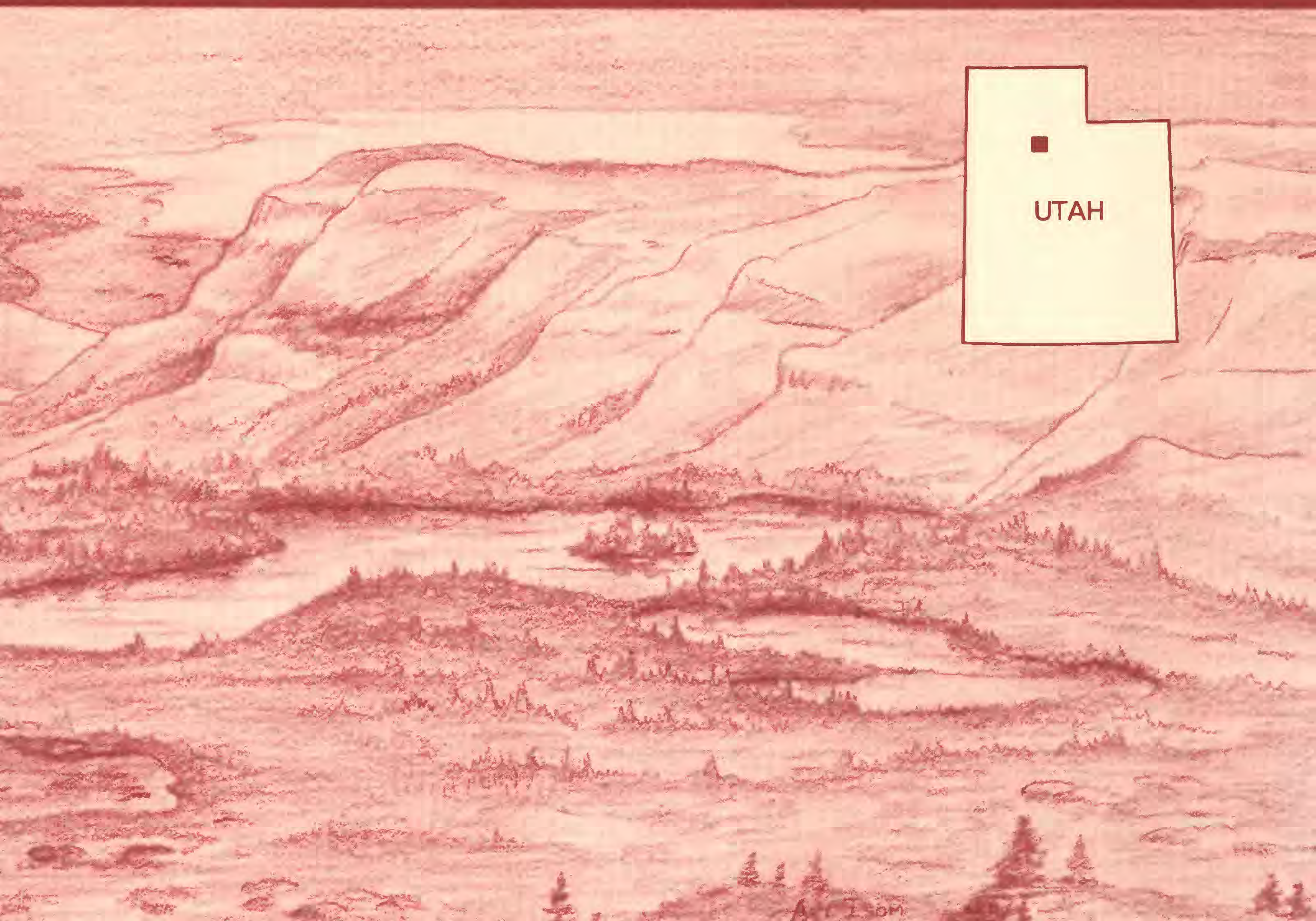
Mineral Resources of the North Stansbury Mountains Wilderness Study Area, Tooele County, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1745–B



AVAILABILITY OF BOOKS AND MAPS OF THE U.S. GEOLOGICAL SURVEY

Instructions on ordering publications of the U.S. Geological Survey, along with prices of the last offerings, are given in the current-year issues of the monthly catalog "New Publications of the U.S. Geological Survey." Prices of available U.S. Geological Survey publications released prior to the current year are listed in the most recent annual "Price and Availability List." Publications that are listed in various U.S. Geological Survey catalogs (**see back inside cover**) but not listed in the most recent annual "Price and Availability List" are no longer available.

Prices of reports released to the open files are given in the listing "U.S. Geological Survey Open-File Reports," updated monthly, which is for sale in microfiche from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. Reports released through the NTIS may be obtained by writing to the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161; please include NTIS report number with inquiry.

Order U.S. Geological Survey publications **by mail** or **over the counter** from the offices given below.

BY MAIL

Books

Professional Papers, Bulletins, Water-Supply Papers, Techniques of Water-Resources Investigations, Circulars, publications of general interest (such as leaflets, pamphlets, booklets), single copies of Earthquakes & Volcanoes, Preliminary Determination of Epicenters, and some miscellaneous reports, including some of the foregoing series that have gone out of print at the Superintendent of Documents, are obtainable by mail from

U.S. Geological Survey, Books and Open-File Reports
Federal Center, Box 25425
Denver, CO 80225

Subscriptions to periodicals (Earthquakes & Volcanoes and Preliminary Determination of Epicenters) can be obtained ONLY from the

Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

(Check or money order must be payable to Superintendent of Documents.)

Maps

For maps, address mail orders to

U.S. Geological Survey, Map Distribution
Federal Center, Box 25286
Denver, CO 80225

Residents of Alaska may order maps from

Alaska Distribution Section, U.S. Geological Survey,
New Federal Building - Box 12
101 Twelfth Ave., Fairbanks, AK 99701

OVER THE COUNTER

Books

Books of the U.S. Geological Survey are available over the counter at the following Geological Survey Public Inquiries Offices, all of which are authorized agents of the Superintendent of Documents:

- **WASHINGTON, D.C.**--Main Interior Bldg., 2600 corridor, 18th and C Sts., NW.
- **DENVER, Colorado**--Federal Bldg., Rm. 169, 1961 Stout St.
- **LOS ANGELES, California**--Federal Bldg., Rm. 7638, 300 N. Los Angeles St.
- **MENLO PARK, California**--Bldg. 3 (Stop 533), Rm. 3128, 345 Middlefield Rd.
- **RESTON, Virginia**--503 National Center, Rm. 1C402, 12201 Sunrise Valley Dr.
- **SALT LAKE CITY, Utah**--Federal Bldg., Rm. 8105, 125 South State St.
- **SAN FRANCISCO, California**--Customhouse, Rm. 504, 555 Battery St.
- **SPOKANE, Washington**--U.S. Courthouse, Rm. 678, West 920 Riverside Ave..
- **ANCHORAGE, Alaska**--Rm. 101, 4230 University Dr.
- **ANCHORAGE, Alaska**--Federal Bldg, Rm. E-146, 701 C St.

Maps

Maps may be purchased over the counter at the U.S. Geological Survey offices where books are sold (all addresses in above list) and at the following Geological Survey offices:

- **ROLLA, Missouri**--1400 Independence Rd.
- **DENVER, Colorado**--Map Distribution, Bldg. 810, Federal Center
- **FAIRBANKS, Alaska**--New Federal Bldg., 101 Twelfth Ave.

Chapter B

Mineral Resources of the North Stansbury Mountains Wilderness Study Area, Tooele County, Utah

By MICHAEL P. FOOSE and KAREN A. DUTTWEILER
U.S. Geological Survey

CARL L. ALMQUIST
U.S. Bureau of Mines

U.S. GEOLOGICAL SURVEY BULLETIN 1745

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—NORTHWESTERN 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 North Stansbury Mountains Wilderness Study Area, Tooele County, Utah / by Michael P. Foose, Karen A. Duttweiler, and Carl L. Almquist.

p. cm. — (Mineral resources of wilderness study areas—Northwestern Utah ; ch. B) (U.S. Geological Survey bulletin ; 1745–B)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1745–B
1. Mines and mineral resources—Utah—North Stansbury Mountains Wilderness. 2. North Stansbury Mountains Wilderness (Utah) I. Duttweiler, K. A. II. Almquist, Carl L. III. Title. IV. Series. V. Series: Studies related to wilderness. VI. Series: U.S. Geological Survey bulletin ; 1745–B.
QE75.B9 no. 1745–B
[TN24.U8]
557.3 s—dc19 89-600008
[553'.09792'43] CIP

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 North Stansbury Mountains (UT–020–089) Wilderness Study Area, Tooele County, Utah.

CONTENTS

FIGURES

Mineral Resources of the North Stansbury Mountains Wilderness Study Area, Tooele County, Utah

By Michael P. Foose *and* Karen A. Duttweiler
U.S. Geological Survey

Carl L. Almquist
U.S. Bureau of Mines

ABSTRACT

In 1985, the U.S. Bureau of Mines and the U.S. Geological Survey appraised the mineral resources and assessed the mineral resource potential of the North Stansbury Mountains (UT–020–089) Wilderness Study Area. This area covers approximately 10,175 acres (15.9 square miles) near the northern end of the Stansbury Mountains in northwestern Utah. The area lies 45 miles west of Salt Lake City, about 20 miles west of the Oquirrh Mountains, and 55 miles northwest of the East Tintic Mountains. Both the Oquirrh and East Tintic Mountains are noted for large base- and precious-metal deposits.

A small area in the southeasternmost part of the study area has inferred subeconomic resources of limestone suitable for use in making cement. Inferred subeconomic resources of sand and gravel exist within Muskrat Canyon. These inferred subeconomic resources are not likely to be developed. There are no other identified resources in the study area.

Mineral occurrences and geochemical anomalies in and near the study area are similar to those observed near some of the deposits in the Oquirrh and East Tintic Mountains and provide evidence that hydrothermal mineralization has occurred within the eastern and southern parts of the study area. These parts are considered to have a moderate mineral resource potential for undiscovered lead, zinc, silver, gold, and mercury in vein and replacement deposits. The remaining parts of the study area are assigned a low mineral resource potential for lead, zinc, silver, gold, and mercury in vein and replacement deposits.

In the southwestern and eastern parts of the study area, some samples contain anomalous amounts of silver, bismuth, antimony, arsenic, and, in a few cases, mercury. This same geochemical suite is associated with some sediment-hosted disseminated gold deposits, such as the Mercur deposit in the adjacent Oquirrh Mountains. Based on this association, areas underlain by carbonate and fine-grained siliceous rocks in the southern and eastern parts of the study area are assigned a moderate potential for undiscovered sediment-hosted, disseminated gold resources. The remainder of the area has low potential for gold resources.

A small portion of the southwestern part of the study area may contain thermal waters and is assigned a moderate potential for undiscovered geothermal resources. The entire study area is assigned a low potential for oil and gas resources.

SUMMARY

Character and Setting

The North Stansbury Mountains Wilderness Study Area comprises approximately 10,175 acres (15.9 square miles) located 45 mi (miles) west of Salt Lake City, Utah (fig. 1). The area is near the northern end of the Stansbury Mountains and is bounded to the west by Skull Valley and to the east by Tooele Valley. Elevations in these flanking valleys are between 4,200 and 4,300 ft (feet), and the maximum

Manuscript approved for publication February 1, 1989.

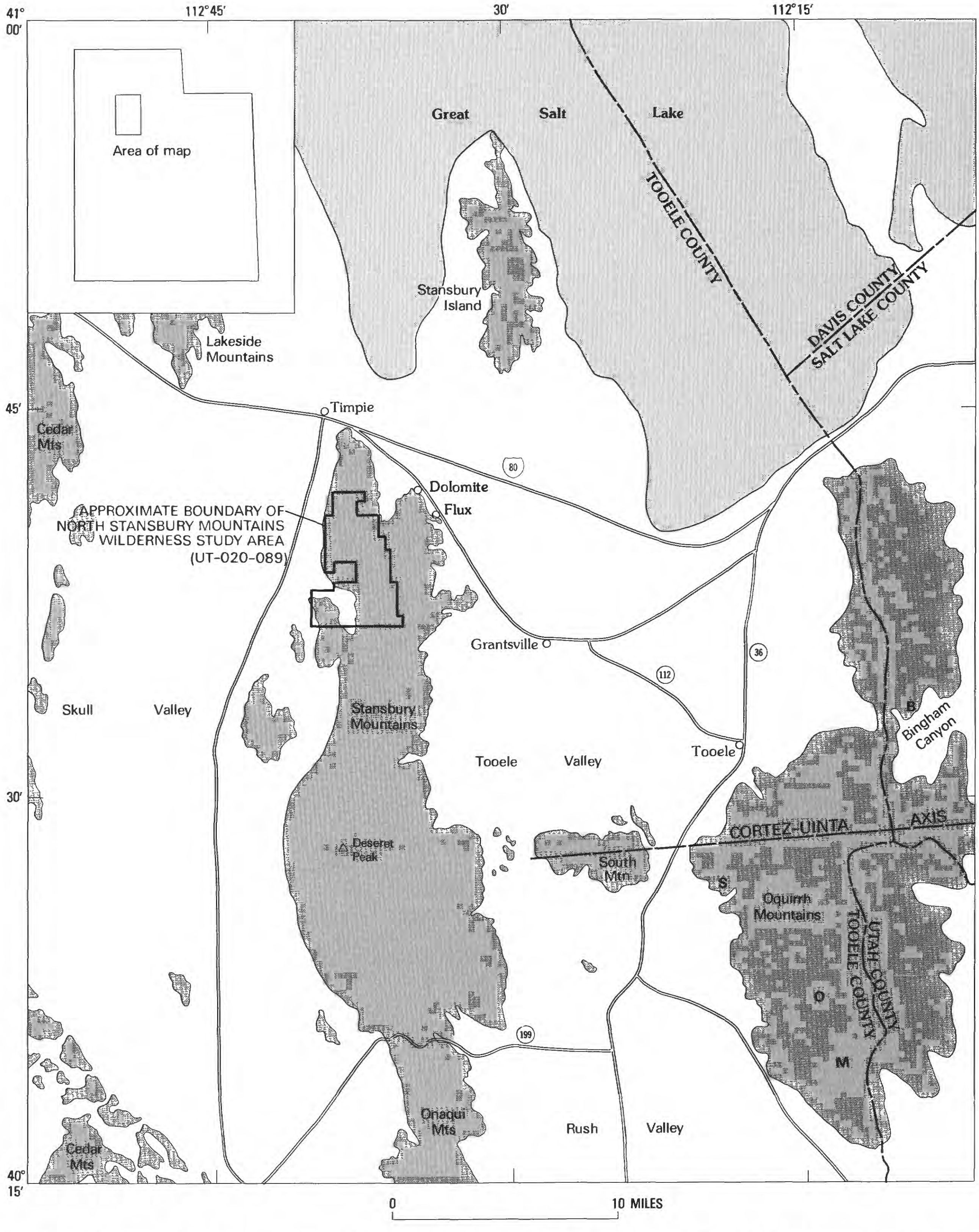


Figure 1. Location of the North Stansbury Mountains Wilderness Study Area, Tooele County, Utah. Letters show locations of the Bingham (B), Stockton (S), Ophir (O), and Mercur (M) mining districts in the Oquirrh Mountains.

elevation within the study area is 8,885 ft. Access to the area is provided by several unpaved roads and by Interstate Highway 80, which passes within 3 mi of the northern end of the area.

The Stansbury Mountains, including the study area, lie within the eastern Great Basin, an area that is also part of the Basin and Range structural province. The following generalized geologic history of this area is taken from Tooker (1983).

Carbonate and clastic sediments were deposited as part of a westward-thickening miogeocline during the early Paleozoic (Cambrian through Devonian). (See geologic age chart in the Appendix.) This deposition was interrupted in the Devonian by uplift on the east-west-trending Cortez-Uinta axis. Unconformable clastic sediments deposited during this uplift grade upward into a sequence of Mississippian through Permian sediments, most of which were deposited in shallow water. During the Mesozoic, eastward-directed thrusting resulting from the Sevier orogeny developed a series of imbricated thrust sheets. Mesozoic sediments are preserved in only a few of these. Thrusting was followed by some Tertiary igneous activity, which emplaced several small intrusions of intermediate composition in the central part of the range (Davis, 1959). Cenozoic normal faulting and eastward tilting have subsequently segmented these rocks to form north-trending mountain ranges that are flanked by intervening valleys filled with young clastic sediments.

The young sediments filling Tooele Valley separate the study area from the Oquirrh Mountains, which lie approximately 20 mi to the east (fig. 1). These adjacent mountains host the copper, lead, zinc, silver, and gold mineralization of the extremely large Bingham mining district and the smaller Stockton and Ophir districts to the south. Still farther south is the Mercur disseminated gold deposit (Kornze, 1987). In the East Tintic Mountains, 25 mi farther south, are the silver, lead, gold, copper, and zinc vein and replacement deposits of the East Tintic district.

Identified Mineral Resources

The Free Coinage mining district, whose boundaries are not well defined, probably includes the study area, but there are no mines or active mining claims within the study area. Lead and zinc have been mined at several localities within 1 mi east of the study area, and the workings of one mine extend to its eastern boundary. Mercury reportedly was mined from limestone breccias 1 mi east of the study area. Limestone that crops out in a small area in the southeastern-most part of the study area is quarried for use as cement raw material 2 mi to the east. The limestone is classified as an inferred subeconomic resource. Sand and gravel, present mainly in Muskrat Canyon, is poorly sorted and made up of material ranging from sand-size particles to boulders. The sand and gravel is classified as an inferred subeconomic resource because it is far from market and not likely to be developed. No other identified resources are present.

Mineral Resource Potential

Geological and geochemical evidence indicates that some of the eastern and southern parts of the study area have been mineralized by hydrothermal solutions. This mineral enrichment is most clearly evident at several mines and prospects, most of which are located outside but close to the eastern margin of the study area. However, a few prospects are within the study area, and geochemical anomalies similar to those associated with these mines and prospects are also found in the study area. These occurrences indicate that mineralization, similar to that which has enriched parts of the Oquirrh and East Tintic Mountains, has affected this part of the Stansbury Mountains.

The mines, prospects, and geochemical anomalies along the eastern part of the study area closely follow the contact that separates Lower Devonian and older rocks from Upper Devonian and younger rocks. This association suggests that this contact, which is probably an unconformity, localized hydrothermal solutions. However, some similar mineral occurrences in the south-central part of the study area are not near this contact and indicate that shears and fractures also were conduits for mineralizing solutions. Therefore, not all mineralization in the study area was confined to areas that are near the contact between older and younger Devonian rocks.

The geochemical signature of mineral occurrences in and near the study area is similar to that of some of the lead, zinc, silver, gold, and mercury replacement deposits found in peripheral parts of the Bingham mining district (Rubright and Hart, 1968) and in the vein and replacement deposits of the East Tintic district (Morris and Lovering, 1979). The data indicate that similar mineralization has occurred within the eastern and southern parts of the study area, and these areas are therefore assigned a moderate potential for undiscovered lead, zinc, silver, gold, and mercury resources in vein and replacement deposits (fig. 2).

The remaining part of the study area is underlain by carbonates and shales, which may be favorable host rocks for replacement and vein deposits. Fractures and faults in this area may be mineralized, although we have found no specific evidence that they are. This area is, therefore, assigned a low mineral resource potential for metals in replacement and vein deposits.

Some of the samples from the south-central and eastern parts of the study area have anomalous concentrations of gold, silver, arsenic, antimony, and bismuth. High concentrations of mercury are also observed in some of these samples. This geochemical suite is characteristic of sediment-hosted disseminated gold deposits, such as the Mercur deposit in the southern part of the adjacent Oquirrh Mountains. On the basis of this geochemical association, a moderate potential for undiscovered gold resources in sediment-hosted disseminated deposits is assigned to the southern and eastern parts of the study area, except where the bedrock is quartzite (fig. 2).

Warm springs occur in both Skull and Tooele Valleys at the north end of the Stansbury Mountains. The southwest part of the study area extends into Skull Valley, and the potential for undiscovered geothermal resources in this area is rated as moderate.

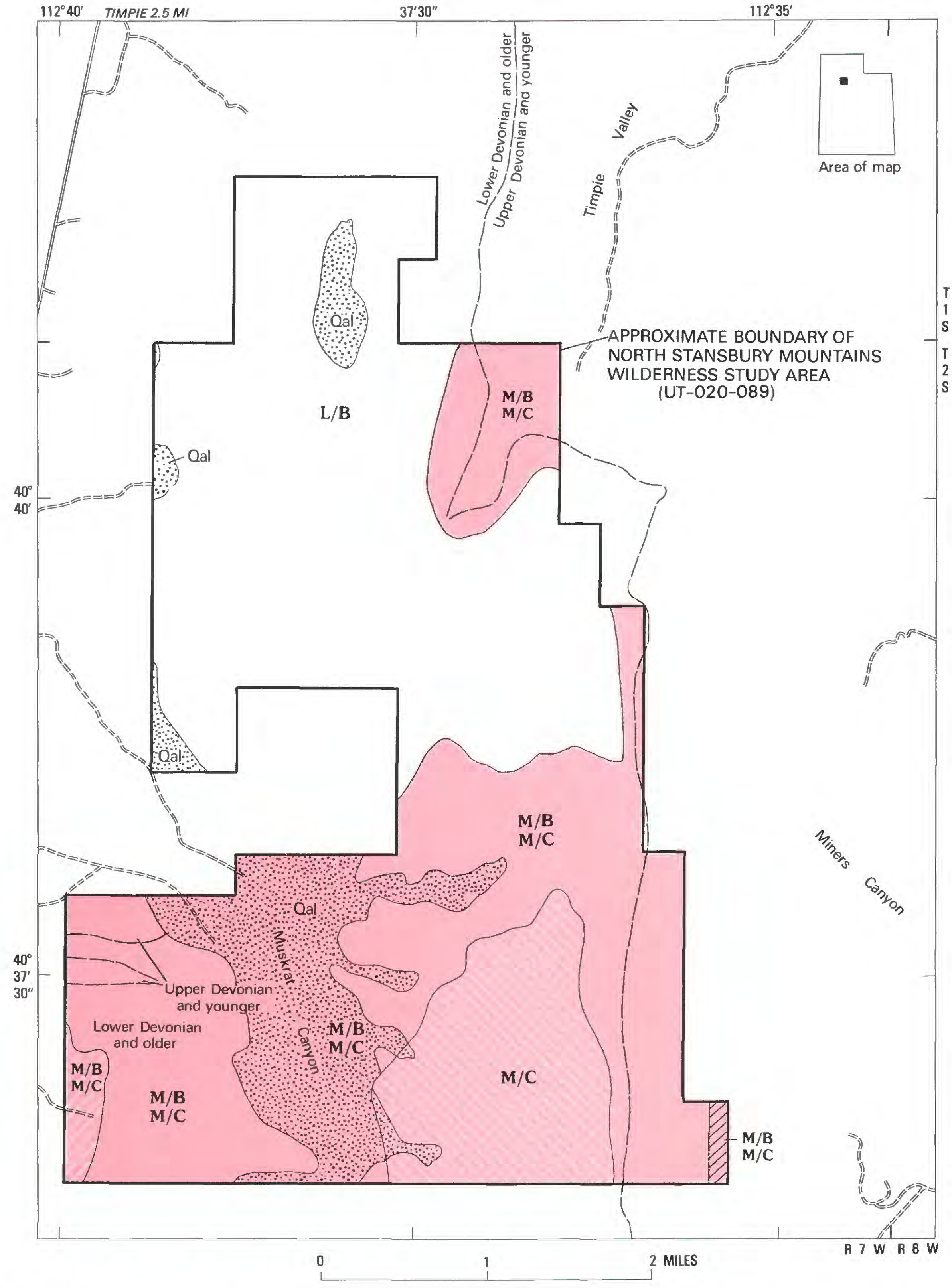


Figure 2 (above and facing page). Mineral resource potential and pertinent geologic features of the North Stansbury Mountains Wilderness Study Area, Tooele County, Utah.

EXPLANATION OF MINERAL RESOURCE POTENTIAL

(stippled pink)	Area having inferred subeconomic resource of sand and gravel
(diagonal lines)	Area having inferred subeconomic resource of limestone suitable for use in cement—Resource is in the Mississippian Great Blue Limestone, which crops out only in the southeast corner of the study area
M/C	Geologic terrane having moderate mineral resource potential for vein and replacement deposits of lead, zinc, silver, gold, and mercury, with certainty level C—Applies to all areas shown in pink, with and without stripes
M/B	Geologic terrane having moderate mineral resource potential for sediment-hosted disseminated gold resources, with certainty level B—Applies to all areas marked "M/B"
M/B	Geologic terrane having moderate resource potential for geothermal energy, with certainty level B
L/B	Geologic terrane having low mineral resource potential for oil and gas and for all metals, with certainty level B—For oil and gas, applies to entire study area; for metals, applies only outside the "moderate" (pink) areas

Levels of certainty:

B	Data indicate geologic environment and suggest the level of resource potential
C	Data indicate geologic environment and give a good indication of the level of resource potential

GEOLOGIC FEATURES

Qal	Alluvial deposits of Quaternary age
(dashed line)	Contact separating Lower Devonian and older rocks from Upper Devonian and younger rocks
(double line)	Paved road
(double dashed line)	Unpaved road

The energy resource potential for oil and gas in the entire study area is considered to be low. Although most current thinking suggests that the rock types and the thermal history of this area make oil and gas accumulations unlikely, it is also recognized that some current assumptions could be disproven by further work. Particularly, it is possible that some hydrocarbons may have accumulated in some of the younger rocks along the west edge of the study area.

INTRODUCTION

Location and Setting

At the request of the U.S. Bureau of Land Management (BLM), approximately 10,175 acres (15.9 square miles) that constitute the North Stansbury Mountains Wilderness Study Area were studied to appraise the mineral resources and assess the mineral resource potential. This area, which is referred to in this report as the study area, is in the northern part of the Stansbury Mountains (fig. 1), about 45 mi (miles) west of Salt Lake City, Utah. It is bounded on the west by Skull Valley and on the east by Tooele Valley. Elevations in these flanking valleys are between 4,200 and 4,300 ft (feet), and the maximum elevation within the study area is 8,885 ft. Several unpaved roads extend to the flanks of the area and provide access to it. A major route, Interstate Highway 80, passes 3 mi north of the study area boundary.

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 (USBM) and the U.S. Geological Survey (USGS). 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 USBM. 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), which also is shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

Investigations by the USBM included a review of published literature, unpublished USBM and BLM file data, and mining claim and land status records; a field investigation of mines, prospects, and mineralized areas; and an evaluation of analyses of 107 chip, grab, and select samples and 5 panned-concentrate samples (fig. 3). Samples from the area were analyzed by Bondar-Clegg, Inc., Lakewood, Colo. Gold was determined by fire assay plus atomic absorption; lead, zinc, copper, silver, and beryllium by atomic absorption; and mercury by cold-vapor atomic absorption. Limestone samples were analyzed by whole-rock methods. Complete analytical results 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

Rigby (1958) presented a detailed discussion of the geology of the Stansbury Mountains, including stratigraphy and structure. Subsequently, Rigby's stratigraphic work has been slightly modified and generalized by Sorensen (1982) for a mineral resource appraisal of the area immediately to the south of the study area. In order

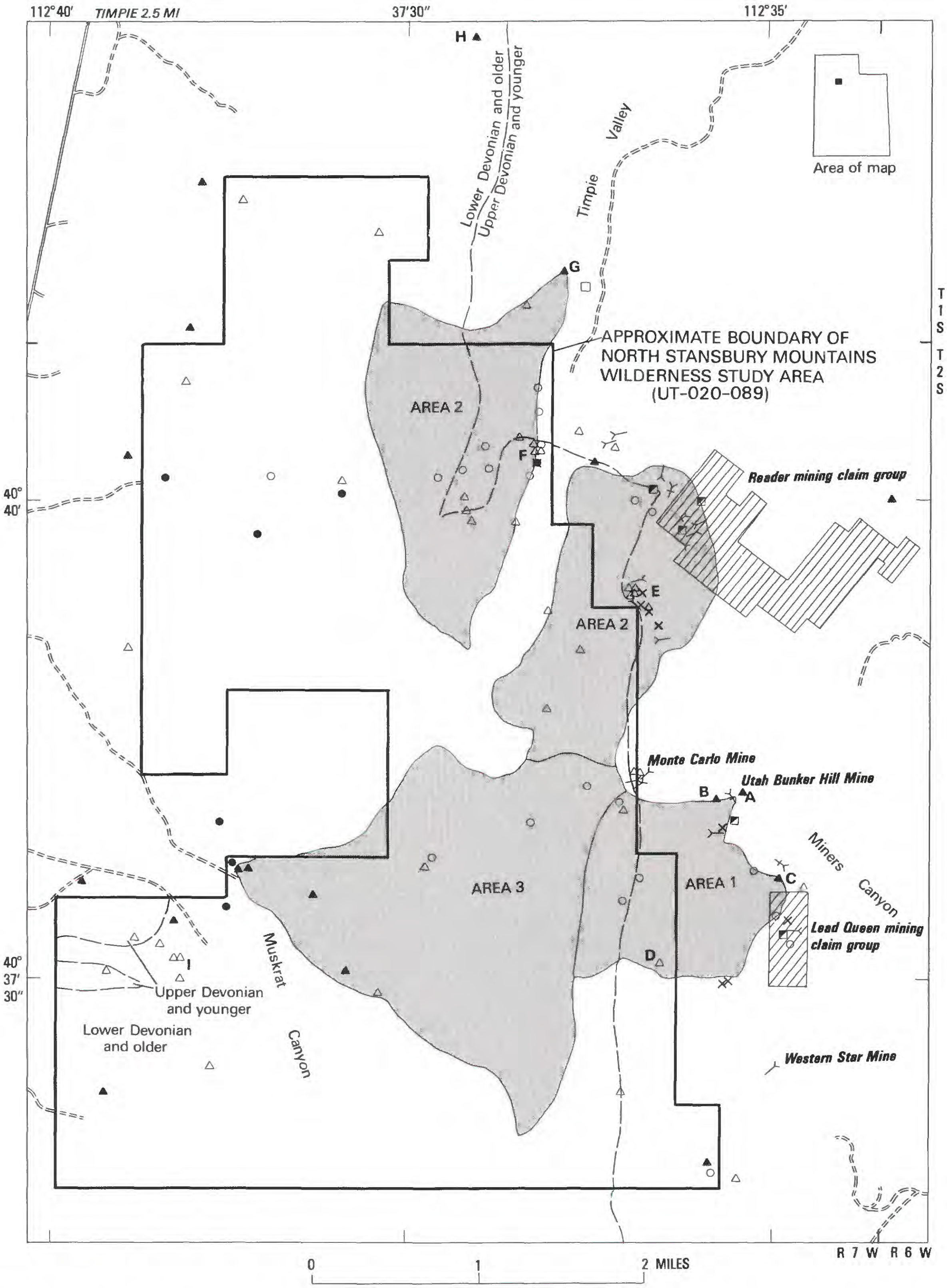


Figure 3 (above and facing page). Geochemical sampling localities, mines, prospects, mining claims, and areas represented by samples having anomalous metal concentrations in and near the North Stansbury Mountains Wilderness Study Area, Utah.

EXPLANATION

U.S. Geological Survey sampling localities:

▲ Panned concentrate and rock sample

□ Panned concentrate only

△ Rock sample only

U.S. Bureau of Mines sampling localities:

● Panned concentrate

○ Rock sample

D Locality discussed in text

Drainage areas represented by samples having anomalous metal concentrations

Unpatented mining claims

× Prospect pit

Adit

Inaccessible adit

Shaft

Contact separating Lower Devonian and older rocks from Upper Devonian and younger rocks

Paved road

Unpaved road

to provide continuity with Sorensen's work, his more generalized stratigraphy was used in this study. The USGS authors did additional field mapping in the area and compared their results with those of Rigby (1958). Where appropriate, Rigby's work was modified (Foose, in press). In addition, regional geochemical sampling and site-specific sampling, as described below, were conducted.

Geologic Setting

The Stansbury Mountains, including the study area, are within the Basin and Range structural province. Tooker (1983) has summarized the geology of this region. According to Tooker, Cambrian through Devonian carbonate and clastic sediments were deposited as part of a westward-thickening miogeocline. Late Devonian uplift interrupted this sedimentation and created an erosional unconformity. Upper Devonian clastic sediments deposited on this unconformity grade upward into a sequence of mostly shallow-water Mississippian through Permian sediments. Eastward-directed thrusting, resulting from the Mesozoic Sevier orogeny, deformed these rocks and created a series of imbricated thrust sheets. Mesozoic sediments occur in only a few of these sheets. Subsequent Tertiary igneous activity is represented by several small intrusions of intermediate composition that occur mostly in the central portion of the Stansbury Mountains (Davis, 1959). Finally, Cenozoic normal faulting has segmented these rocks to form north-trending mountain ranges that are characteristic of the Basin and Range province. The intervening valleys have been filled with young clastic sediments, largely derived from the adjacent mountains.

The young sediments filling Tooele Valley separate the study area from the mineral-rich Oquirrh Mountains, which lie approximately 20 mi to the east. These adjacent mountains contain the large Bingham mining district (fig. 1), which includes one of the world's largest porphyry copper deposits. Bingham has produced more copper than any other mine in the world and leads the state of Utah in gold production. Hydrothermal vein and replacement deposits within this district show a concentric zoning, from deposits rich in molybdenum and copper outward to deposits having predominantly lead, zinc, and silver (John, 1975). Some of these lead-zinc replacement deposits are also rich in mercury (Rubright and Hart, 1968). Other mineralized areas in the Oquirrh Mountains occur south of the Bingham district. These include the lead, silver, copper, zinc, and gold deposits in the Stockton and Ophir districts, and the disseminated gold and mercury of the Mercur deposit (fig. 1). Approximately 25 mi south of the Mercur deposit, in the East Tintic Mountains, are the vein and replacement deposits of the East Tintic mining district. These deposits range from copper-, gold-, silver-, lead-, and zinc-bearing fissures and veins, which occur mostly in the Cambrian Tintic Quartzite, to large lead and zinc replacement deposits that are concentrated in middle Cambrian carbonates. Tertiary felsic intrusions adjoin the ore zones in all of these districts (Morris and Lovering, 1979; Moore and McKee, 1983), although a direct genetic relationship is not certain in all cases.

Felsic intrusive rocks of the type associated with ore deposits in the Oquirrh and East Tintic Mountains are not exposed in the study area. However, a small monzonite porphyry occurs within a half mile of the southeast corner of the study area, and several other small felsic intrusions occur south of the study area (Rigby, 1958; Davis, 1959).

The general lack of felsic intrusive rocks in the northern part of the Stansbury Mountains may, in part, be due to its location north of the Cortez-Uinta structural axis. This roughly east-west-trending arch appears to be an important and long-lived structural feature in this region (Tooker, 1983). Movement along this axis, which passes just south of the Bingham district and trends through South Mountain (fig. 1), disrupted sedimentation in the Devonian and then, much later, apparently acted to localize intrusions and associated mineralization in the Tertiary. For example, the Park City, Alta-Cottonwood, and Bingham districts form an east-west trend coincident with this axis (Smith, 1975).

Tooker and Roberts (1971) suggest that this feature provided a structurally favorable zone of weakness along which magmas could intrude and localize mineral deposits.

Within the Stansbury Mountains, however, areas south of the study area, which lie on the Cortez-Uinta axis, also contain fewer felsic intrusive rocks than do the adjacent Oquirrh Mountains (Moore and Sorensen, 1979; Moore and McKee, 1983). Tooker and Roberts (1971) suggest that the Oquirrh and Stansbury Mountains are part of a westward-thickening sequence of stacked thrust sheets. Tooker (oral commun., 1987) speculates that the stack of thrust slices in the Stansbury Mountains, being thicker than in the Oquirrh Mountains, either inhibited emplacement of magmas or induced them to solidify at greater depths so that they have not been exposed. Regardless of the relative paucity of igneous rocks near the study area, it is apparent that the base- and precious-metal-rich veins and concentrations of mercury found along the eastern margin of the study area indicate that this part of the Stansbury Mountains has been affected by mineralization similar to that which has enriched the Oquirrh and East Tintic Mountains.

Acknowledgments

U.S. Geological Survey field work was done with the assistance of William Moore, Ricardo Lopez, and Jerry Gaccetta. U.S. Bureau of Mines personnel assisting in the field work were Patricia A. Corbetta and Russell A. Schreiner.

APPRAISAL OF IDENTIFIED RESOURCES

By Carl L. Almquist
U.S. Bureau of Mines

Mining Activity

The Free Coinage mining district, organized in 1895, apparently included the entire study area, but its boundaries are uncertain (Butler and others, 1920, p. 147, 149). Mining activity centered on lead-zinc deposits in Mississippian rocks along the east side of the Stansbury Mountains. Most of the district's production came from two mines: the Monte Carlo Mine, on the eastern boundary of the study area, and the Utah Bunker Hill Mine, one-half mile farther east (fig. 3). Recorded production from the district, from 1917 through 1948, totaled 449,244 pounds of lead, 5,400 pounds of zinc, 1,458 pounds of copper, 6,160 ounces of silver, and 5.17 ounces of gold from 1,053 tons of ore (U.S. Geological Survey, 1917–1923; U.S. Bureau of Mines, 1924–1948). Nearly 2,000 ft of underground workings were driven at the Lead Queen Mine in an unsuccessful effort to intersect the subsurface extension of a lead-zinc vein outcrop (Oliver Peasnall, Lead Queen Mine owner, oral commun., 1986). In the 1950's, mercury reportedly was produced from a deposit near the head of Timpie Valley (location E, fig. 3) and sold on the local market (Rigby, 1958, p. 125). As of January 1987, there were no mining claims in the study area.

At the time of the USBM's investigation, Genstar Cement and Lime Co., Grantsville, Utah, and Lonestar Industries Inc., Salt Lake City, Utah, were quarrying limestone and dolomite in the vicinity of processing facilities at Flux and Dolomite, 2–3 mi east of the study area (fig. 1). One of the quarried formations, the Mississippian Great Blue Limestone, crops out in the extreme southeast part of the study area (Rigby, 1958).

Sites Examined for This Study

Metallic mineral occurrences at the north end of the Stansbury Mountains are confined to moderately deformed, steeply dipping Mississippian limestones and dolomites. Faults and fissures along the contact between these rocks and Lower Devonian and older rocks were conduits for mineralizing solutions that deposited lead, zinc, copper, silver, mercury, and gold.

The most abundant mineral commodity in the area is lead. It occurs along with zinc, copper, silver, and traces of gold in irregular-shaped replacement deposits in some of the prospects and mines shown in figure 3. The ore consists of argentiferous galena, quartz, calcite, limonite, occasional pyrite and chalcopyrite, and lead and zinc carbonate alteration minerals. Host rocks are jasperized or silicified and commonly contain barren quartz and calcite stringers. Samples of lead-zinc vein material contained as much as 11.80 percent lead, 11.70 percent zinc, 0.36 percent copper, 2.99 ounces of silver per short ton, and 30 parts per billion gold (Almquist, 1987, table 2).

At the Monte Carlo Mine, which extends to the eastern boundary of the study area, underground workings consist of three adits driven at different levels to intersect a fissure-vein lead-zinc deposit exposed at the head of Miners Canyon. At the lowest accessible point in underground workings (Almquist, 1987, fig. 3), the vein strikes north and dips 65 degrees west. This underground point is close to the study area boundary and may be within it. Judging from the size and shape of the stope at this depth, the vein was an irregular podlike mass about 5–6 ft thick and 40–60 ft wide. Stoping extended above the haulage level, probably to the upper adit driven on the vein's surface exposure, and for an undetermined distance below. The vein, which reportedly contained 35–40 percent lead (Buranek, 1942, p. 4), was probably mined out between the upper and lower adits, a vertical distance of nearly 280 ft. Samples from the walls of the stope on the Monte Carlo vein contained as much as 1.41 ounces of silver per short ton, 8.10 percent lead, and 2.19 percent zinc (Almquist, 1987, fig. 3).

Near the head of Timpie Valley, mercury and low concentrations of gold were deposited in limestone breccia. The breccia is in a shear zone that strikes northerly and dips steeply east. Cinnabar is disseminated in quartz and calcite gangue. A select sample of mineralized limestone breccia contained more than 1,000 parts per million mercury and 75 parts per billion gold (Almquist, 1987, table 2).

In the early 1960's, the U.S. Bureau of Mines (unpublished data, 1961–1963) investigated reported occurrences of nonpegmatitic beryllium at several sites in the northern Stansbury Mountains, but none were found. Twelve samples collected during the present investigation were analyzed for beryllium but no significant concentrations were detected (Almquist, 1987, fig. 3 and table 2).

No mineralized areas were identified in the part of the study area west of the range crest. Gold was detected in a panned-concentrate sample collected by the USGS on the west side of the study area (see geochemistry results section later in this report), but none was detected in the five panned-concentrate samples collected by the USBM in the study area.

The only nonmetallic mineral commodity of interest is an outcrop of the Mississippian Great Blue Limestone, classified as an inferred subeconomic resource, in the extreme southeast corner of the study area. Limestone from this site is similar in quality to limestone from a nearby active quarry in the same formation (Almquist, 1987, plate 1, sample localities 101 and 112, respectively; table 1). Limestone from the quarry is used by Lone Star Industries, Inc., to produce raw material for cement (Bryce Tripp, staff geologist, Utah Geological and Mineral Survey, written commun., 1986). Limited outcrop at the exposure within the study area prevented measurements necessary for calculating deposit size, but according to Rigby's geologic map (1958, plate 1), the Great Blue Limestone underlies approximately 20 acres in the southeast corner of the study area.

Alluvial deposits in the study area, classified as inferred subeconomic resources, consist of poorly sorted material ranging in size from sand to boulders. These deposits, which occur in Muskrat Canyon and other canyons extending into the study area on the west side, represent a small fraction of the abundant supply of sand and gravel available in established pits and other more accessible sites along the flanks of the Stansbury Mountains.

As of August 1985, 4,400 acres of the study area were under lease for oil and gas (fig. 4), though no wells have been drilled in the study area and no producing fields are near the area.

Conclusions

Inferred subeconomic resources of limestone and sand and gravel are in the study area. The Mississippian Great Blue Limestone is exposed in the extreme southeast corner of the study area. Limestone at this

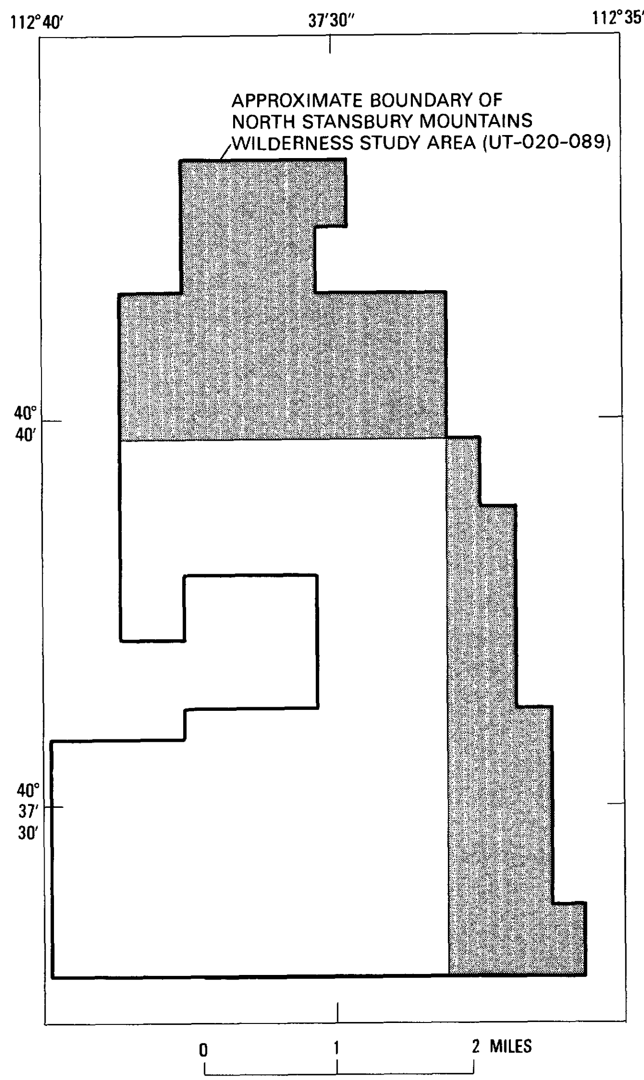


Figure 4. Lands under lease for oil and gas (shaded) in the North Stansbury Mountains Wilderness Study Area, Utah (Almquist, 1987).

locality is similar in quality to limestone being quarried 2 mi to the east, but it would not be utilized in favor of more accessible sources that are closer to processing facilities. Sand and gravel in Muskrat Valley and in other drainages are poorly sorted, have no unique qualities, and are not likely to be utilized.

Mississippian carbonate rocks in the north end of the Stansbury Mountains, less than 1 mi from the study area, host occurrences of lead, zinc, copper, silver, mercury, and low concentrations of gold. These Mississippian host rocks are exposed along the eastern boundary of the study area.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

By Michael P. Foose and Karen A. Duttweiler U.S. Geological Survey

Geology

Rocks within the study area may be divided into three groups. The first of these is Cambrian through Lower Devonian in age and consists of (1) a thick Cambrian quartzite (Tintic Quartzite), the base of which is not exposed, (2) overlying shales and sandstones (Ophir Group rocks), and (3) interlayered Cambrian through Lower Devonian limestones, shales, and dolomites. The thickness of this lower Paleozoic sequence is about 10,000 ft (Rigby, 1958; Tooker and Roberts, 1971; Sorensen, 1982). A major break, which may be either an unconformity or a thrust fault, separates these lower rocks from the second group, which consists locally of Upper Devonian conglomerate (Stansbury Formation) and overlying limestones and calcareous sandstones of Upper Devonian and Mississippian age. The third group of rocks is made up of younger surficial deposits and a few exposures of Tertiary basalt flows that locally cover parts of the area.

These rocks have been folded into two northeast-trending anticlines and an intervening syncline. The folds have an average trend of N. 11° E. and a plunge of 20° NE. Axial planar cleavages are locally well developed in the centers of folds, but otherwise are generally absent or weakly developed. Subsequent to folding, these rocks have been slightly disrupted by basin-and-range faulting.

The nature of the contact between the first sequence (Lower Devonian and older rocks) and the second sequence (Upper Devonian and younger rocks) is not clear. Rigby (1958) interprets this contact to be an unconformity, an interpretation that is consistent with this region's general geologic history. However, Tooker and Roberts (1971) suggest that this particular contact is a west-dipping thrust. Exposures in the study area were not sufficient to determine which of these interpretations is correct. However, several lines of evidence support Rigby's interpretation. First, the Stansbury Formation, which locally is immediately above this contact, varies widely in thickness and locally contains abundant and large clasts derived from underlying rocks. It therefore indicates a major erosional period. Second, observations made by W.J. Moore and M.L. Sorensen outside and to the north of the study area indicate that this contact is paraconformable and dips east. They found no evidence of a west-dipping thrust (Moore, written commun., 1985; Sorensen, oral commun., 1987). Third, the thrust hypothesis requires younger rocks to have been emplaced over older rocks along a thrust that cuts through a considerable stratigraphic thickness of lower plate rocks without regard to differences in lithology and at right angles to their strike (Rigby, 1958; Foose, in press). Such stratigraphic and crosscutting relations are not typical of thrust systems.

Although this contact is probably not a west-dipping thrust, rocks near it do show evidence of shearing. Specifically, rocks adjacent to it are commonly brecciated, veined, and silicified. These features may have developed as a result of differential movement along the angular unconformity during folding and subsequent introduction of hydrothermal fluids.

This contact between the older and younger sequences of rocks clearly exerted an important control in localizing mineralization. The Utah Bunker Hill and Monte Carlo Mines and the mercury deposit near the head of Timpie Valley (location E, fig. 3) are all situated near this contact. Anomalous metal values have been determined from rocks, stream-sediments, and panned concentrates collected elsewhere along or near this contact. The distribution of mineralized areas along this contact indicates a laterally extensive zone along which hydrothermal solutions moved.

Geochemistry

Methods

During the summer of 1986, the USGS conducted a reconnaissance geochemical survey of the North Stansbury Mountains Wilderness Study Area. Minus-30-mesh (<0.6-mm) stream-sediment samples, nonmagnetic heavy-mineral concentrates derived from the stream-sediment samples, and rock samples were collected. Stream sediments were useful because they represent a composite of rock and soil exposed in the drainage basin upstream from the sample site; since minus-30-mesh sediments are coarse, they contain relatively little of the very fine grained wind-borne material, which commonly contaminates stream-sediment samples in arid regions, such as the study area. The nonmagnetic fraction of heavy-mineral concentrates is useful in locating mineralized areas because it may contain ore and ore-related minerals, and the selective concentration of these heavy minerals permits determination of some elements that are not easily detected in bulk stream-sediment samples.

Altogether, 21 stream-sediment and concentrate samples and 69 rock samples were collected (fig. 3). Rock samples were taken from loose pieces along stream courses, from outcrops, and from prospects and mines. Analytical data, sample localities, and descriptions of the sampling and analytical techniques are given in Adrian and others (1989) and Foose (in press).

Results and Interpretation

Three areas having anomalous metal concentrations (areas 1, 2, and 3 in fig. 3) were delineated by data from stream sediments and nonmagnetic heavy-mineral concentrates. Area 1 straddles the southeast border of the study area west of Miners Canyon; area 2 consists of two drainages near the head of Timpie Valley that extend into the northeast part of the study area; and area 3 includes much of the south-central part of the study area.

Area 1 includes the Utah Bunker Hill Mine and is near the Monte Carlo Mine. Stream-sediment samples were collected both downstream and upstream of the Utah Bunker Hill Mine (locations A and B respectively, fig. 3) and from a small tributary which joins Miners Canyon downstream from the mine (location C). These minus-30-mesh stream-sediment samples contain high concentrations of zinc (100 parts per million, or ppm), cadmium (1.5–1.6 ppm), and arsenic (23–27 ppm). The nonmagnetic heavy-mineral-concentrate samples contain trace amounts of galena and corresponding anomalous concentrations of lead (500–3,000 ppm) and also have high amounts of zinc (700 ppm) and barium (2,000 ppm).

Mineralized and altered rock samples from the mines and nearby areas have anomalous values ranging up to 16,000 ppm for zinc, 50 ppm for cadmium, more than 20,000 ppm for lead, and 150 ppm for silver. Some rocks also show high concentrations of copper, bismuth, arsenic, and antimony. Outside of this area, along strike with the Lower Devonian-Upper Devonian contact and to the south (location D, fig. 3), silicified Mississippian limestone was found to contain detectable (0.7 ppm) silver.

Stream sediments and heavy-mineral concentrates from drainages near the head of Timpie Valley (area 2) also have high values of lead, silver, zinc, and cadmium. The minus-30-mesh stream sediments contain as much as 50 ppm lead, 2 ppm silver, 100 ppm zinc, and 2.2 ppm cadmium. Corresponding heavy-mineral-concentrate samples contain 500 ppm lead and 5 ppm silver.

Mineralized and altered dolomite collected from a small prospect pit in area 2 (location E, fig. 3), which lies within the mineralized area from which some mercury has been produced (Rigby, 1958), contains up to 7,000 ppm lead, 30 ppm silver, 10,000 ppm zinc, 22 ppm cadmium, 18 ppm antimony, 360 ppm arsenic, and 4 ppm bismuth. One sample of dolomite with quartz veins contains 300 ppm copper. High concentrations of these elements were also found in a small prospect pit 1 mi to the northwest (location F) and in loose pieces of rock from two small tributaries draining into Timpie Valley from the west about 2 mi and 3½ mi north of the mercury showing (locations G and H respectively, fig. 3).

The geochemical signatures of the samples from areas 1 and 2 are similar. The location of these areas along the contact between older and younger Paleozoic rocks indicates that this contact is a laterally extensive zone along which hydrothermal fluids moved and in which minerals were locally deposited.

Area 3, northeast of Muskrat Canyon, is distinguished by stream-sediment and heavy-mineral-concentrate samples that have a geochemical suite consisting of gold, silver, bismuth, antimony, arsenic, copper, zinc, and lead. One nonmagnetic heavy-mineral concentrate from this area contains 20 ppm gold, 7 ppm silver, 70 ppm bismuth, 1,500 ppm antimony, 500 ppm copper, and more than 50,000 ppm lead. These high values were confirmed with follow-up sampling. Native gold, visible with a binocular microscope, was observed in concentrate samples from area 3. Although the anomalous values of silver, bismuth, and antimony in these samples are probably related to the gold, some of the lead (and possibly antimony) is clearly due to lead shot fragments, which were observed as a contaminant. Gold was not detected in the minus-30-mesh sediment samples at the lower limit of detection of 0.1 ppm (Adrian and others, 1989).

In area 3, loose fragments of silicified and limonitically altered limestone have high concentrations of many elements, including 340 ppm arsenic, 470 ppm zinc, 10 ppm cadmium, and 150 ppm copper, with minor amounts of lead, antimony, and bismuth. A sample from a silicified fault zone near this area (location I) contained anomalous amounts of silver (10 ppm), lead (1000 ppm), and zinc (500 ppm). This sample is important because it is geochemically similar to the mineralized samples from areas 1 and 2 collected near the contact of Lower Devonian and older rocks with Upper Devonian and younger rocks. This sample, however, is from a fault that separates Cambrian limestone and Ordovician shales, and indicates that structures other than the Lower Devonian-Upper Devonian contact may be mineralized within the study area.

Geophysics

Aerial Radiometric Survey

Aerial gamma-ray spectroscopy provides estimates of near-surface (0 to 20 inches depth) concentrations of potassium, uranium, and thorium. Because the presence of uranium and thorium are estimated from measurements of their daughter products, their abundances are listed as "equivalent" concentrations. The data thus provide a partial geochemical representation of surface material within the area of the survey. Surveys in the Stansbury Mountains were flown using a 3-mi flight-line spacing. Reported results (J. Duvall, written commun., 1987) show a low to moderate overall concentration of radioactivity in the study area, indicative of concentrations ranging from 0.8 to 1.6 percent potassium, 1.0 to 2.5 ppm equivalent uranium, and 2 to 6 ppm equivalent thorium. No gamma-ray anomalies were observed within or near the study area.

Aeromagnetic Survey

Aeromagnetic surveys flown along east-west-trending flight lines using a 3-mi spacing and along north-south-trending flight lines using a 1-mi spacing show no anomalous patterns within the study area (D.L. Campbell, written commun., 1987). Although broadly spaced, these data should be sufficient to locate a moderate size intrusion, if the intrusion contains magnetic minerals. Intrusions having prominent magnetic signatures occur at Bingham Canyon and other mineralized areas in the adjacent Oquirrh Mountains (fig. 1), and in the Tintic-Deep Creek belt (about 40 mi southeast of the study area). The absence of pronounced magnetic anomalies beneath this part of the North Stansbury Mountains indicates that similar large intrusions do not occur here.

Regional Gravity Survey

A regional gravity survey that includes the study area shows a small gravity high centered near Flux, northeast of the study area (fig. 1). The survey also shows a small northwest-trending gravity low extending into the southeast corner of the study area. However, gravity stations in this area are so sparse that this feature is not well controlled. In general, the gravity data lack any well-defined anomalies within or near the study area (D.L. Campbell, written commun., 1987).

Mineral and Energy Resources

Lead, Zinc, Silver, Gold, and Mercury in Vein and Replacement Deposits

Good geochemical evidence shows that parts of the study area have been mineralized. This mineral enrichment is most clearly evident at the mines and prospects, most of which are outside but close to the eastern margin of the study area (fig. 3). However, a few of these prospects do occur within the study area, and geochemical anomalies similar to those associated with the mines and prospects are also found in the study area.

The mines, prospects, and geochemical anomalies are generally on or near the contact separating Lower Devonian and older rocks from Upper Devonian and younger rocks. This contact—most likely an unconformity—has clearly acted as a favorable pathway along which solutions moved. However, the mineralization in the south-central part of the study area (area 3; fig. 3) is not near this contact. Particularly, the mineralized sample collected from location I (fig. 3) indicates that shears and fractures may also have provided effective conduits along which mineralizing solutions may have moved. Therefore, mineralization was not necessarily confined to areas near this contact.

Regionally, the study area lies close to the Oquirrh Mountains, which are noted for several large, important base- and precious-metal deposits. The large porphyry copper deposit at Bingham Canyon is associated with vein and replacement deposits consisting of copper, lead, and zinc. These deposits typically show a geochemical zoning in which copper-rich deposits grade outward to those rich in lead and zinc. Concentrations of silver and gold may occur in these deposits, and small mercury deposits accompany some of the peripheral lead-zinc occurrences (Rubright and Hart, 1968).

Vein and replacement deposits also occur in the East Tintic Mountains, about 55 miles southeast of the study area. These deposits show a zoning from ores rich in copper and gold, outward through those richer in silver and lead, to deposits containing abundant zinc. Importantly, almost all the gold-rich ores occur as veins within the Tintic Quartzite, while the lead- and zinc-rich deposits form replacement structures in the overlying carbonates (Morris and Lovering, 1979).

The association of lead, zinc, gold, silver, and mercury in some deposits in the Oquirrh and East Tintic Mountains is similar to the geochemical association found in this study and strongly indicates a potential for similar types of vein and replacement deposits in the study area. As is common in the East Tintic district, parts of the study area underlain by the Tintic Quartzite may contain precious-metal-rich veins that are related to the lead-zinc mineralization in the overlying carbonates.

Perhaps the visible gold observed in concentrate samples from the south-central part of the area (area 3) is derived from veins of this type.

The mineral deposits in the Oquirrh and East Tintic Mountains are adjacent to Tertiary intrusions. Although such intrusions are not observed in the study area, and there is no aeromagnetic evidence for them at depth, some small felsic intrusions do occur just outside the southeast and south margins of the study area. A comparison with the Oquirrh Mountains suggests that intrusions would be more likely to occur south of the study area, closer to the axis of the Cortez-Uinta uplift.

The mines, prospects, and geochemical anomalies within the study area clearly indicate the invasion of hydrothermal and mineral-bearing fluids. The presence of the small intrusions outside the study area suggests that the source for the mineralizing fluids may have been from the south or southeast. This source direction accords well with the excellent evidence for hydrothermal mineralization within the southern and eastern parts of the study area. The geochemistry of known deposits and geochemical anomalies in these areas is similar to that of vein and replacement deposits in the Oquirrh and East Tintic Mountains. The southern and eastern parts of the study area are, therefore, assigned a moderate potential for resources of lead, zinc, silver, gold, and mercury in vein and replacement deposits, at certainty level C (fig. 2).

The remaining portion of the study area is underlain by carbonates and shales, which may be favorable host rocks for replacement and vein deposits. Fractures and faults in this area may be mineralized, although we have found no specific evidence that they are. This area is thus considered to have a low potential for lead, zinc, silver, gold, and mercury resources in vein and replacement deposits, with a certainty level of B.

Gold in Sediment-Hosted, Disseminated Deposits

The Mercur deposit, in the southern part of the adjacent Oquirrh Mountains, is a strata-bound, sediment-hosted, disseminated gold deposit formed by hydrothermal replacement of the host Upper Mississippian Great Blue Limestone (Kornze, 1987; Jewell and Parry, 1987). The solutions that formed this deposit were rich in gold, silver, arsenic, antimony, and mercury (Lenzi, 1973). At Mercur, the gold occurs as submicroscopic particles disseminated in discontinuous stratabound orebodies.

The Great Blue Limestone crops out along the southeastern margin of the study area. Anomalous values of silver, arsenic, antimony, and bismuth are found in the south-central and eastern parts of the study area (areas 1, 2, and 3; fig. 3). Mercury analyses were not obtained for samples collected inside the study area, but the mercury occurrence in area 2 (fig. 3) indicates that it is concentrated locally. A sample of mercury-rich breccia from this area also contained 75 parts per billion gold.

High gold values are associated with visible gold in panned concentrates from one drainage in the south-central part of the study area (area 3). While the occurrence of gold is significant, it may not be direct evidence for disseminated gold deposits, because gold in deposits of this type is generally so fine grained that it is not visible even under most microscopes.

In an area that contained disseminated gold deposits, fine-grained sediments would probably have the highest gold concentrations. Gold was not detected in any of the stream-sediment samples, but the analytical method used in this study has a lower limit of detection for gold in the stream-sediment samples of 0.1 ppm. Significant concentrations of less than 0.1 ppm would, therefore, not be detected. For this reason, the gold data are inconclusive and other indicator elements must be used in evaluating the potential for disseminated gold deposits.

The strong association of arsenic, antimony, and, locally, mercury in areas underlain by carbonate rocks and shale could be evidence for occurrences of sediment-hosted gold. Therefore, based on the geochemical association and distribution of rock units, the southern and eastern parts of the study area, except where underlain by Cambrian Tintic Quartzite, are assigned a moderate potential for undiscovered sediment-hosted, disseminated gold resources, at a certainty level of B (fig. 2). The other parts of the study area are assigned a low potential for resources of this type, with a certainty level of B.

Geothermal Resources

Warm springs occur in both Skull and Tooele Valleys at the north end of the Stansbury Mountains. The southwest part of the study area extends into Skull Valley and thus probably contains thermal waters. However, no geothermal resources have been identified in this area (Utah Geological and Mineralogical Survey, 1980). The potential for geothermal resources in this area is rated as moderate with a certainty level of B.

Oil and Gas

The potential for oil and gas resources in the study area is considered to be low, but the level of certainty, level B, is also low. Most current thinking suggests that the absence of recognized good source rocks, the fragmentation due to basin and range faulting, and the proximity to young intrusive rocks make rocks in this area poor prospects for oil and gas. Molenaar and Sandberg

(1983, p. K12), for example, rated the petroleum potential of the study area as "low." They cite fossil evidence (thermal alteration of conodonts) that indicates Paleozoic source rocks were subjected to temperatures that would generate hydrocarbons ranging from mature to overmature. However, these factors may not preclude the accumulation of hydrocarbons in some of the younger rocks along the west edge of the study area. It is also quite possible that further work will show some of these assumptions to be invalid.

REFERENCES CITED

Adrian, B.M., Duttweiler, K.A., Gaccetta, J.D., and Fey, D.L., 1989, Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the North Stansbury Mountains Wilderness Study Area, Utah: U.S. Geological Survey Open-File Report 88–520.

Almquist, C.L., 1987, Mineral investigation of a part of the North Stansbury Mountains Wilderness Study Area (UT–020–089), Tooele County, Utah: U.S. Bureau of Mines Open-File Report MLA 49–87, 24 p., 1 pl.

Buranek, A.M., 1942, Initial report on the Lead Ore mine, Tooele County, Utah: Utah Department of Publicity and Industrial Development Circular 9, 5 p.

Butler, B.S., Loughlin, G.F., Heikes, V.C., and others, 1920, The ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Davis, B.L., 1959, Petrology and petrography of the igneous rocks of the Stansbury Mountains, Tooele County, Utah: Brigham Young University Research Studies Geology Series, v. 6, no. 2, 56 p.

Foose, Michael P., in press, Geologic map of the North Stansbury Mountains Wilderness Study Area, Tooele County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–2061.

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

Jewell, P.W., and Parry, W.T., 1987, Geology and hydrothermal alteration of the Mercur gold deposit, Utah: Economic Geology, v. 82, p. 1958–1966.

John, E.C., 1975, Mineral zones of the Bingham district, *in* Bray, R.E., and Wilson, J.C., eds., Guidebook to the Bingham mining district; Society of Economic Geologists Field Conference, Bingham Canyon, Utah, October 23, 1975: Lancaster, Pa., Economic Geology Publishing Co., p. 59–72.

Kornze, L.D., 1987, Geology of the Mercur gold mine, *in* Johnson, J.L., ed., Bulk mineable precious metal deposits of the Western United States: Geological Society of Nevada Guidebook, 1987 Symposium, p. 381–389.

Lenzi, G.W., 1973, Geochemical reconnaissance at Mercur, Utah: Utah Geological and Mineralogical Survey Special Studies, no. 43, 16 p.

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 A–P, p. K1–K14.

Moore, W.J., and McKee, E.H., 1983, Phanerozoic magmatism and mineralization in the Tooele 1° x 2° quadrangle, Utah, *in* Miller, D.M., Todd, V.R., and Howard, K.A., eds., Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 183–190.

Moore, W.J., and Sorensen, M.L., 1979, Geologic map of the Tooele 1° by 2° quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I–1132, scale 1:250,000.

Morris, H.T., and Lovering, T.S., 1979, General geology and mines of the East Tintic mining district, Utah and Juab Counties, Utah: U.S. Geological Survey Professional Paper 1024, 203 p.

Rigby, J.K., 1958, Geology of the Stansbury Mountains, eastern Tooele County, Utah: Utah Geological Society Guidebook to the Geology of Utah, no. 13, p. 1–133.

Rubright, R.D., and Hart, O.J., 1968, Non-porphyry ores of the Bingham district, Utah, *in* Ridge, J.D., ed., Ore deposits of the United States, 1933–1967 (Graton-Sales Volume): New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, v. 1, p. 886–907.

Smith, W.H., 1975, General structural geology of the Bingham mining district, *in* Bray, R.E., and Wilson, J.C., eds., Guidebook to the Bingham mining district; Society of Economic Geologists Field Conference, Bingham Canyon, Utah, October 23, 1975: Lancaster, Pa., Economic Geology Publishing Co., p. 41–48.

Sorensen, M.L., 1982, Geologic map of the Stansbury Roadless Area, Tooele County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–1353–A, scale 1:62,500.

Tooker, E.W., 1983, Variations in structural style and correlation of thrust plates in the Sevier foreland thrust belt, Great Salt Lake area, Utah, *in* Miller, D.M., Todd, V.R., and Howard, K.A., eds., Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 61–73.

Tooker, E.W., and Roberts, R.J., 1971, Structures related to thrust faults in the Stansbury Mountains, Utah, *in* Geological Survey research 1971: U.S. Geological Survey Professional Paper 750–B, p. B1–B12.

U.S. Bureau of Mines, 1924–1931, Mineral resources of the United States [annual volumes for the years indicated].

______ 1932–1948, Minerals yearbook [annual volumes for the years indicated].

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, 1917–1923, Mineral resources of the United States [annual volumes for the years indicated].

Utah Geological and Mineralogical Survey, 1980, Geothermal resources of Utah, 1980: scale 1:500,000.

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.

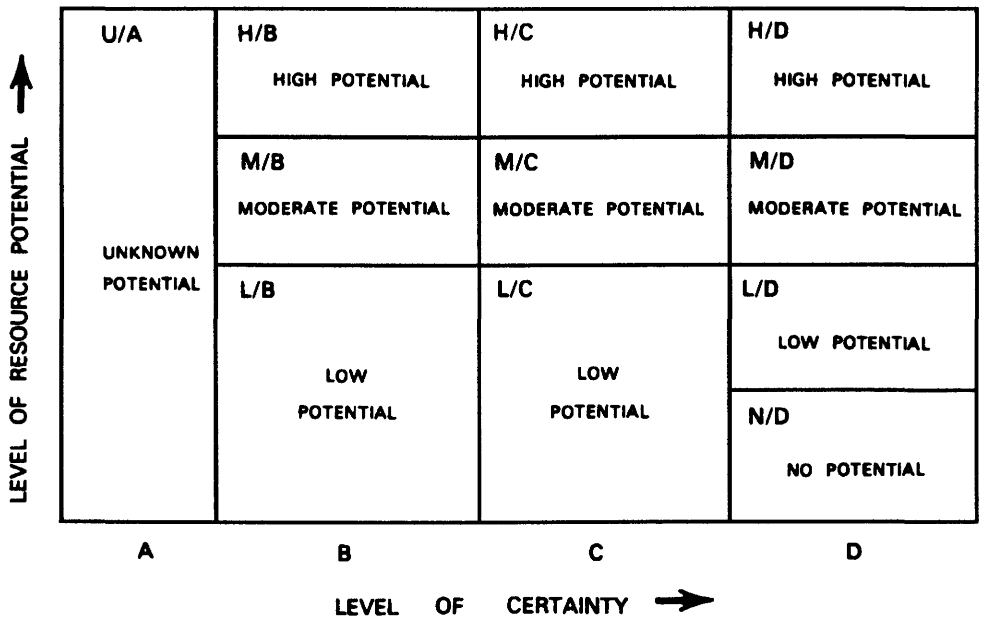
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application 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: 1989-673-047/86092

SELECTED SERIES OF U.S. GEOLOGICAL SURVEY PUBLICATIONS

Periodicals

Earthquakes & Volcanoes (issued bimonthly).
Preliminary Determination of Epicenters (issued monthly).

Technical Books and Reports

Professional Papers are mainly comprehensive scientific reports of wide and lasting interest and importance to professional scientists and engineers. Included are reports on the results of resource studies and of topographic, hydrologic, and geologic investigations. They also include collections of related papers addressing different aspects of a single scientific topic.

Bulletins contain significant data and interpretations that are of lasting scientific interest but are generally more limited in scope or geographic coverage than Professional Papers. They include the results of resource studies and of geologic and topographic investigations; as well as collections of short papers related to a specific topic.

Water-Supply Papers are comprehensive reports that present significant interpretive results of hydrologic investigations of wide interest to professional geologists, hydrologists, and engineers. The series covers investigations in all phases of hydrology, including hydrogeology, availability of water, quality of water, and use of water.

Circulars present administrative information or important scientific information of wide popular interest in a format designed for distribution at no cost to the public. Information is usually of short-term interest.

Water-Resources Investigations Reports are papers of an interpretive nature made available to the public outside the formal USGS publications series. Copies are reproduced on request unlike formal USGS publications, and they are also available for public inspection at depositories indicated in USGS catalogs.

Open-File Reports include unpublished manuscript reports, maps, and other material that are made available for public consultation at depositories. They are a nonpermanent form of publication that may be cited in other publications as sources of information.

Maps

Geologic Quadrangle Maps are multicolor geologic maps on topographic bases in 7 1/2- or 15-minute quadrangle formats (scales mainly 1:24,000 or 1:62,500) showing bedrock, surficial, or engineering geology. Maps generally include brief texts; some maps include structure and columnar sections only.

Geophysical Investigations Maps are on topographic or planimetric bases at various scales; they show results of surveys using geophysical techniques, such as gravity, magnetic, seismic, or radioactivity, which reflect subsurface structures that are of economic or geologic significance. Many maps include correlations with the geology.

Miscellaneous Investigations Series Maps are on planimetric or topographic bases of regular and irregular areas at various scales; they present a wide variety of format and subject matter. The series also includes 7 1/2-minute quadrangle photogeologic maps on planimetric bases which show geology as interpreted from aerial photographs. Series also includes maps of Mars and the Moon.

Coal Investigations Maps are geologic maps on topographic or planimetric bases at various scales showing bedrock or surficial geology, stratigraphy, and structural relations in certain coal-resource areas.

Oil and Gas Investigations Charts show stratigraphic information for certain oil and gas fields and other areas having petroleum potential.

Miscellaneous Field Studies Maps are multicolor or black-and-white maps on topographic or planimetric bases on quadrangle or irregular areas at various scales. Pre-1971 maps show bedrock geology in relation to specific mining or mineral-deposit problems; post-1971 maps are primarily black-and-white maps on various subjects such as environmental studies or wilderness mineral investigations.

Hydrologic Investigations Atlases are multicolored or black-and-white maps on topographic or planimetric bases presenting a wide range of geohydrologic data of both regular and irregular areas; principal scale is 1:24,000 and regional studies are at 1:250,000 scale or smaller.

Catalogs

Permanent catalogs, as well as some others, giving comprehensive listings of U.S. Geological Survey publications are available under the conditions indicated below from the U.S. Geological Survey, Books and Open-File Reports Section, Federal Center, Box 25425, Denver, CO 80225. (See latest Price and Availability List.)

"Publications of the Geological Survey, 1879-1961" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"Publications of the Geological Survey, 1962-1970" may be purchased by mail and over the counter in paperback book form and as a set of microfiche.

"Publications of the U.S. Geological Survey, 1971-1981" may be purchased by mail and over the counter in paperback book form (two volumes, publications listing and index) and as a set of microfiche.

Supplements for 1982, 1983, 1984, 1985, 1986, and for subsequent years since the last permanent catalog may be purchased by mail and over the counter in paperback book form.

State catalogs, "List of U.S. Geological Survey Geologic and Water-Supply Reports and Maps For (State)," may be purchased by mail and over the counter in paperback booklet form only

"Price and Availability List of U.S. Geological Survey Publications," issued annually, is available free of charge in paperback booklet form only.

Selected copies of a monthly catalog "New Publications of the U.S. Geological Survey" available free of charge by mail or may be obtained over the counter in paperback booklet form only. Those wishing a free subscription to the monthly catalog "New Publications of the U.S. Geological Survey" should write to the U.S. Geological Survey, 582 National Center, Reston, VA 22092.

Note.--Prices of Government publications listed in older catalogs, announcements, and publications may be incorrect. Therefore, the prices charged may differ from the prices in catalogs, announcements, and publications.

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849