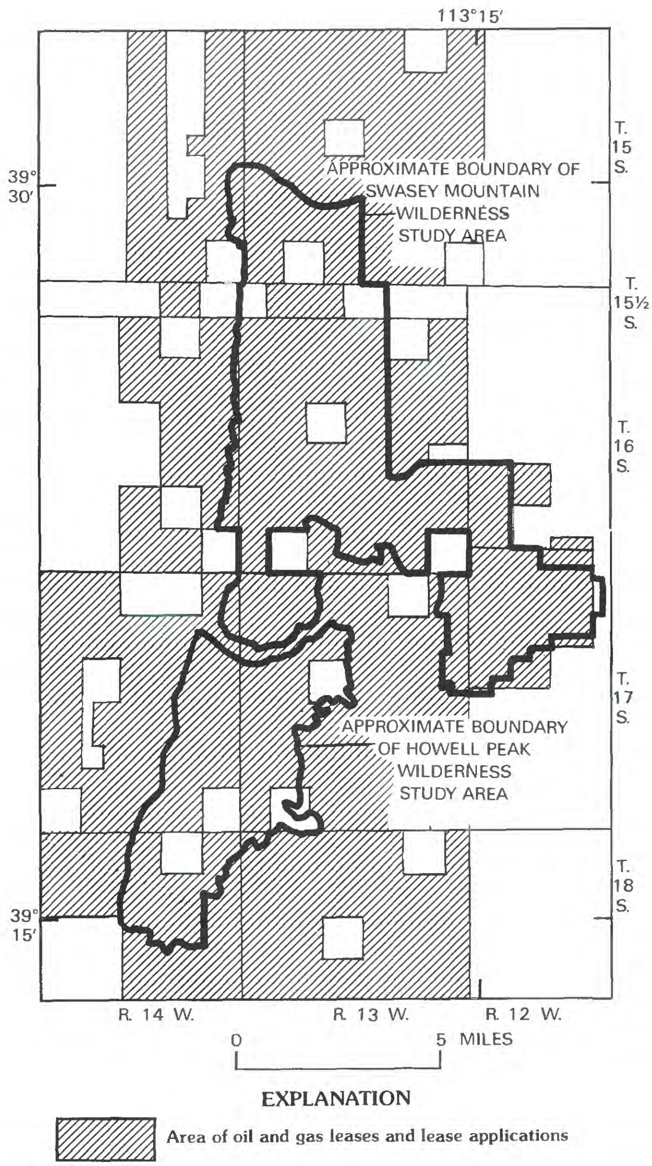


Figure 3. Map showing oil and gas leases and lease applications in the Swasey Mountain and Howell Peak Wilderness Study Areas, Utah. Lease information from the U.S. Bureau of Land Management, August 1985.

Metal concentrations in the samples of jasperoid and altered rock are similar to those found over large low-grade gold deposits currently being mined in Nevada, but only subsurface sampling can determine if a gold resource is present in the study area.

Quartz Veins and Fault Zones

Samples collected from prospects and outcrops in and near the lode claims in the northwestern part of the Howell Peak Wilderness Study Area are from quartz veins, breccia zones, and fault zones. Seventeen samples were taken from these veins and structures; however, none of the samples contained gold or silver (Tuftin, 1987, table 2). Semiquantitative optical emission spectrographic analysis of seven of these samples did not indicate any anomalous concentrations of metals.

In the southern part of the Howell Peak Wilderness Study Area, an inaccessible shaft and a prospect pit are on a northwest-striking fault-vein system in the Middle Cambrian Howell Limestone. Samples were collected from a silicified zone adjacent to the fault, from a calcite vein in the fault zone, and from the dump of the shaft. No gold or silver were detected in any of these samples. No other significant metal concentrations were noted in the samples analyzed by spectrographic methods (Tuftin, 1987, Appendix B).

Limestone

Limestone is a widespread rock type that can be used for cement manufacture, agricultural limestone, flux stone, crushed rock, and construction material. The physical and chemical properties of the limestone are important factors in determining its use; quality standards and reserves are usually determined by each company for its own use. Limestone is a high-bulk, low-unit-value commodity, and transportation cost may exceed the value of the raw material.

The Howell Limestone in and near the study areas is an inferred subeconomic resource of high-purity limestone and could have many commercial uses; however, the area is remote, and similar nearly inexhaustible deposits are available closer to markets in many areas of the United States. The deposits in the study areas may find limited local use if the need for them arises.

Quartzite

The Prospect Mountain Quartzite is a widespread Lower Cambrian formation in Nevada and western Utah. The base of the formation is not exposed in the House Range, but the thickest partial section measured in the range is more than 2,000 ft (Hintze and Robison, 1975, p. 881 and fig. 2). It crops out along the western side of the Swasey Mountain Wilderness Study Area and along the northwestern side of the Howell Peak Wilderness Study Area. The quartzite is medium to coarse grained, pinkish gray to brown gray, and is commonly interbedded with phyllitic, silty sandstone beds. The quartzite is an inferred subeconomic resource with possible value for use in metallurgical processes or in glass manufacture; however, high-purity quartzite is widespread in the Western States, cropping out in hundreds of localities in central Idaho, western Utah, and from eastern Nevada to southeastern California (Ketner, 1982, p. 237). Close access to manufacturing sites or transportation is critical to the development of the quartzite because it has a low unit value. The quartzite in the House Range is unlikely to be developed in the foreseeable future because of its remote location.

Placers

Placer claims in and near the northern and southern part of the Swasey Mountain Wilderness Study Area were examined; however, no prospects were noted, and no gold was detected from the U.S. Bureau of Mines' samples (Tuftin, 1987, table 3). Geological conditions do not favor placer-gold occurrences in these areas because the drainage basins are composed of unmineralized Cambrian sedimentary rocks. The claims in the southern part of the Swasey Mountain Wilderness Study Area may be located on the high-purity limestone that was discussed earlier.

Sand and Gravel

Inferred subeconomic sand and gravel resources occur along the washes and flanks of both study areas, and they also occur in abundance outside the study areas. These deposits are not likely to be developed in the near future because abundant sand and gravel resources exist closer to current markets.

Fossils

Cambrian fossils are particularly important to the scientific community because they are among the earliest multicellular life forms. Animal life with preservable hard parts did not occur on Earth until the beginning of Cambrian time.

Fossil collections have been made from most of the Cambrian section in the House Range (Hintze and Robison, 1975, fig. 3). The Wheeler Shale and the Marjum Formation contain one of the thickest, best exposed, and most fossiliferous successions of upper Middle Cambrian rocks in North America (Robison, 1964, p. 510; Hintze and Robison, 1987). The fauna in these strata are dominated by a diverse assemblage of trilobites but also include brachiopods, sponges, primitive echinoderms, and other invertebrate fossils.

The Wheeler Shale and the Marjum Formation, which contain abundant fossils, crop out in the southeastern part of the Swasey Mountain Wilderness Study Area; the Wheeler Shale also crops out north and south of the study area (Hintze, 1980b; 1981a,b,c).

Fossils, including trilobites, can be found wherever these formations occur, although specimens collected from outcrops are often broken or damaged from weathering. Specimens of high quality are dug from quarries in the Wheeler Shale in the Wheeler Amphitheater, south of the Swasey Mountain Wilderness Study Area.

The Wheeler Shale is found only in small, isolated patches in the Howell Peak Wilderness Study Area. The Marjum Formation occurs outside (south and east) of the study area (Hintze, 1974, 1981c).

Quality, size, rarity, and popularity determine market value for fossils. *Elrathia kingii* (Meek), the most common trilobite fossil found in the commercial quarries, commonly costs between $3 and $30. Rare genera such as *Olenoides* may command $1,000 or more. There is a ready market for high quality and rare fossils.

Conclusions and Recommendations

Jasperoid that crops out northwest of the Swasey Mountain Wilderness Study Area contains anomalously high amounts of arsenic, mercury, antimony, and thallium. These metals commonly indicate the presence of nearby low-grade gold deposits. Trace amounts of gold are also found in the jasperoid and adjacent rocks in part of this area. Surface sampling did not identify a resource; a drilling program is required to determine whether a resource is present. The jasperoid has been extensively sampled by private companies, and there is continued interest in the area.

U.S. Bureau of Mines samples from quartz veins, breccia zones, and fault zones in the northwestern and southern parts of the Howell Peak Wilderness Study Area contained no significant concentrations of metals.

Inferred subeconomic resources of high-purity limestone that have possible commercial value occur in both study areas; however, they are unlikely to be developed in the foreseeable future because of their remote location. Inferred subeconomic resources of quartzite and sand and gravel also have potential commercial values, but they are common materials with low unit value, and they are not likely to be developed in the foreseeable future because of their remote locations. Ample deposits of these materials are closer to current markets.

Both study areas have strata that contain fossils that may be scientifically important and have value to collectors. Some fossils may be very valuable because of their scarcity and quality, but they cannot be found consistently. The fossils in both areas are usable for scientific research and for collecting purposes.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By David A. Lindsey, David R. Zimbelman, David L. Campbell, Joseph S. Duval, Kenneth L. Cook, Melvin H. Podwysocki, David W. Brickey, and Robert A. Yambrick
U.S. Geological Survey

Geology

Geologic Setting and Structure

Swasey Mountain and Howell Peak are the northernmost mountains of the east-tilted fault block of the House Range. The House Range consists mostly of Paleozoic carbonate rocks and has only one exposed boundary fault; as such, the range is typical of the basin-range structure of western Utah that formed in Cenozoic time. The west-tilted block of the Fish Springs Range lies immediately north of Swasey Mountain. The House Range (and adjoining Fish Springs Range) is one of the classic basin ranges originally described by Gilbert (1875, p. 27).

The entire section of Paleozoic rocks in the House Range, and perhaps a thick section of Precambrian sedimentary rocks in the subsurface, rests on the House Range and Sevier Desert detachments, interpreted as low-angle faults on the COCORP seismic profile of western Utah (Allmendinger and others, 1983; 1985). The detachments are interpreted as surfaces of thrusting during the Mesozoic Sevier orogeny and of low-angle extension during Cenozoic basin-range faulting. Rocks overlying the House Range detachment form the broad structural high of the Sevier arch (also known as the House Range antiform). More than 4 mi of structural relief separate the Sevier arch from the Confusion Range synclinorium to the west. The Confusion Range synclinorium contains sedimentary rocks ranging from Devonian to Triassic in age that were folded and thrusted during the Sevier orogeny (Hose, 1977). East of the House Range, the detachment surfaces descend into the Sevier Desert basin.

The western side of Swasey Mountain and Howell Peak is upthrown along a large basin-range fault that separates the wilderness study areas from Tule Valley. The fault extends south from Sand Pass along the foot of the House Range for the entire length of the study areas. As shown on the COCORP seismic line, the fault does not extend below the House Range detachment (Allmendinger and others, 1985). Immediately south of Sand Pass, near the northwestern boundary of the Swasey

Mountain Wilderness Study Area, the fault consists of several strands. South of Trail Canyon and along the western side of Howell Peak, a second major fault downdropped Cambrian strata to form an intermediate step between the high parts of the House Range and Tule Valley. Scarps in alluvium of Tule Valley indicate that the main fault has been active in late Quaternary (Holocene) time.

No basin-range fault is apparent on the eastern side of Swasey Mountain or Howell Peak. Gently east dipping formations of carbonate rock extend eastward beneath alluvium of Whirlwind Valley. Numerous small high-angle faults trend north, northeast, and northwest in the study areas; they may be basin-range structures.

Two northwest-trending faults cut across the structural grain of Swasey Mountain and contain zones of fault breccia and mylonite (unit Mzb, pl. 1). These faults, called by Hintze (1981a) the North Swasey and Trail Canyon tear faults, appear to have formed by differential movement within thrust sheets during the Mesozoic Sevier orogeny. A third (unnamed) complex zone of tear faults extends southeast from Dome Canyon; these faults coincide with the approximate boundary of a trough filled with deposits of late Cenozoic age (Hintze, 1981c).

Hintze (1978, 1980b) mapped and described areas of attenuation faulting southeast of Sand Pass and on both sides of Dome Canyon in the study areas, and also in the Fish Springs Range. Attenuation faults were mapped where formations are abnormally thin or missing and, in some places, brecciated. Hintze (1978) interpreted the faults as detachment surfaces that formed during the Sevier orogeny, resulting from stretching and smearing of Paleozoic formations as the youngest units were moved farthest east.

Reexamination of some of the contacts and associated breccias mapped as attenuation faults in the House Range leads one of us (Lindsey) to propose that they are not faults, but intervals of solution collapse. Immediately southeast of Sand Pass and in the Dome Canyon area (Hintze, 1980b, 1981c), breccias are commonly developed between and within formations where strata are thin or missing. No slickensides or fault gouge were observed, except locally where high-angle faults cut the breccias. The breccias are stratabound in overall aspect but not confined to individual beds in detail. Chaotic, recemented rubble from adjacent and overlying formations makes up the breccias. The breccia rubble is altered rusty red, contains a high proportion of what appears to be insoluble residue, and, in the area southeast of Sand Pass, is extensively silicified to jasperoid. Subterranean channels filled with stratified breccia were identified in NW¼ sec. 6, T. 14 S., R. 13 W. and in N½ sec. 19, T. 15 S., R. 13 W. One-half mile west of Dome Canyon Pass, zones of rusty-red collapse breccia are laterally continuous with bedded carbonate rock where attenuation faults have been mapped by Hintze (1981c). More detailed studies should be made to confirm the solution-breccia origin.

Description of Rocks

The Paleozoic rocks of Swasey Mountain and Howell Peak extend from Early to Late Cambrian in age. The bottom of the exposed section consists of about 2,000 ft of the Lower Cambrian Prospect Mountain Quartzite. The quartzite is overlain by the Lower and Middle Cambrian Pioche Formation (quartzite, carbonate rock, and shale) and a thick section of Middle and Upper Cambrian carbonate rocks (Hintze, 1980b, 1981a). Extensive trilobite faunas are well preserved in the wilderness study areas. The well-known collecting locality in the Middle Cambrian Wheeler Shale at Wheeler Amphitheater is east of Dome Canyon, which separates the two study areas. The reader is referred to Hintze and Robison (1975) for detailed descriptions of rocks and fossils.

The age and relationships of Cenozoic intrusive, volcanic, and sedimentary rocks and unconsolidated sediments are not well known. The rocks and sediments of Cenozoic age were mapped by Hintze (1980b, 1981a) and described by him and by Chidsey (1978).

Small plugs and dikes of rhyolitic to quartz latitic composition intrude the fault system south of Sand Pass (Chidsey, 1978; Hintze, 1980a), northwest of the Swasey Mountain Wilderness Study Area. No intrusive igneous rocks have been identified within either study area. All of the igneous rocks are altered; some contain abundant coarse grains of secondary muscovite. They resemble late Eocene and Oligocene intermediate-composition rocks of the Thomas Range and Drum Mountains (Lindsey, 1982). As discussed under "Geophysics," these small intrusions are interpreted as apophyses of a buried stock.

Conglomerate, tuffaceous sandstone, and limestone of Oligocene or younger age crop out along the eastern side of Swasey Mountain and in a trough southeast of Dome Canyon (Hintze, 1980b, 1981a, 1981b, 1981c). Older conglomerate of Skull Rock Pass (Hintze, 1980b) is composed of boulders of Ordovician Eureka Quartzite and Ordovician and Silurian dolomites that are not now exposed in the House Range. The older conglomerate overlies latitic ash-flow tuff of Red Knolls of Oligocene age (informal unit of Morris, 1987) at Red Knolls.

Geochemistry

Methods

A reconnaissance geochemical survey was made in the wilderness study areas and vicinity. Collected for analysis were 58 samples of minus-80-mesh stream sediment, 58 heavy-mineral concentrates of stream sediment, and 189 rock samples. These were evaluated for possible indicators of altered or mineralized rock. Chemical analysis of sediments provides information that helps identify those stream basins that contain unusually high concentrations of elements that have been derived from mineralized areas. Stream sediments and heavy-mineral concentrates were collected from alluvium in channels of first-order (unbranched) and second-order streams below the junction of two first-order streams (pl. 1). Stream-sediment samples were prepared for analysis of the minus-80-mesh fraction and heavy-mineral concentrates. Threshold values (highest values not considered anomalous) were determined by inspection of frequency-distribution histograms for each element. Rock samples were collected from both within and near the study area. Rocks that appeared unaltered were sampled for information on geochemical background values. Visibly altered rocks were sampled at mines, prospects, and other areas to determine suites of elements associated with mineralized and altered rock. Sample sites, analytical data, and a description of sampling and analytical techniques are in Arbogast and others (1989). All elements were analyzed by atomic absorption or spectrographic methods.

Analysis of the nonmagnetic fraction of heavy-mineral concentrates was the most useful geochemical method for a reconnaissance evaluation of the study area. Concentrate samples generally contain minerals derived from mineralized rock if mineralization has occurred in the area. In mineralized areas, generally, concentrates may include minerals such as pyrite (FeS_2), galena (PbS), cassiterite (SnO_2), sphalerite (ZnS), stibnite (Sb_2S_3), barite ($BaSO_4$), scheelite ($CaWO_4$), and native gold. The selective concentration of ore-related minerals permits determination of some elements that are not easily detected by analysis of bulk stream sediments. The minus-80-mesh fraction of bulk stream sediments collected from the area contained no significant geochemical anomalies and is not discussed further.

Table 1. Anomalous concentrations of selected elements in nonmagnetic heavy-mineral concentrates of stream-sediment samples, Swasey Mountain and Howell Peak Wilderness Study Areas, Utah

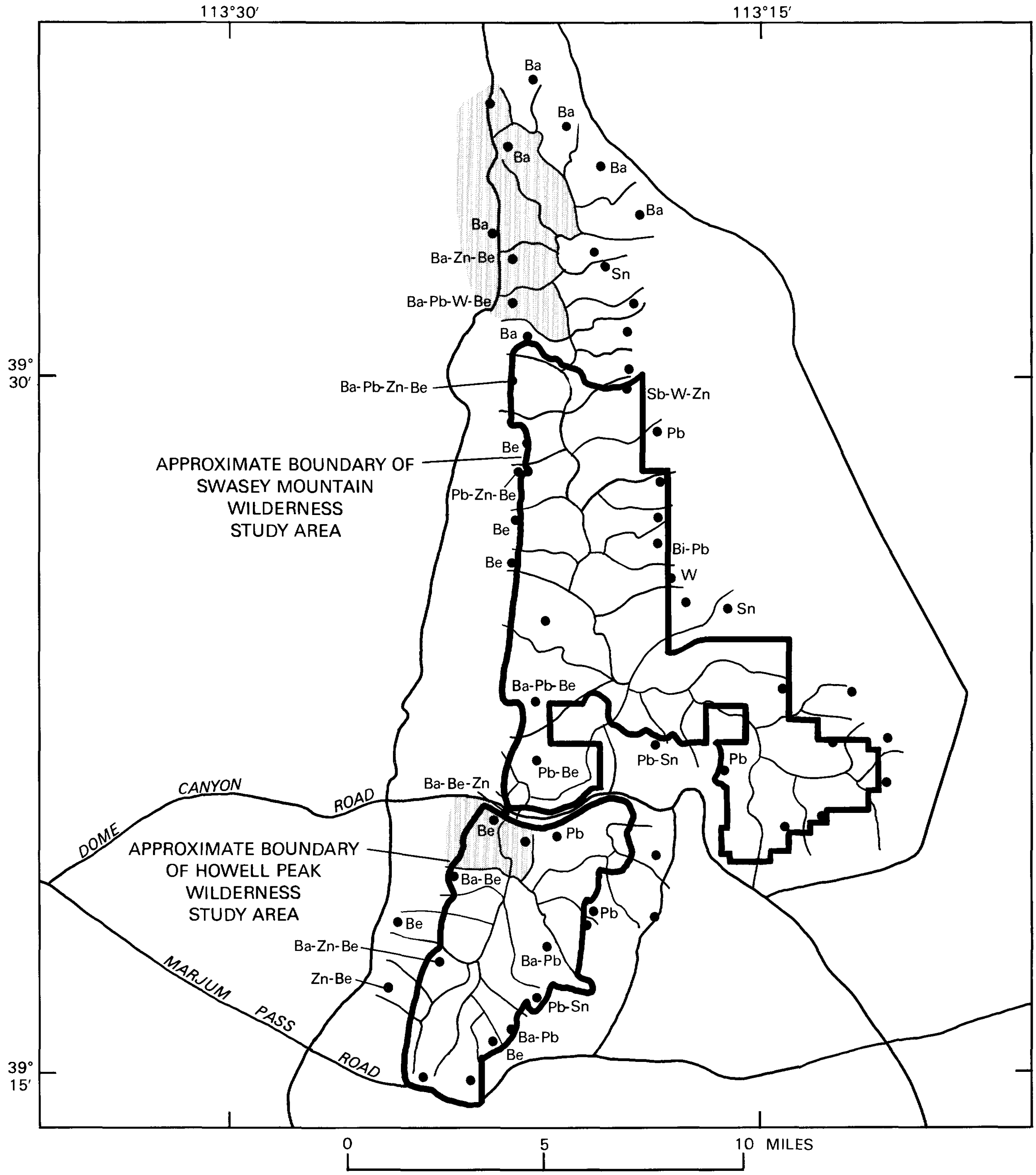
[Elements and minimum values (in parts per million) considered anomalous include: Au (20), Ag (5), As (500), Ba (>10,000), Be (20), Bi (20), Cd (50), Cu (500), Mo (20), Pb (500), Sb (200), Sn (20), W (100), and Zn (500). >, more than]

Field No.	Anomalous elements (In parts per million)
0001	Sn (500)
0002	W (300)
0004	Pb (500)
0007	Ba (>10,000)
0009	Ba (>10,000)
0011	Ba (>10,000), Be (20), Zn (2,000)
0022	Ba (>10,000)
0042	Ba (>10,000)
0088	Zn (500)
1001	Pb (500), Sn (70)
1002	Ba (>10,000), Pb (1,000)
1003	Pb (1,500)
1004	Ba (>10,000), Pb (50,000)
1005	Pb (2,000)
1006	Pb (1,000)
1007	Pb (500)
1011	Pb (500)
1012	Be (100)
1014	Pb (1,000), Zn (500)
1016	Pb (1,000), Zn (1,000)
1019	Ba (>10,000), Pb (5,000)
1020	Pb (700)
1021	Ba (>10,000), Zn (500)
1023	Zn (1,000)
1036	Ba (>10,000), Pb (1,500), W (200)
1037	Pb (1,000)
1063	Sn (50)
1067	Bi (20), Pb (3,000)
1073	Pb (500)
1076	Pb (2,000), Sn (200)

Results of Study

Anomalous concentrations of one or more selected elements were found in 30 of the 58 heavy-mineral concentrates (table 1). Samples from all of the drainages on the western side of the Swasey Mountain Wilderness Study Area north of Trail Canyon contain geochemically anomalous amounts of one or more of the elements beryllium, lead, zinc, or barium (fig. 4). Geochemical anomalies identified from stream-sediment concentrates collected from the eastern side of the study area include local occurrences of barium, tin, antimony, tungsten, lead, zinc, or bismuth. The only drainages on this side of the study area that contain more than one of these elements (that is, drainages that do not contain single-element anomalies) are an unnamed drainage north of North Canyon, which contains anomalous amounts of antimony, tungsten, and zinc, and an unnamed drainage south of Robbers Roost Canyon, which contains anomalous amounts of bismuth and lead.

Geochemical anomalies in stream sediments from the western side of the Swasey Mountain Wilderness Study Area extend north into the Sand Pass mineralized area, which has been explored by mining companies. Jasperoid and other altered rocks from the mineralized



EXPLANATION

Drainage divide

Ba-Pb — Sample locality showing elements present in anomalous concentrations

Area of geochemical anomalies in rock samples

Road

Figure 4. Map showing stream-sediment sample sites, drainage basins, and anomalous elements in heavy-mineral concentrates in the Swasey Mountain and Howell Peak Wilderness Study Areas, Utah. Refer to table 1 for threshold values for anomalous elements.

area contain anomalous amounts of gold, arsenic, antimony, manganese, molydenum, tungsten, beryllium, lead, and tin.

Many of the stream drainages in the western part of the Howell Peak Wilderness Study Area and the southern part of the Swasey Mountain Wilderness Study Area contain geochemically anomalous amounts of barium, beryllium, zinc, or lead. Rock samples from south of the Dome Canyon road include mineralized rock from fault zones which contain geochemically anomalous amounts of silver, arsenic, antimony, beryllium, copper, lead, zinc, molybdenum, and tungsten. This suite of elements is similar to that found in many nearby mining districts, suggesting that the Dome Canyon area was subjected to similar mineralizing processes.

Anomalous amounts of barium are widespread in the study areas. Although the origin of the barium has not been traced, anomalous barium in carbonate rocks of the Richfield quadrangle has been attributed to iron-barite mineralized fault zones (W.R. Miller, oral commun., 1987). Such barium anomalies may represent the distal effects of hydrothermal mineralization.

Ninety rock samples (table 2) from altered outcrops northwest of the Swasey Mountain Wilderness Study Area and the Dome Canyon area contain anomalous concentrations of antimony (62 samples), arsenic (26 samples), tungsten (21 samples) and gold, molybdenum, beryllium, zinc, lead, tin, manganese, barium, and silver (nine or fewer samples for each element). Gold in amounts of 0.05 ppm (parts per million) or more was found in six rock samples immediately outside the northern boundary. Of these six samples, four were jasperoid, one was shale, and one was shaly limestone.

Geophysics

Gravity

A north-northwest-trending gravity high extends over the eastern part of the Swasey Mountain Wilderness Study Area, and a less prominent high occurs over the southern part of the Howell Peak Wilderness Study Area (fig. 5). The two highs are apparently separated by a weak gravity low that may reflect a structural low. However, the amplitudes and detailed configuration of gravity anomalies over the study areas are not well defined because of the sparsity of data in the ranges.

The high Bouguer gravity values over the House Range and low values over Tule Valley to the west and Whirlwind Valley to the east reflect the density contrast between high-density Paleozoic rocks of the range and the low-density Cenozoic rocks and sediments in the

Table 2. Anomalous concentrations of selected elements in rock samples, Swasey Mountain and Howell Peak Wilderness Study Areas, Utah

[Selected elements (and associated minimum values (in parts per million) considered anomalous) include: Au (0.05), Ag (5), As (200), Ba (>5,000), Be (10), Bi (10), Cd (20), Cu (500), Mn (>5,000), Mo (20), Pb (500), Sb (100), Sn (10), W (50), and Zn (500). >, more than. Sample sites shown in Arbogast and others (1989)]

Field No.	Anomalous elements (In parts per million)	Rock type
RY-101	Mo(20), Pb(500), Zn(500)	Limestone.
RY-102	W(300)	Jasperoid.
RY-107	As(2,000)	Silicified breccia.
RY-110	W(50)	Silicified breccia.
RY-111	As(500), W(50)	Silicified breccia.
RY-112	W(100)	Silicified breccia.
RY-114	W(50)	Silicified breccia.
RY-115	Sb(200)	Jasperoid.
RY-118	Be(10)	Breccia.
RY-120	As(200), Zn(700)	Limestone.
RY-121	As(1,000)	Dolomite.
0100	Mn(>5,000)	Limestone.
0102	Mn(>5,000)	Limestone.
0111	Sb(200), W(50)	Jasperoid.
0112	Sb(100)	Limestone.
0113	Sb(150)	Jasperoid.
0117	Sb(100)	Breccia.
0119	Sb(150)	Limestone.
0120	As(2,000)	Shaley limestone.
0122	As(5,000), Sb(200)	Jasperoid.
0129	Mn(>5,000)	Limestone.
0134	Sb(100)	Limestone.
0135	Sb(100)	Jasperoid.
0137	As(1,000), Sb(500)	Jasperoid.
0138	As(300), Sb(200)	Jasperoid.
0139	Sb(200), W(50)	Jasperoid.
0144	Sb(100)	Jasperoid.
0148	Sb(100)	Jasperoid.
0151	As(300), Sb(200)	Jasperoid.
0152	Sb(150)	Jasperoid.
0153	As(200), Sb(200)	Jasperoid.
0157	Sb(100)	Jasperoid.
0160	Sb(300)	Jasperoid.
0161	Sb(300)	Jasperoid.
0162	As(300), Sb(100)	Jasperoid.
0164	As(500), Sb(100)	Jasperoid.
0166	As(200)	Jasperoid.
0170	Sb(100)	Jasperoid.
0171	Sb(100)	Jasperoid.
0172	Sb(100)	Jasperoid.
0178	Pb(1,000), Sb(100)	Jasperoid.
0179A	Sb(150)	Jasperoid.
1013	As(3,000), Sb(100), W(1,000), Be(10).	Limestone.
5010A	Sb(200), W(50)	Jasperoid.
5010B	Sb(300), W(100)	Jasperoid.
5010C	Sb(500)	Jasperoid.
5011	Ba(>5,000), Sb(200), W(50).	Jasperoid.
5013A	Sb(100)	Jasperoid.
5013B	Sb(100)	Jasperoid.
5014	Sb(100), Be(10)	Jasperoid.

Table 2. Anomalous concentrations of selected elements in rock samples, Swasey Mountain and Howell Peak Wilderness Study Areas, Utah—Continued

Field No.	Anomalous elements (In parts per million)	Rock type
5031	Au(0.10), As(200), Mo(100), Sb(300), Zn(500).	Jasperoid.
5032	Ba(>5,000)-------------	Jasperoid.
5033	Mo(20), Sb(100)--------	Jasperoid.
5034A	Sn(20), Be(10)---------	Quartz latite.
5034B	As(200), Mo(30), Sb(200)	Jasperoid.
5035	Sb(150)----------------	Jasperoid.
5160	Sb(100)----------------	Jasperoid.
5161	Sn(30), Be(10)---------	Quartz latite.
5162	Au(0.05), As(1,000), Mo(100), Sb(150).	Jasperoid.
5165A	As(500), Pb(1,500), Sb(100).	Jasperoid.
5165	As(500), Sb(100), W(100)	Jasperoid.
5166	Sb(100), W(50)---------	Jasperoid.
5168	As(7,000), Sb(200), W(70).	Limestone.
5169	Sb(100), W(70)---------	Limestone.
5170	Au(0.05), As(1,500), Pb(500), Sb(500), W(50).	Jasperoid.
5171	Sb(300), W(100)--------	Limestone.
5172	As(500), Sb(100)-------	Jasperoid.
5173	Sb(200), W(50)---------	Jasperoid.
5174A	Sb(200)----------------	Jasperoid.
5174B	As(200), Sb(200), W(50)-	Jasperoid.
5174C	Sb(200), W(50)---------	Jasperoid.
5174D	Sb(100)----------------	Dolomite.
5175	Zn(500)----------------	Carbonate breccia.
5176	Sn(20), Be(10)---------	Quartz latite.
5177	Sn(20), Be(10)---------	Quartz latite.
5180A	Sb(150)----------------	Jasperoid.
5181	As(1,000), Mo(200), Sb(100).	Jasperoid.
5182	Sb(100)----------------	Jasperoid.
5187	Au(0.10), Mo(50), Sb(100).	Shaley limestone.
5188A	Sb(100)----------------	Jasperoid.
5190A	Au(0.85), As(100), Mo(70), Sb(100), Zn(1,000).	Shale.
5190C	Au(1.25), Ag(5), As(2,000), Mo(100), Pb(500), Sb(200), W(50), Zn(2,000).	Jasperoid.
5193	Sb(100)----------------	Jasperoid.

adjacent valleys. The relatively steep gravity gradient along the western side of the House Range reflects the mapped basin-range fault along which Tule Valley was downdropped relative to the range.

A similar but more subdued gradient lies along the eastern side of the House Range north of Marjum Pass. That gradient extends south-southeast over the western margin of Whirlwind Valley and probably marks the edge of a pediment of Paleozoic rocks extending east from the House Range. Compared to the gradient west of the House Range, this gradient is gentler, suggesting that any basin-range faults there may have less displacement, may be more deeply buried, or may juxtapose rocks of less density difference than the fault on the western side. Alternatively, this eastern gravity gradient may only reflect the topography of the buried surface where denser bedrock at depth meets the overlying sedimentary rocks of the valley.

Seismic Studies

The COCORP profile through Marjum Pass shows at least two concave-down reflecting surfaces that represent the Sevier arch (House Range antiform) (Allmendinger, 1983, 1985). Both surfaces dip as much as 30° west on the western side of the House Range and about 10° east on the eastern side. The upper reflector, known as the House Range detachment, is interpreted to correlate with either the Canyon Range or Pavant thrust; its top is about 2.5 mi deep. A lesser reflecting surface may represent either a stratigraphic horizon or a detachment about 0.6 mi above the upper reflector. Strata above the upper reflector are identified tentatively as Cambrian carbonate rocks underlain by Precambrian clastic rocks. The basin-range fault between the House Range and Tule Valley is seen on the section to dip steeply west from the surface to the top of the upper reflector, which either truncates or merges with it.

The lower reflecting surface is interpreted as the Sevier Desert detachment; it may correlate with the Pavant thrust (Mitchell and McDonald, 1986), reactivated by crustal extension during Cenozoic time. Its top lies about 5 mi deep. Rocks between the two reflecting surfaces are tentatively identified as Precambrian clastic strata overlying Precambrian crystalline basement, but they may include Paleozoic sedimentary rocks. Under the lower reflector is a possible Mesozoic basement duplex, an interval containing some west-dipping reflectors that may represent rocks deformed in a plastic state. The transition between brittle and ductile crust is estimated at 6–7 mi deep in western Utah (Smith and Bruhn, 1984). At the bottom of the section, 19 mi deep, is a horizontal reflector which may represent the Moho. Refraction seismic work in this same area, however, has put the Moho at only 16 mi, leading to speculation (Kerr, 1986) that magma may have underplated the basin-range province, pooling and solidifying in the interval between 16 and 19 mi depth.

The COCORP profile across Marjum Pass shows a basin-range fault bounding the western side of the House Range but not the eastern side. Any fault on the east, which is possible from interpretation of gravity data, must lie north of the COCORP line.

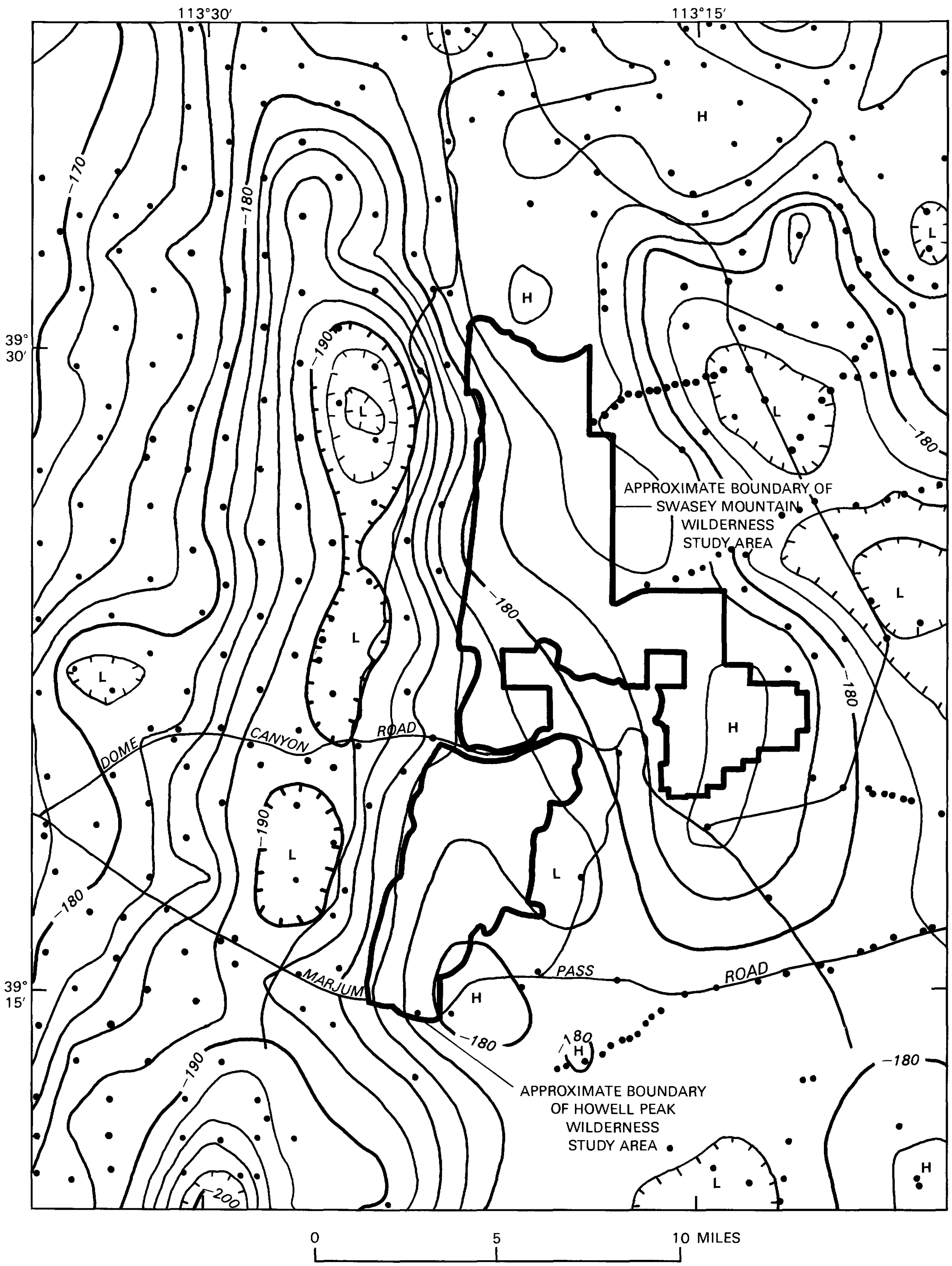


Figure 5 (above and facing page). Complete Bouguer gravity anomaly map of the Swasey Mountain and Howell Peak Wilderness Study Areas and vicinity, Utah. Reduction density, 2.67 grams per cubic centimeter.

Aeromagnetics

Flight lines of the aeromagnetic survey were spaced (nominally) 3 mi apart over most of the study areas and 2 mi apart in the northern part of the Swasey Mountain Wilderness Study Area (fig. 6). These flight lines were draped over topography at a nominal 1,000 ft. Using the general rule that airborne surveys can detect anomalous magnetic bodies on the ground directly under the aircraft and about 45° from vertical on either side, only about 13 percent of possible magnetic sources on the ground surface would be detected by this survey. Although the likelihood of detection increases for deeply buried bodies, small, shallow magnetic bodies between flight lines might go undetected. The absence of magnetic anomalies where the survey did sample, however, argues against the presence of such bodies at other places in the study areas. Furthermore, an earlier aeromagnetic survey (U.S. Geological Survey, 1971, 1972) that was flown to different specifications also detected no magnetic anomalies inside the study areas.

Three areas of major magnetic anomalies occur near the wilderness study areas. Magnetic highs and lows in Whirlwind Valley and the Drum and Little Drum Mountains east of the study areas reflect Cenozoic volcanic rocks at and near the surface. These rocks do not extend into the study areas. A magnetic high south of Marjum Canyon reflects a probable deep body of intrusive rock to the south, near Notch Peak. The magnetic low that extends east-west across the southern part of the Howell Peak Wilderness Study Area is a polarity effect from this deep intrusive body and does not reflect rocks in the study area.

A magnetic high in Tule Valley south of Sand Pass and northwest of the Swasey Mountain Wilderness Study Area probably reflects another buried igneous body. The shape and amplitude of the anomaly suggest that the body is an intrusion; alternatively (but less likely), the body might be a thick volcanic sequence covered by Lake Bonneville sediments. Exposed intrusions and volcanic rocks of all three stages of igneous activity in the nearby Thomas Range and Drum Mountains (Lindsey, 1982) include strongly magnetic phases.

A vertical electrical sounding over the area of the magnetic high in Tule Valley provided a minumum depth for the inferred buried intrusion (R.J. Bisdorf, written commun., 1987). The sounding penetrated about 0.6 mi of electrically conductive material interpreted as water-bearing sediment and sedimentary rock. Below the conductive sediment, Bisdorf measured resistivity values of about 40 ohm-meters. The electrical resistivity of most plutons is greater than 300 ohm-meters. Accordingly, the top of the inferred intrusion must lie more than 0.6 mi below the surface.

EXPLANATION

- —— Gravity contour—Contour interval 2 milligals. Hachures show closed areas of lower gravity values
- • Gravity station
- H Gravity high
- L Gravity low

Radiometrics

Radiometric data were collected in 1976–78 along several east-west-trending lines crossing the study areas (Texas Instruments, Inc., 1977, 1979). The survey detected gamma rays emitted by radiogenic potassium, and by daughter isotopes of uranium and thorium. Because of possible disequilibrium, the parent uranium and thorium are reported as equivalent uranium (eU) and equivalent thorium (eTh). Gamma rays are readily absorbed by soil and rock, so that radiometric signatures reflect only potassium, eU, and eTh within a few inches of the surface.

As part of a geophysical mapping project of Utah, the gamma-ray data were compiled and processed to make a series of color-composite maps (Duval, 1983). These maps were reviewed to estimate the potassium, eU, and eTh concentrations for each study area and to look for anomalous concentrations of radioelements.

The Swasey Mountain Wilderness Study Area has concentrations of 0.4–1.5 percent potassium, 0.5–4.0 ppm eU, and 2–8 ppm eTh. The Howell Peak Wilderness Study Area has concentrations of 0.4–2.2 percent potassium, 1.0–3.0 ppm eU, and 2–10 ppm eTh. No gamma-ray anomalies were detected in or near the Howell Peak Wilderness Study Area. The potassium composite color map shows an anomaly on the northwestern side of the Swasey Mountain Wilderness Study Area, approximately coinciding with the mineralized area of altered intrusive rocks and jasperoid.

Remote Sensing

Part of a Landsat Thematic Mapper (TM) data set covering the study area (scene ID 50123–17425, July 2, 1984) was processed digitally and analyzed to delineate areas of hydrothermally altered, potentially mineralized rocks. A CRC (color ratio composite) image was used to identify lithologies where vegetation did not obscure outcrops. Generally, vegetation cover greater than 25 percent obscures the spectral signature of rocks. Using a CRC image composed of the band ratios TM3/TM1, TM5/TM4, and TM5/TM7, rocks containing ferric iron oxides, oxyhydrides, and sulfates (these minerals are referred to here collectively as limonite) were distinguished from rocks lacking these components. In addition, rocks containing significant quantities of the

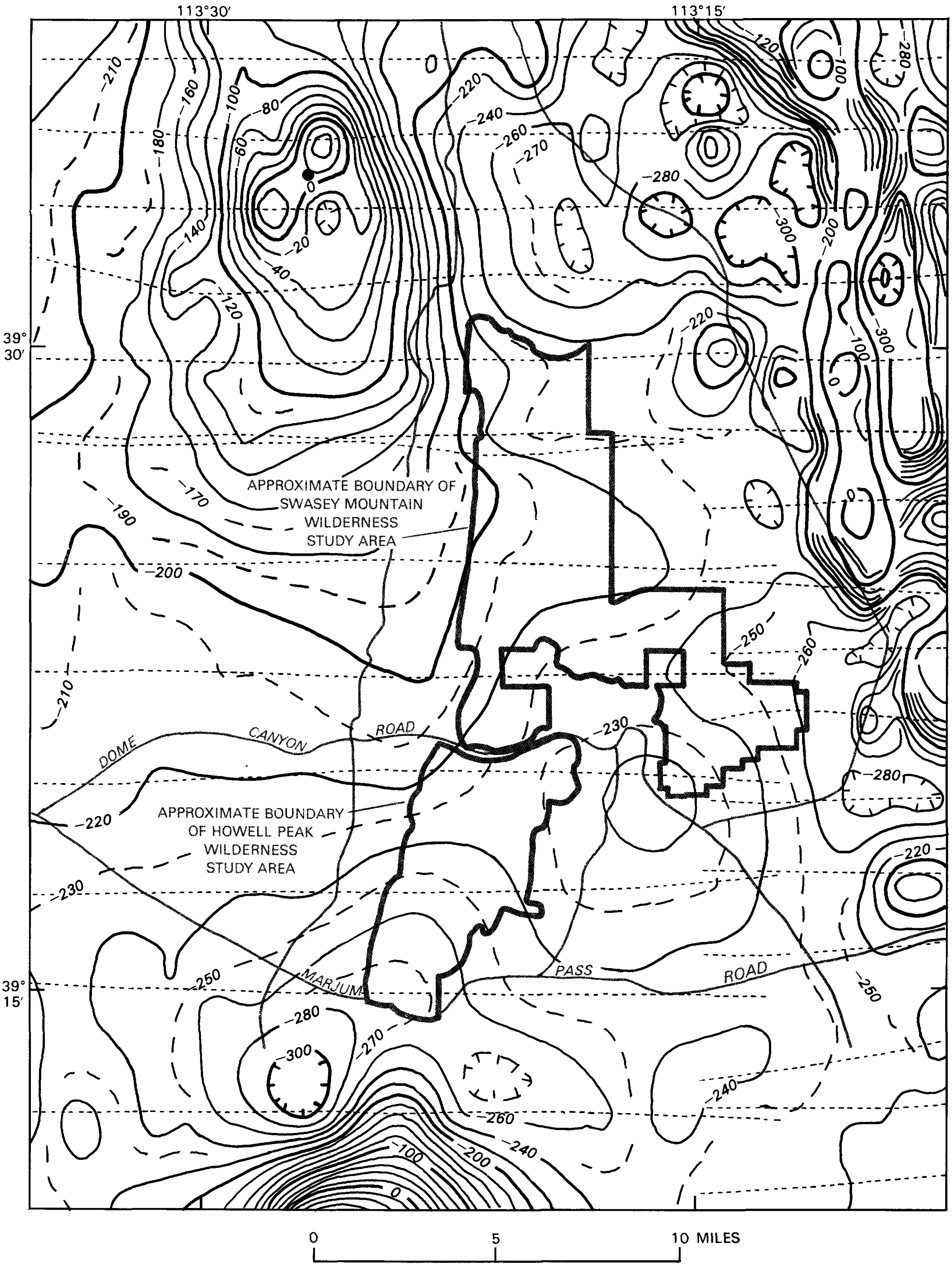


Figure 6 (above and facing page). Aeromagnetic map of the Swasey Mountain and Howell Peak Wilderness Study Areas and vicinity, Utah.

Table 3. Anomalous areas determined from Landsat Thematic Mapper data north of the Swasey Mountain Wilderness Study Area, Utah

Location	Anomaly description	Interpretation
1. SE1/4SE1/4, sec. 36, T. 14 S., R.14W.; NW1/4 NW1/4, sec. 6, T. 15 S., R. 13 W.	Limonitic rocks with strong carbonate or moderate hydroxyl.	Large areas of brown hydrothermally altered dolomite containing small to large jasperoid bodies. Only jasperoid shown on plate 1.
2. S1/2NE1/4, sec. 12, T. 15 S., R. 14 W.; SE1/4SE1/4, sec. 1, T. 15 S., R. 14 W.	Limonitic rocks with strong carbonate or moderate hydroxyl.	Large areas of brown hydrothermally altered dolomite containing moderate-sized jasperoid bodies. Only jasperoid shown on plate 1.
3. SW1/4, sec. 18, T. 15 S., R. 13 W.	Limonitic rocks with strong carbonate or moderate hydroxyl.	Large areas of brown hydrothermally altered dolomite containing moderate-sized jasperoid bodies. Only jasperoid shown on plate 1.

Fe^{+2} -bearing minerals, such as the chlorite minerals, also were detected. Likewise, rocks containing significant quantities of hydroxyl (OH) (for example, sheet silicate minerals such as clay and mica) were distinguished from rocks lacking this composition. Hydrothermally altered rocks commonly contain an abundance of sheet silicate minerals and (or) ferric iron-bearing minerals.

Many other rocks also may produce remote-sensing signatures in TM data similar to hydrothermally altered rocks. Such false anomalies are caused by supergene weathering of ferromagnesian minerals producing both hematite and goethite, in otherwise unaltered rocks, and by the presence of large quantities of mica and clay as original minerals in shale, phyllite, schist, and mica-rich igneous rocks. Likewise, bright carbonate minerals show a similar remote-sensing signature in TM data. Also, some silicified and altered rocks are not visible on remote-sensing images. Many false anomalies were seen in the study areas. These anomalies were due primarily to the presence of Cambrian quartzite and shale containing abundant supergene limonite and OH-bearing chlorite and muscovite. These sites were visited, evaluated, and removed from the list of anomalous areas.

All of the anomalous areas identified on the Thematic Mapper CRC image (listed in table 3 and located on plate 1) are northwest of the Swasey Mountain Wilderness Study Area. Nearly all the anomalous areas were visited in the field. Areas of recrystallized dark-brown dolomite are widespread northwest of the Swasey Mountain Wilderness Study Area and are readily detected on the digitally processed Thematic Mapper CRC image. Small bodies of dark-brown jasperoid occur within the areas of recrystallized dolomite. Anomalies 1, 2, and 3 (table 3, pl. 1) all contain jasperoid. No anomalies identified with altered rocks were found in the Howell Peak Wilderness Study Area.

EXPLANATION

——— **Magnetic contour**—Contour interval, 20 nanoteslas. Intermediate contours are dashed. Hachures show closed areas of lower magnetic values

- - - - - - - - **Flight line**

● **Locality of vertical electrical sounding**

Mineral and Energy Resource Potential

Base and Precious Metals

The model.—The nature of undiscovered base- and precious-metal deposits (lead, zinc, copper, molybdenum, gold, and silver) in the study areas may be predicted from a model of mineralization that incorporates several different types of mineral deposits found in western Utah (Zimbelman and Campbell, 1987). Although the Tintic mining district, 70 mi east of the wilderness study areas, is the best-known example of the model (Morris and Mogensen, 1978), the Fish Springs mining district, the mineralized area south of Sand Pass, and the Detroit mining district in the Drum Mountains are other examples. The model encompasses mineral deposits found in and around mineralized intrusive centers in western Utah: porphyry copper-molybdenum; skarns; vein and replacement deposits of lead, silver, zinc, manganese, gold, and clay; and disseminated gold deposits.

The principal features of the model are (1) shallow intrusive centers, (2) concentric zones of mineral deposits, and (3) localization of alteration and mineralization along fractures. (1) Shallow intrusive centers provide a heat source for convection of mineralizing fluids. Features associated with shallow intrusive centers include stocks, plugs, dikes, radial and concentric faults, pebble dikes, altered rocks, and geochemical and aeromagnetic anomalies. (2) Concentric zones of mineral deposits around the intrusive center indicate fluid movement, cooling, or physical and chemical gradients around the center. The zoned deposits may extend outward along faults and fractures. The complete sequence of mineral deposits from the intrusive center outward consists of porphyry copper and molybdenum; skarns bearing tungsten, tin, and other metals; copper- and gold-bearing veins; lead, zinc, and silver veins and replacement deposits; zinc, lead, and manganese veins and replacement deposits; and gold with jasperoid. Some zones are incompletely developed in the mining districts of western Utah. (3) In most districts, rock alteration and mineralization have been localized along faults and fractures. On a regional scale, the intrusive centers may have been localized by intersecting structural features such as major fault systems and transfer zones. On a local scale, individual ore deposits may occur in intensely shattered and brecciated rock in faults and zones of solution collapse.

Disseminated gold deposits are the target of current (1988) exploration near the wilderness study areas. Although the disseminated gold deposits and occurrences in western Utah broadly resemble other sediment-hosted disseminated gold deposits in the western United States (Berger, 1986; Tooker, 1985), they differ in their characteristic association with shallow intrusive centers and zoned mineralized systems and in their complex geochemical assemblage of incompatible elements.

In the Drum Mountains (Detroit mining district), gold is associated with numerous silicified (jasperoid) masses in Lower and Middle Cambrian carbonate rocks (McCarthy and others, 1969). A stock and dikes of altered quartz monzonite (Crittenden and others, 1961) of probable late Eocene or early Oligocene age crop out in the midst of the district. Jasperoid and gold occur along faults and in zones of intense fracturing. Most of the host rocks are thin-bedded silty and shaly carbonate rocks between the Prospect Mountain Quartzite and the Pierson Cove Formation (Dommer, 1980). The combination of abundant silt, many bedding planes, and abundant fractures makes the Lower and Middle Cambrian rocks of the Drum Mountains, and the similar House Range, good hosts for mineral deposits.

The Sand Pass mineralized area lies immediately north of the Swasey Mountain Wilderness Study Area. The mineralized area has been explored extensively for gold and may contain deposits of other metals (Chidsey, 1978). The area lies east of the shallow concealed pluton inferred from geophysical surveys. At the surface, the principal features of the mineralized area are: (1) small plugs of igneous rocks containing secondary muscovite and clay minerals, outside the study area; (2) a zone of north-striking high-angle faults that appear to have been conduits for the igneous plugs and mineralizing fluids; (3) laterally extensive breccia zones that intersect the faults and served as conduits for mineralizing fluids; (4) numerous rusty, silicified masses (jasperoid) in the breccia zones; and (5) geochemical anomalies of gold, arsenic, and other metals associated with the jasperoid.

Mineral resource potential.—Areas of moderate mineral resource potential for base and precious metals (lead, zinc, copper, molybdenum, silver, and gold) extend into the northern part of the Swasey Mountain Wilderness Study Area; level of certainty is C. One area follows the North Swasey tear fault and isolated geochemical anomalies along this structure. The second area, extending south along the range-front fault on the western side of Swasey Mountain, is defined by extensive geochemical anomalies. No solution breccia or jasperoid are known in these areas of moderate potential.

A large area of moderate potential for the same base and precious metals extends south from the Trail Canyon tear fault in the southwestern part of the Swasey Mountain Wilderness Study Area along the entire western boundary of the Howell Peak Wilderness Study Area. The area contains numerous faults of small-to-moderate displacement and intervals of iron-stained stratabound solution-breccia bodies (mapped as attenuation faults by Hintze, 1981c). No jasperoid or intrusive igneous rocks have been mapped. Most of the breccias are within 1–3 mi of the range-bounding fault, and this structure is regarded as the most likely immediate source of mineralizing fluids. Anomalous levels of silver, arsenic, and other metals are found locally in the stratabound breccia and in fault breccia. Widespread occurrence of anomalous amounts of metals in stream sediments defines the area of moderate potential. Level of certainty for assignment to moderate potential is C.

High-Purity Limestone and Dolomite

The model.—Limestone and dolomite have been quarried for metallurgical flux from a variety of formations in Utah (Morris, 1964), including Cambrian rocks in the Cricket Mountains, about 25 mi southeast of the study areas, and from the Ordovician Fish Haven and Silurian Laketown Dolomites in the Stansbury Mountains, about 70 mi northeast of the study areas. In addition to resources of high-purity limestone in the Howell Limestone, identified by the U.S. Bureau of Mines in this study, other carbonate rock formations of Cambrian and Ordovician age that crop out in the study areas may contain rock of sufficient purity to serve as flux.

Mineral resource potential.—Both the Swasey Mountain and Howell Peak Wilderness Study Areas have a moderate potential for resources of high-purity limestone and dolomite that could be used as metallurgical flux. Level of certainty is B; available information only suggests moderate potential. Testing for purity of carbonate rock in the study areas, other than the previously mentioned Howell Limestone, would be necessary to identify resources within the thick section of carbonate formations.

Oil and Gas

The model.—Exploration for oil and gas in western Utah has involved wildcat drilling of a variety of targets, including: (1) asymmetric anticlines and thrusts associated with shaly source rocks in the Confusion Range synclinorium to the southwest, outside the study areas, (2) gravity lows and seismic features that might indicate anticlines in thick basin fill of Tertiary age, not found in the study areas, and (3) subthrust oil-bearing structures including those in sandstone of Mesozoic age. Target 1 is illustrated on the interpretative sections of the COCORP line (Allmendinger and others, 1985). Targets 2 and 3 are illustrated by the drilling of the Argonaut Energy No. 1 Federal wildcat well in the Sevier Desert basin (Mitchell, 1979).

A variant of target 3, oil- and gas-bearing structures associated with the Sevier arch (House Range antiform), was proposed by Allmendinger and others (1985). Although such structures may occur in Precambrian rocks above the House Range detachment fault, their most likely location is in Paleozoic rocks that might lie below the detachment. Structures that might trap oil and gas within the arch, although highly speculative and ill-defined, are probably the only place where oil and gas might be discovered in the vicinity of the wilderness study area.

Energy resource potential.—Oil and gas resource potential of the wilderness study areas is rated with respect to the variant of target 3, possible structures associated with the Sevier arch. Target 3 is the only one likely to occur beneath the study areas. The potential is moderate with a certainty level of B throughout both study areas. The low level of certainty (B) for resource assessment is dictated by the inability to predict the critical factors for oil and gas accumulation in hypothesized subthrust rocks beneath the study areas in the House Range.

For a resource to occur beneath the study areas, the rocks beneath the Sevier arch must contain suitable traps for oil and gas deposits, must contain or be updip from source rocks, and must be thermally mature. Suitable traps for oil and gas consist of permeable zones capped by impermeable barriers. Such traps are most likely to be found in folded and faulted Paleozoic or Mesozoic rocks, but their presence cannot be excluded from Precambrian rocks.

Evidence for the presence of Paleozoic or Mesozoic rocks beneath the detachments of the study areas depends upon tenuous correlations with distant test holes and outcrops to the south and east. The Pavant thrust brings Paleozoic rocks over Mesozoic rocks in the Pavant Range (Mitchell and McDonald, 1986), more than 60 mi southeast of the study areas, and this thrust is correlated westward in seismic profiles as the Sevier Desert detachment (Mitchell and McDonald, 1987). If one of the detachments seen in the COCORP profile of the House Range is equivalent to the Pavant thrust, then rocks of Paleozoic or Mesozoic age may underlie the wilderness study areas at depths of at least 2.5 mi.

Suitable source rocks occur west of the study areas in the Confusion Range synclinorium, but they are stratigraphically and structurally above rocks of the study areas. Structural repetition of these source rocks below one of the detachments of the study areas is problematical.

Available data on conodont alteration and thermal maturation of hydrocarbons indicates that rocks east and west of the study areas may have been heated within the window of oil and gas generation (Molenaar and Sandberg, 1983; McDowell, 1988). However, these data may not represent the thermal maturity of rocks beneath the detachments of the study areas.

Molenaar and Sandberg (1983), in their study of the petroleum potential of wilderness lands in Utah, assigned a medium (moderate) potential for oil and gas to the region of the House Range that includes the wilderness study areas. They based their rating on the same evidence presented above, but they appear to have been unaware of the existence of the antiformal structure of detachments beneath the House Range.

Geothermal Energy and Coal

No hot springs occur in or near the wilderness study areas, and evidence of recent volcanic activity is absent. The potential for resources of geothermal energy is low, with a certainty level of C. No beds of coal occur within the Cambrian and Ordovician rocks of western Utah; there is, therefore, no energy resource potential for coal, with certainty level D.

Recommendations for Further Work

An extensive structural analysis of all available seismic profiles in the vicinity of the House Range is needed to determine the correlation of detachments in the Sevier arch. A test hole along the COCORP line is recommended to penetrate rocks and structures beneath the House Range detachment. Such a test would seek to determine the character and number of detachment faults, the identity of rock formations between the House Range and Sevier Desert detachments, the presence or absence of oil and gas source rocks beneath the detachment, and the thermal maturity of such rocks if they occur. All test holes drilled nearby have been in basinal areas, where the likelihood of answering questions about the detachments and rocks below them is low.

REFERENCES CITED

Allmendinger, R.W., Sharp, J.W., Von Tish, D., Oliver, J., and Kaufman, S., 1985, A COCORP crustal-scale seismic profile of the Cordilleran hingeline, eastern basin and range province, *in* Gries, R.R., and Dyer, R.C., eds., Seismic exploration of the Rocky Mountain region: Denver, Rocky Mountain Association of Petroleum Geologists and Denver Geophysical Society, p. 23–30.

Allmendinger, R.W., Sharp, J.W., Von Tish, D., Serpa, L., Brown, L., Kaufman, S., Oliver, J., and Smith, R.B., 1983, Cenozoic and Mesozoic structure of the eastern Basin and Range province, Utah, from COCORP seismic-reflection data: Geology, v. 11, no. 9, p. 532–536.

Arbogast, B.F., Hageman, P.L., Roemer, Theodore, Whitney, Helen, and Zimbelman, D.R., 1989, Analytical results and sample locality maps of stream-sediment, heavy-mineral-concentrate, and rock samples from the Swasey Mountain and Howell Peak Wilderness Study Areas, Millard County, Utah: U.S. Geological Survey Open-File Report 88–577, 36 p.

Berger, B.R., 1986, Descriptive model of carbonate-hosted Au-Ag, *in* Cox, D.P., and Singer, D.A., eds., Mineral deposit models: U.S. Geological Survey Bulletin 1693, p. 175.

Chidsey, T.C., Jr., 1978, Intrusions, alteration, and economic implications in the northern House Range, Utah: Brigham Young University Geology Studies, v. 25, pt. 3, p. 47–65.

Crittenden, M.D., Jr., Straczek, J.A., and Roberts, R.J., 1961, Manganese deposits in the Drum Mountains, Juab and Millard Counties, Utah: U.S. Geological Survey Bulletin 1082–H, p. 493–544.

Dommer, M.L., 1980, The geology of the Drum Mountains, Millard and Juab Counties, Utah: Brigham Young University Geology Studies, v. 27, pt. 3, p. 55–72.

Duval, J.S., 1983, Composite color images of aerial gamma-ray spectrometric data: Geophysics, v. 48, p. 722–735.

Gilbert, G.K., 1875, Report on the geology of portions of Nevada, Utah, California, and Arizona: U.S. Geographical and Geological Explorations and Surveys West of the One Hundreth Meridian [Wheeler Survey], v. 3 (Geology and Mineralogy), pt. 1, p. 21–42.

Goudarzi, G.H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–787, 42 p.

Hintze, L.F., 1974, Preliminary geologic map of the Notch Peak quadrangle, Millard County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–636, scale 1:48,000.

——— 1978, Sevier orogenic attenuation faulting in the Fish Springs and House Ranges, western Utah: Brigham Young University Geology Studies, v. 25, pt. 1, p. 11–24.

——— 1980a, Preliminary geologic map of the Sand Pass quadrangle, Juab and Millard Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1151, scale 1:24,000.

——— 1980b, Preliminary geologic map of the Sand Pass NE and Sand Pass SE quadrangles, Juab and Millard Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1150, scale 1:24,000.

——— 1981a, Preliminary geologic map of the Swasey Peak and Swasey Peak NW quadrangles, Millard County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1333, scale 1:24,000.

——— 1981b, Preliminary geologic map of the Whirlwind Valley NW and Whirlwind Valley SW quadrangles, Millard County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1335, scale 1:24,000.

——— 1981c, Preliminary geologic map of the Marjum Pass and Swasey Peak SW quadrangles, Millard County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1332, scale 1:24,000.

——— Hintze, L.F., and Robison, R.A., 1975, Middle Cambrian stratigraphy of the House, Wah Wah, and adjacent ranges in western Utah: Geological Society of America Bulletin, v. 86, no. 7, p. 881–891.

——— 1987, The House Range, western Utah—Cambrian mecca, *in* Beus, S.S., ed., Rocky Mountain Section: Geological Society of America Centennial Field Guide, v. 2, p. 257–260.

Hose, R.K., 1977, Structural geology of the Confusion Range, west-central Utah: U.S. Geological Survey Professional Paper 971, 9 p.

Kerr, R.A., 1986, Tracing a young and malleable Moho: Science, v. 233, p. 621–622.

Ketner, K.B., 1982, High-grade silica deposits, *in* Erickson, R.L., compiler, Characteristics of mineral deposit occurrences: U.S. Geological Survey Open-File Report 82–795, p. 237–238.

Lindsey, D.A., 1982, Tertiary volcanic rocks and uranium in the Thomas Range and northern Drum Mountains, Juab County, Utah: U.S. Geological Survey Professional Paper 1221, 71 p.

McCarthy, J.H., Jr., Learned, R.E., Botbol, J.M., Lovering, T.G., Watterson, J.R., and Turner, R.L., 1969, Gold-bearing jasperoid in the Drum Mountains, Juab and Millard Counties, Utah: U.S. Geological Survey Circular 623, 4 p.

McDowell, R.R., 1988, Middle Ordovician Kanosh Formation—Remaining source-rock potential? Mountain Geologist, v. 25, no. 4, p. 141–154.

Mitchell, G.C., 1979, Stratigraphy and regional implications of the Argonaut No. 1 Federal, Millard County, Utah, *in* Newman, G.W., and Goode, H.D., eds., Basin and Range Symposium and Great Basin Field Conference: Denver, Colo., Rocky Mountain Association of Geologists, and Salt Lake City, Utah, Utah Geological Association, p. 503–514.

Mitchell, G.C., and McDonald, R.E., 1986, History of Cenozoic extension in central Sevier Desert, west-central Utah, from COCORP seismic reflection data--Discussion: American Association of Petroleum Geologists Bulletin, v. 70, no. 8, p. 1015–1021.

______ 1987, Subsurface Tertiary strata, origin, depositional model and hydrocarbon exploration potential of the Sevier Desert basin, west central Utah, *in* Copp, R.S., and Cohenour, R.E., eds., Cenozoic geology of western Utah—sites for precious metal and hydrocarbon accumulations: Utah Geological Association Publication 16, p. 533–556.

Molenaar, C.M, and Sandberg, C.A., 1983, Petroleum potential of wilderness lands in Utah, *in* Miller, B.M., ed., Petroleum potential of wilderness lands in the western United States: U.S. Geological Survey Circular 902–K, 14 p.

Morris, H.T., 1964, Limestone and dolomite, *in* Mineral and water resources of Utah: Utah Geological and Mineralogical Survey Bulletin 73, p. 188–194.

______ 1987, Preliminary geologic map of the Delta 2° quadrangle, Tooele, Juab, Millard, and Utah Counties, Utah: U.S. Geological Survey Open-File Report 87–185, 22 p., 3 plates, scale 1:250,000.

Morris, H.T., and Mogensen, A.P., 1978, Tintic mining district: Brigham Young University Geology Studies, v. 25, pt. 1, p. 33–45.

Robison, R.A., 1964, Late Middle Cambrian faunas from western Utah: Journal of Paleontology, v. 38, no. 3, p. 510–566.

Smith, R.B., and Bruhn, R.L., 1984, Intraplate extensional tectonics of the eastern basin-range—Inferences on structural style from seismic reflection data, regional tectonics, and thermal-mechanical models of brittle-ductile deformation: Journal of Geophysical Research, v. 89, no. B7, p. 5733–5762.

Texas Instruments, Inc., 1977, Aerial gamma-ray and magnetic survey of the Delta area, Utah, final report: U.S. Department of Energy Report GJBX–18(77). Available from Books and Open-File Reports Section, U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225.

______ 1979, Aerial radiometric and magnetic reconnaissance survey of the Delta quadrangle, Utah: U.S. Department of Energy Report GJBX–24(79), 576 p., 28 fiche. Available from Books and Open-File Reports Section, U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225.

Tooker, E.W., 1985, Discussion of the disseminated-gold-ore-occurrence model, *in* Tooker, E.W., ed., Geologic characteristics of sediment- and volcanic-hosted disseminated gold deposits—search for an occurrence model: U.S. Geological Survey Bulletin 1646, p. 107–148.

Tuftin, S.E., 1987, Mineral resources of a part of the Swasey Mountain Wilderness Study Area (UT–050–061), and a part of the Howell Peak Wilderness Study Area (UT–050–077), Millard County, Utah: U.S. Bureau of Mines Open-File Report MLA 71–87, 28 p.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

U.S. Geological Survey, 1971, Aeromagnetic map of part of west-central Utah: U.S. Geological Survey Open-File Report 71–289, 1 sheet, scale 1:250,000.

______ 1972, Aeromagnetic map of parts of the Delta and Richfield 1°x2° quadrangles, Utah: U.S. Geological Survey Open-File Report 72–385, 1 sheet, scale 1:250,000.

Zimbelman, D.R., and Campbell, D.L., 1987, Regional-scale geochemical and geophysical characteristics of the Tintic-Deep Creek mineral belt, west-central Utah: Geological Society of America Abstracts with Programs, v. 19, no. 7, p. 905.

APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

LOW mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is unlikely. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

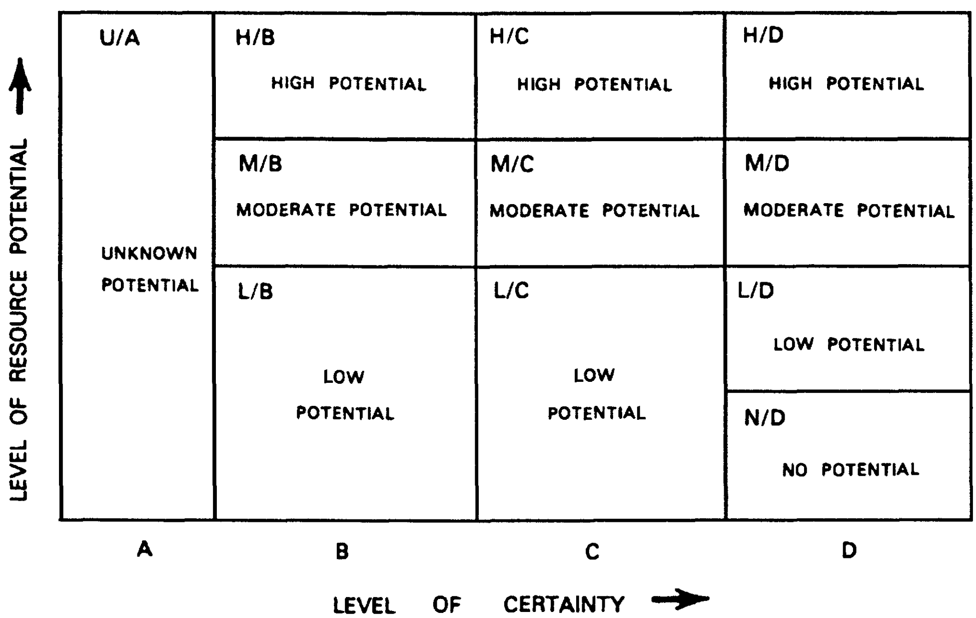
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information suggests the level of mineral resource potential.
C. Available information gives a good indication of the level of mineral resource potential.
D. Available information clearly defines the level of mineral resource potential.

Abstracted with minor modifications from:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, 1972, Mineral resource estimates and public policy: American Scientist, v.60, p.32-40, and U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p.5.

GEOLOGIC TIME CHART

Terms and boundary ages used in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~ 240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~ 330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~ 570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				
		3800?			
pre-Archean[2]					4550

[1] Rocks older than 570 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1989—673-047/ 86,088 REGION NO