U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Mineral Resources and Mineral Resource Potential of the Kelso Dunes Wilderness Study Area (CDCA-250), San Bernardino County, California

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral values potential. 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 Kelso Dunes Wilderness Study Area (CDCA-250), California Desert Conservation Area, San Bernardino County, California.

SUMMARY

Geologic, geochemical, and geophysical evidence, together with a review of historical and modern mining and prospecting activities, indicates that the Kelso Dunes Wilderness Study Area contains an estimated 16 billion tons of marginal glass and feldspar sand reserves, with byproduct magnetite and gold, at 1982 prices and technology. There is a low to moderate potential for undiscovered hydrothermal gold-copper resources in granitic rocks underlying the southeast corner of the study area. No potential is recognized for other resources in the Kelso Dunes Wilderness Study Area.

No mines were active in the wilderness study area in 1982, and the only mineral production from the area occurred in the early 1970's when approximately 1,000 tons of magnetite were produced from dune sand by a pilot plant. Several active claims and leases in the study area are held for gold, iron, glass sand, and oil and gas.

INTRODUCTION

The Kelso Dunes Wilderness Study Area lies in a remote part of the eastern Mojave Desert, southeastern California, approximately 60 mi west of the Colorado River (fig. 1). It encompasses approximately 52,000 acres in the central part of San Bernardino County, Calif. A vegetated sand blanket and active sand dunes as much as 1,200 ft high lie within a topographic basin rimmed by mountains. Elevations range from approximately 1,500 to 3,000 ft, and vegetation is sparse shrub, grass, and wildflower. The paved Kel-Baker Road extends along part of the east boundary of the area and connects with Interstate Highway 15 at Baker, Calif. The Union Pacific railroad line runs along the north boundary. A network of U.S. Bureau of Land Management powerline and gasline maintenance routes parallels the south boundary. The settlement of Kelso, at the northeast corner of the area, is primarily a maintenance way station for the railroad. There are no concessions or commercial businesses in Kelso.

GEOLOGY
Geomorphology

The Kelso Dunes are clustered in a topographic basin rimmed by the Granite, Providence, Old Dad, and Kelso Mountains and, 6 mi to the east, the Bristol Mountains. The prominent and picturesque sand dunes are the tallest and most extensive dune field in the Mojave Desert (Thompson, 1929) and among the tallest in the United States (Glazner and Bilodeau, 1980). They are located at the southeastern extent of the Devils Playground on the northern

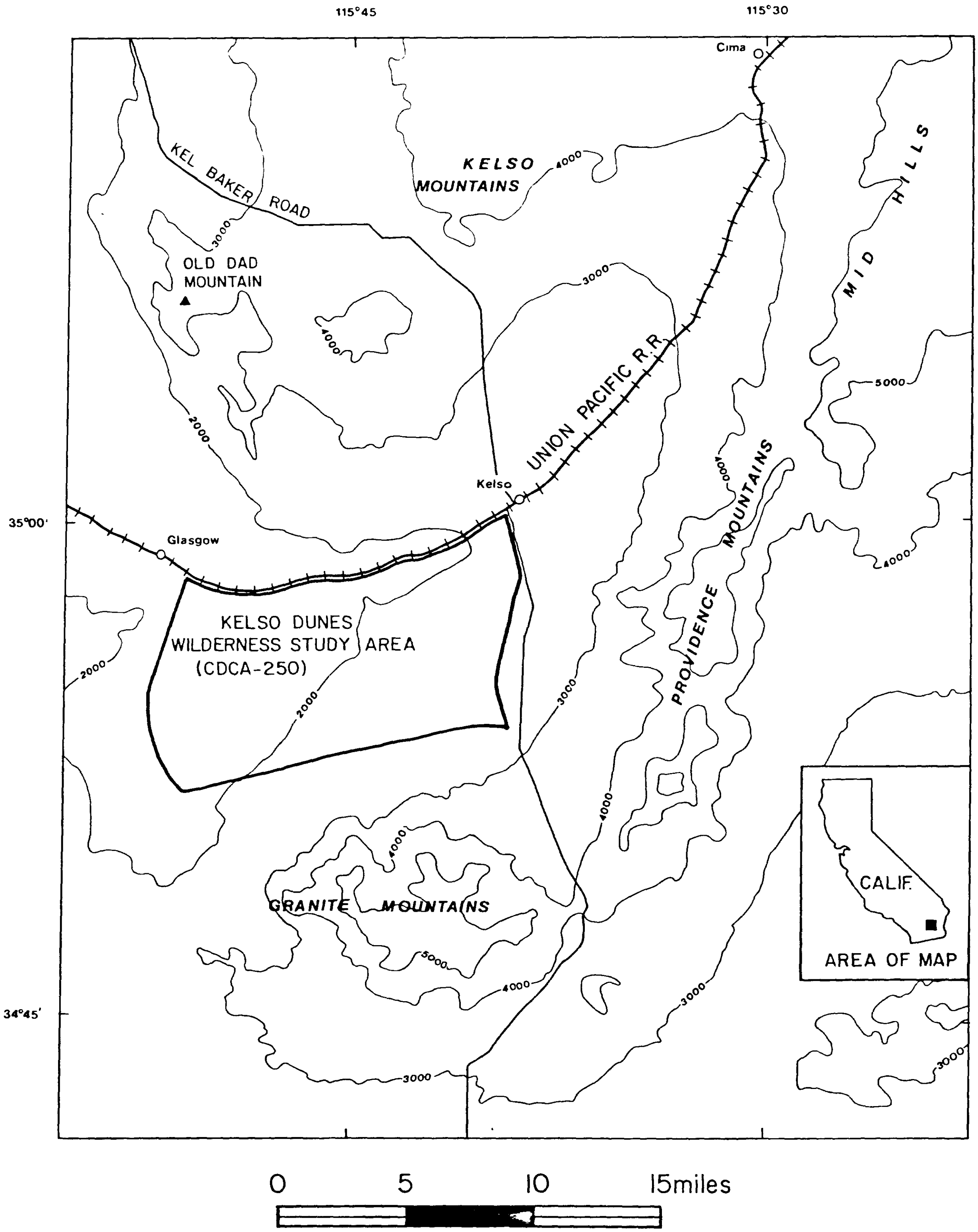


Figure 1.--Index map showing the location of the Kelso Dunes Wilderness Study Area, San Bernardino County, California.

piedmont of the Granite Mountains. The tallest dunes are found as three discontinuous east-northeast-trending ridges, increasing in height to the south where peaks are approximately 500 ft above the surrounding dunes. A complex topography of peaks, hollows, and low ridges on and around these three ridges contains the only active dunes. These active dunes are surrounded by low rounded dunes whose form has been largely stabilized by plant cover. Figure 2 is a geologic map showing the distribution of the sand units. Cottonwood Wash and Winston Wash cut obliquely across the dune field from south to north and Kelso Wash and Devils Playground Wash form portions of the north and south boundaries of the study area. These ephemeral stream channels, particularly Cottonwood Wash, provide exposures of the lower portion of the sand dunes as well as of the uppermost deposits underlying them.

Several bedrock knobs of granite rock are found above the dunes near Cottonwood Wash on the southeast side of the dunes; however, the bedrock is deeper than 882 ft at Kelso (Thompson, 1929).

Kelso Dunes have been studied extensively by Sharp (1966, 1978, 1982) and also by H. T. U. Smith (1967), Anders (1974), and Dean (unpub. data, 1978).

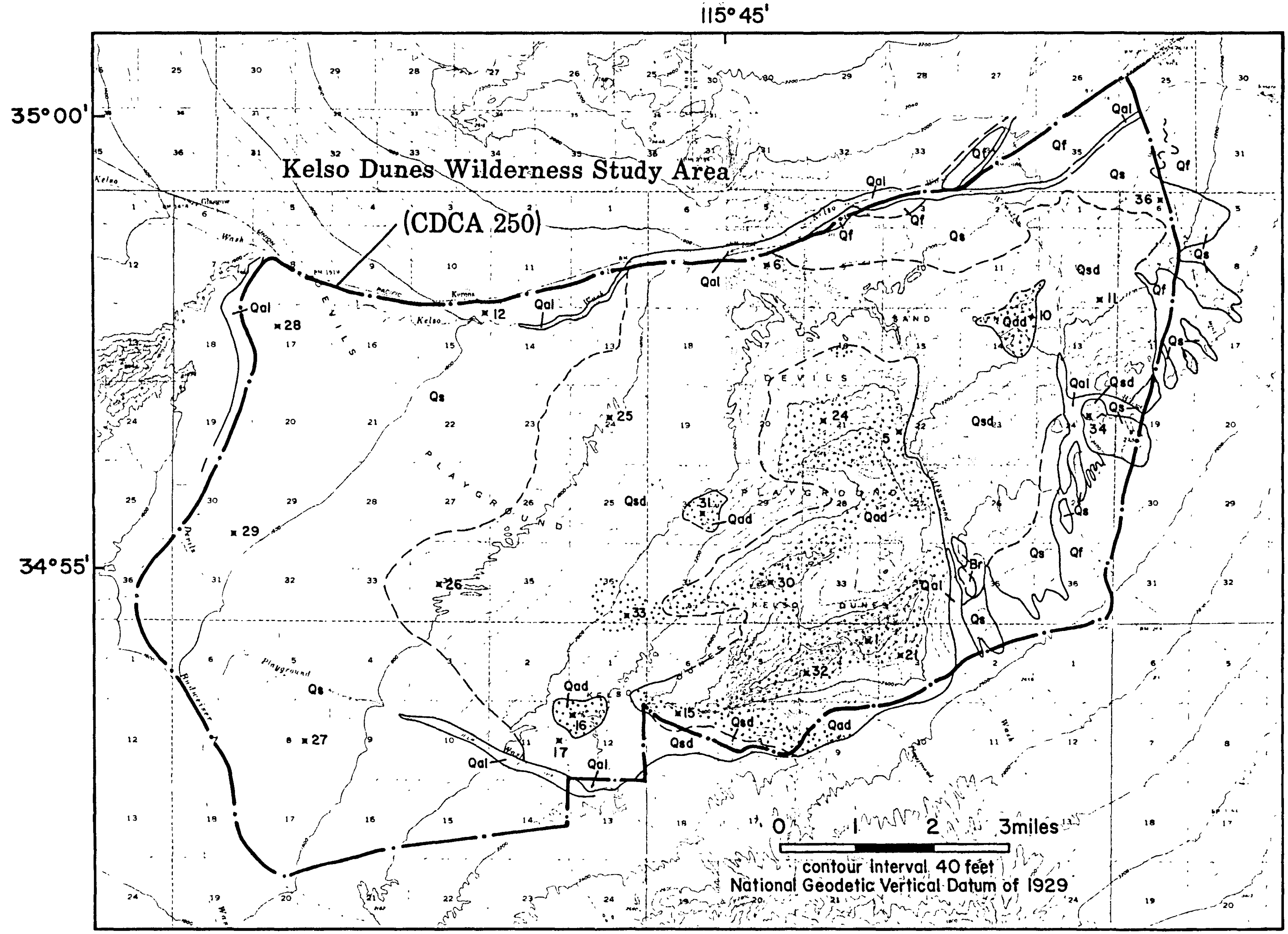
Geologic Setting

The Kelso Dunes Wilderness Study Area is located in a broad valley formed as a graben. The mountains are characteristically bound by vertically displaced high-angle faults typical of the Basin and Range Province. The mountains are composed of a multitude of rock types including granite, diorite, limestone, andesite, rhyolite, quartzite, shale, and mafic-rich metamorphic rock. Base- and precious- metal deposits are present in the mountains east of the study area.

The sand of the Kelso Dunes overlies gently sloping alluvial deposits that extend north from the Granite Mountains and northwest from the southern Providence Mountains. A substantial part of the Granite Mountains directly south of the dune field is composed of mafic-rich metamorphic rocks. Dissected and poorly sorted alluvial fan and mudflow deposits from those mountains are found immediately south of the dunes across Devils Playground Wash.

Stratigraphy

The stratigraphy of the Kelso Dunes study area is poorly exposed. Perhaps the best exposures are found along Cottonwood Wash, a north flowing drainage in the eastern part of the study area. Here approximately 30 ft of alternating sand, silt, and clay beds are exposed in the bank of the wash. Much of the sand displays cut-and-fill structure and is probably of fluvial origin. The clay beds may be pond deposits. As much as 10 ft of section is exposed in the banks of Kelso Wash. Sand of probable eolian origin is present here, separated by thin 4-in.-thick clay beds. Also, a 3-ft-thick buried soil zone developed on sandy gravel is present in the lower reaches of the wash. This soil zone is composed of a reddish-orange sand overlying a white carbonate horizon. The soil is overlain by brown sand of suspected eolian origin. Charcoal collected from sand approximately 3 ft below the ground surface has been dated at 2,800 years B.P.

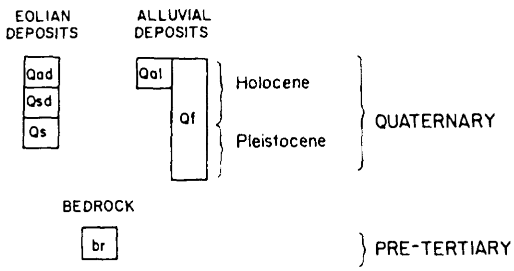


Base from U.S. Geological Survey
Kelso, 1955; Flynn, Old Dad Mtn.,
1956; Kerens, 1957

Geology mapped in 1983
by Warren Yeend

Figure 2.--Geologic map of the Kelso Dunes Wilderness Study Area, San Bernardina County, California.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

EOLIAN DEPOSITS

Qad ACTIVE DUNE SAND (HOLOCENE) - Medium- to fine-grained sand with sharp dune forms that change shape with each successive wind storm. Black sand consisting of magnetite, ilmenite and various ferromagnesian minerals is concentrated at the surface of most of the higher active dunes. Vegetation is sparse , consisting of Galleta and Rice Grass, Locoweed, Desert Willow, and a few Cresote bushes near the margins of these dunes. Increment borings of Desert Willows located on the southeast side of the high dunes indicate ages of approximately 30 to 40 years for these trees.

Qsd STABILIZED DUNE SAND (HOLOCENE) - Primarily medium- to fine- grained sand that is generally well sorted. Dune forms are subdued and of various shapes. Vegetation is similar to that on the sand sheets, but vegetation is not as dense and areas between grass clumps are frequently devoid of vegetation.

Qs SAND SHEETS (PLEISTOCENE) - Medium- to fine-grained sand; however, it is not as well sorted as the younger sand deposits (units Qad, Qsd). Sand sheets are found as a relatively thin blanketlike veneer and generally lack dune form. Less vegetation is found on the sand sheets than on the fan deposits but more than on the stabilized dune sand.

ALLUVIAL DEPOSITS

Qal ALLUVIUM (HOLOCENE) - Typically sandy gravel and gravelly sand present in modern drainageways. Well-rounded boulders as large as 1 ft are present, but more commonly 4 in. or less in diameter. Granule sand predominates. Most of the washes are well vegetated; due no doubt, to the presence of more moisture than other areas

Qf ALLUVIAL FANS (HOLOCENE AND PLEISTOCENE) - Poorly sorted boulder gravel with subangular to subrounded gray limestone and dark-reddish-brown rhyolite clasts, common rock types found on the west flank of the Providence Mountains. This gravel most likely extends beneath the Kelso Dunes. Young fan deposits interfinger with the dune deposits on the east side of the dune field. The fan deposits are readily differentiated from the dune deposits on the basis of vegetation. Creosote Bush and Burroweed are more common on the fan deposits, whereas cactus, present on the fan gravel is absent from the younger sand deposits

br BEDROCK (PRE-TERTIARY) - Fine-grained granitic bedrock is present on the east side of Cottonwood Wash as two small knobs. Varnished ventifacts indicate several different wind directions

Surface concentrations of black sand

x 27 Bulk sand sample location

Sand texture and composition

Kelso Dunes sand has many characteristics typical of most eolian sand deposits. About 90 percent of the grains are 0.01 to 0.02 in. in diameter (Sharp, 1966), and most are well rounded. The active dunes are composed of very well-sorted sand in contrast to moderately well to well-sorted sand of stabilized dunes and sand sheets.

The active dune sand contains a variety of minerals. Quartz makes up approximately 70 to 80 percent, feldspar 10 to 30 percent, heavy minerals 5 to 10 percent, and rock fragments 3 to 10 percent (by volume). Magnetite, amphibole, hematite, and ilmenite dominate the heavy minerals. The dark-colored heavy minerals occasionally are found in sufficiently high concentrations to form dark-colored beds within the sand and dark to black surface coatings on the active dunes. These grains are usually 0.004 to 0.012 in. in diameter, about 0.5 times the size of the associated quartz and feldspar grains. Thus, both the light-colored and smaller darker grains are about equal in weight. Other minerals common in the heavy fraction are sphene, epidote, pyroxene, and biotite. Zircon, garnet, hypersthene, rutile, apatite, actinolite, and tourmaline are also present.

Magnetite was separated from 22 of the sand samples collected in the Kelso Dunes area, and weight percentages were determined (table 1). Magnetite contents averaged 2.86 percent and ranged from 0.5 to 10.0 percent. Average magnetite concentrations for each of the dune sand units are as follows:

Active (10 samples), 4.32 percent
Stabilized (7 samples), 2.12 percent
Nondune sand (5 samples), 0.71 percent

The Kelso Dunes contain a natural phenomenon that is very rare in the U.S.--booming sand. Such sand produces a low-frequency sound during avalanching. The sound-producing sand is commonly termed "desert thunder," "booming dunes," and "roaring sands."

Booming dunes have been known and reported in early literature for at least 1,500 years (Lindsay and others, 1976). Deserts in the Middle East, the Sahara, Southern Africa, Chile, and Baja California, possess booming sand. Sand Mountain, Nevada is the only other location in the Continental U.S. other than Kelso Dunes where booming dunes have been identified (Lindsay and others, 1976).

Criswell and others (1975), in a study of the physical characteristics of booming dunes, note that sand grains from booming dunes seem to be more polished than grains from nonbooming dunes. Whether the polished grains result from some local-polishing conditions at the dune site or are present as a result of a selection and sorting process is not known. The sound appears to be the result of the shearing of the grains during avalanching.

Table 1.--Samples from Kelso Dune Wilderness Study area showing percent magnetite of total sand sample

Sampling localities and magnetite concentrations are shown on accompanying map

Sample no.	Percent magnetite (weight)	Deposit type
24	10	Active dune
21	8.4	" "
16	7.1	" "
31	5.8	" "
10	2.7	" "
33	2.7	" "
15	2.2	" "
32	1.9	" "
1	1.3	" "
5	1.1	" "
25	4.7	Stabilized dune
26	3.6	" "
30	2.7	" "
34	2.1	" "
11	0.7	" "
6	0.6	" "
17	0.5	" "
29	1.3	Inactive (no dune form)
27	1.2	" " " "
36	1.0	" " " "
28	0.8	" " " "
12	0.7	" " " "

Black sand and heavy mineral provenance

The dark-colored sand layers within and on the surface of the dunes are composed predominantly of well-rounded grains of magnetite and amphibole. It seems apparent that a large component of these minerals are derived locally from the Granite Mountains to the south and the southern Providence Mountains to the southeast. Sediments within drainages draining north from the mountains toward the dunes were sampled for their heavy-mineral contents. Two samples within Bull Creek contained an average of 4.5 percent magnetite and 28.7 percent amphibole. These are weight percentages of the total sand (60 mesh) fraction. Another sample of granule sand in a small unnamed wash between Bull Creek and Devils Playground Wash contained 3.3 percent magnetite and 3.2 percent amphibole. The total heavy-mineral-suite composition compares closely to those found in the dunes, predominantly biotite, sphene, epidote and zircon. The only differences are that the grains within the washes were very angular and 2 to 5 times larger in diameter than the dune-sand grains. Thus, a large component of the heavy minerals, particularly the black sand within the Kelso Dunes, is being derived from the Granite Mountain terrain to the south. These grains are subsequently wind sorted, rounded, and frosted as they are blown about the dune complex.

Wind regime

The modern wind regime of the Kelso Dunes is not well known because systematic observations of local surface winds have not been made. The nearest station was active from 1939 to 1950 at Silver Lake, 37 mi northwest of the Kelso Dunes. The Kelso Dunes appear to be located near the boundary between two distinct wind regimes, one that prevails to the west of the dunes and the other that prevails to the east, each influenced by local topography. The wind regime west of the dunes is characterized by strong persistent winds from the west and southwest during all seasons but peaking during spring and waning during early fall. The wind regime east of the dunes is more complex and less directional than the western regime, however, the annual resultant of modern sand-driving wind is toward S. 77^{o} E. at Silver Lake and toward S. 53^{o} E. at Needles (60 mi east of the study area).

Previous investigators have assumed that the sand in the Kelso Dunes originated from the Mojave River and was blown eastward, then southeastward across the Devils Playground to the Kelso Dunes (Thompson, 1929; Sharp, 1966, 1978, 1982; H.T.U. Smith, 1967; Anders, 1974). Sharp (1966) determined that sand becomes progressively well sorted, better rounded, and depleted in ferromagnesian minerals eastward from the fan of the Mojave River to the Kelso Dunes, changes that he attributed to the cumulative effects of eolian transport. He inferred that local sand was added to Mojave River sand, presumably by wind, from the north-northwest between the southern Cowhole and Kelso Mountains where sand showed an excess of grains coarser than 0.02 in. He also noted that the mineralogy of Kelso Dunes sand was consistent with derivation from the Mojave River and speculated that its prominent fraction of magnetite probably came from a mine at the mouth of Afton Canyon. Sharp's findings do not preclude derivation of much of the Kelso Dunes sand from nearby granitic terranes that surround the dunes on the east, south and west. Local sources for the magnetite and amphibole in the dunes appear more likely than Sharp's proposed Afton Canyon because; 1) Devils Playground Wash drains a terrane in the northern Granite Mountains that is very rich in amphibole and magnetite and is adjacent to the locality in the dunes where attempts have been made to mine magnetite from the dune sand, 2) sand now crossing the southern Cowhole Mountains seems to contain much less magnetite than does Kelso Dunes sand, suggesting that the sand flow from the Mojave River now contains little magnetite, 3) Sharp (1966) noted that the fraction of iron minerals decreased eastward from the Mojave River, and 4) minable quantities of magnetite are found near the Kelso Dunes in the Providence Mountains, and at Old Dad Mountain (Carlisle and others, 1954). These relations suggest that local sources could have provided much of the sand in the Kelso Dunes. However, they do not preclude the Mojave River as a major contributor of the sand. Local sand could have either been blown directly onto the dunes from local washes, namely Devils Playground Wash and Kelso Wash or carried westward and northwestward past the dunes and blown back southeastward mixed with Mojave River sand.

Dune form within much of the Devils Playground and the Kelso Dunes is strongly linear, but at Kelso Dunes the orientation of dune ridges relative to wind is unclear. Sharp (1966) concluded that dune orientations did not represent the presumed westerly regional wind very well and "...that the dunes are localized at crossroads of winds whose net effect is near zero."

Ventifacts also indicate that effective winds blew sand in many directions throughout most of the area, even where other eolian features are strongly linear. The wind pattern agrees with Sharp's conclusion that the slight and ambiguous migration of dune ridges indicated a wind regime of balanced opposing winds (Sharp, 1966)

Age of the dunes

The age of the Kelso Dunes is not known. Sharp (1966) inferred an age of several thousand to as much as 20,000 years but did not state how he determined this estimate. H.T.U. Smith (1967) noted that "It is most unlikely that the great bulk of dune sand could have accumulated under existing conditions." He inferred that the dunes are a relic of a past regime of much more intense wind action. This is indicated by relict ventifacts and climbing and falling dunes throughout the eastern Mojave Desert, a regime tentatively correlated with the Altithermal Interval of Antevs (1948) that lasted from 7,000 to 4,500 years ago. This arid interval was followed by a wetter one during which dunes were stabilized and stream action dominated wind action, indicated by the entrenchment of Cottonwood and Winston Washes into the dune surface (Smith, 1967). Pond deposits within dune sand also indicate wetter conditions.

Calculations of sand transport suggest that the total duration of episodes of active sand transport toward the Kelso Dunes was at least tens of thousands of years and quite possibly hundreds of thousands of years. When the duration of active eolian episodes is added to the intervening dormant pluvial episodes, the age of the dunes is very likely greater than 100,000 years, and quite possibly more than a million years.

Depth to bedrock

It seems apparent that the sand dunes within the study area unconformably overlie the alluvial fans extending out from the Providence and Granite

Mountains. Deposits of probable alluvial origin are exposed in Cottonwood Wash beneath the dune sand. The fan deposits, in turn, mantle granitic bedrock in this same area where a small hillock of granite is exposed.

Gravity and magnetic data (see geophysics section) indicate a thickness of about 2,400 ft of unconsolidated fill deposits in the northeast corner of the study area, approximately 400 to 600 ft in the southwest corner, and a shallow pediment surface on the west and south edges of the study area. There may be less than 100 ft of sand and gravel on bedrock in these latter two areas.

Three wells are known in the area (Thompson, 1929). Two water wells at Kelso penetrated 882 ft and 606 ft of sand and gravel without reaching bedrock. Approximately 4 mi northwest of the northwest corner of the study area along the railroad at "Sands" a water well penetrated granite bedrock at 205 ft depth. The Bouguer gravity map (fig. 3) would seem to bear out these findings and indicates a moderately deep basin roughly paralleling the railroad but shifted a few miles to the south within the study area.

GEOPHYSICS

Aeromagnetic Data

Aeromagnetic data for the Kelso Dunes Wilderness Study Area is contained in an aeromagnetic survey of the Needles 1^{o} by 2^{o} quadrangle (U.S. Geological Survey, 1981). The survey was flown in an east-west direction at a constant nominal elevation of 1,000 ft above the land surface. Flight line spacing was approximately 0.5 mi with north-south tie lines every 10 mi. That part of the aeromagnetic survey encompassing the Kelso Dunes area was reduced to the Pole (Baranov and Naudy, 1964; Hildenbrand, 1983) using an assumed direction of magnetization with inclination equal to 60^{o} and declination equal to 14^{o}. Reduction to the Pole removes asymmetries in magnetic anomalies by mathematically replacing dipping magnetization and field vectors with downward directed vectors such as would be found at the magnetic North Pole. The resulting map of aeromagnetic anomalies is displayed as figure 4.

An aeromagnetic high (H1) in the southeast corner of the study area lies over exposures of Jurassic(?) igneous rocks. This anomaly is connected by way of a southeast trending high (H2), with aeromagnetic high values over Jurassic igneous rocks exposed in the southern Providence Mountains.

A broad low (L1) in the northeast corner of the wilderness study area probably reflects a great depth to magnetic basement under weakly magnetic eolian sand and alluvium. The absence of any short wavelength features on the aeromagnetic map in this area implies that magnetic concentrations within the sand dunes are not of sufficient volume to produce any sizable anomalies on an airborne magnetometer 1,000 ft above the ground. This inferred sediment-filled basin appears to be bounded on the east by a north-trending fault (indicated by a magnetic gradient (G1) located about 2 mi east of the wilderness study area boundary), and judging from the continuation of broad aeromagnetic lows, extends to the northeast outside of the wilderness study area.

An aeromagnetic high (H3) on the west boundary of the study area probably indicates Jurassic igneous rocks at shallow depth. This conjecture is based on 1) the continuity of this high with other highs to the northwest (H4)

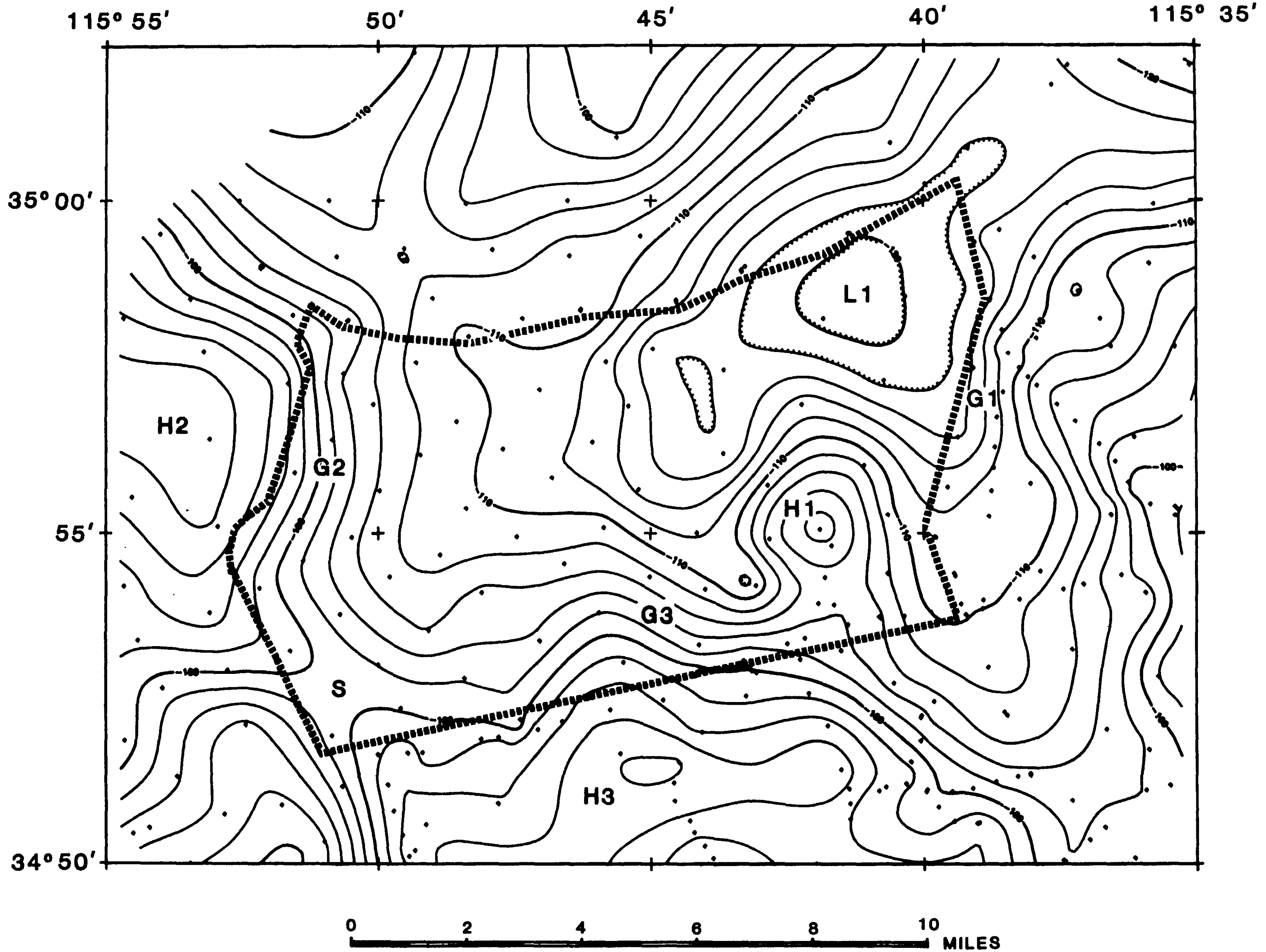


Figure 3.--Complete Bouguer gravity map of the Kelso Dunes Wilderness Study Area. Contour interval, 2mGal; hachured to indicate closed areas of lower gravity values. Features of the gravity field discussed in the text are labelled as high (H), low (L), gradient (G), and saddle (S). Gravity data prepared by Thomas B. Gage.

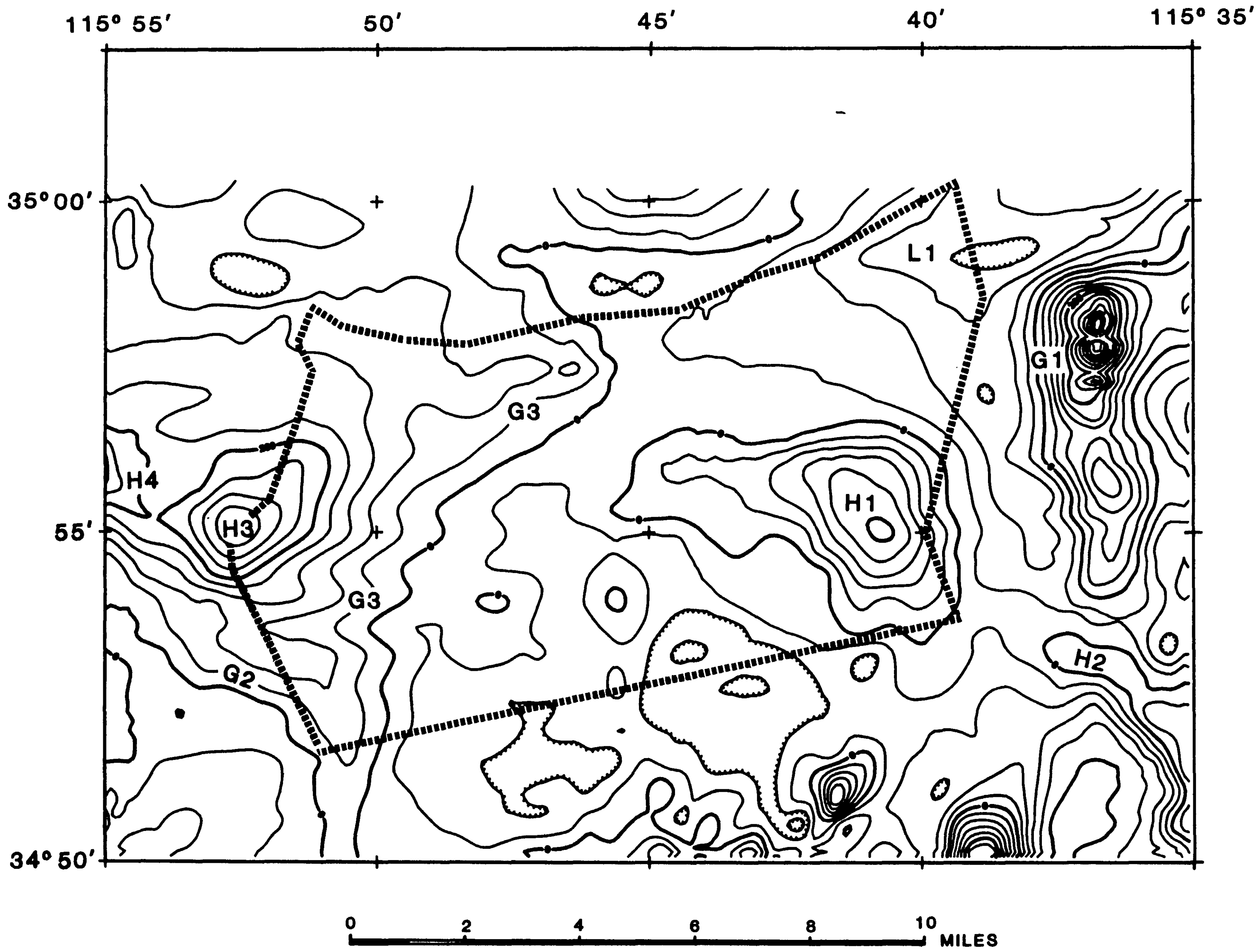


Figure 4.--Aeromagnetic anomaly map reduced to the Pole for the Kelso Dunes Wilderness Study Area. Contour interval, 50 gammas; hachured to indicate closed areas of lower intensity. Features of the aeromagnetic field discussed in the text are labelled as high (H), low (L), and gradient (G).

associated with exposures of Jurassic granites in the Bristol Mountains and 2) the sharpness of the anomaly. The granites in the Bristol Mountains have few mines or prospects and appear to have little mineral potential (Keith Howard, oral commun., 1983).

A southeast-trending gradient (G2) in the aeromagnetic data just touches the southwest corner of the study area. This gradient probably indicates a fault separating more magnetic rocks on the northeast from less magnetic basement or sedimentary deposits to the southwest. Faults along this trend are indicated on the Needles 1° by 2° geologic map (Bishop, 1963). Another gradient (G3), roughly perpendicular to G2, trends north-northwest and then northeast across the northwest corner of the study area. Subparallel faults are mapped in the Bristol Mountains immediately to the west. This gradient may also indicate a fault. Magnetic anomalies on the southeast side of the gradient are broad and low, suggesting a sudden increase in depth to basement on this side.

Gravity data

Bouguer gravity values range from a high of -106 mGal at the west end of the wilderness study area to a low of almost -120 mGal in the northeast corner of the study area (fig. 3). The most significant density contrast between geologic units in the Kelso Dunes Wilderness Study Area is found between basement rocks, probably granitic rocks with densities of 2.6 to 2.7 g/cm^3, and sedimentary fill with densities of approximately 2.1 to 2.4 g/cm^3. Areas with low Bouguer values, therefore, are thought to coincide with large thicknesses of sedimentary fill. Because sedimentary fill is typically also weakly magnetic, coincidence of gravity lows with the broad aeromagnetic lows in the Kelso Dunes area strengthens this interpretation.

A large gravity low (L1) in the northeast corner of the study area is approximately 12 mGal lower than gravity values recorded for nearby bedrock outcrops. This contrast in gravity data implies a basin-fill thickness of approximately 2,400 ft assuming a density contrast between fill and bedrock of 0.4 g/cm^3. This low is bounded on the east by a north- to northeast-trending gradient (G1), which may indicate a range-front fault. The low extends to the south-southeast along the east edge of the study area and to the southwest across the northern half of the study area. These extensions of the main gravity low probably indicate thinning wedges of sedimentary fill.

Near the southeast corner of the wilderness study area a gravity high (H1) coincides with an aeromagnetic high (H1) and probably indicates where the Jurassic igneous rocks associated with the southern Providence Mountains are closest to the surface.

The southwest corner of the study area lies within a 1- to 2-mi-wide gravity saddle (S), which connects gravity highs over the Bristol Mountains to the west (H2) and the Granite Mountains to the south (H3). This saddle suggests a subsurface bedrock ridge connecting these two ranges. Gravity values indicate approximately 400 to 600 ft of sedimentary cover over this saddle with thicknesses increasing rapidly to the northeast and southwest.

A north-northeast trending gradient (G2) along the west side of the study area and an east-southeast trending gradient (G3) across the south boundary of the study area probably mark the positions of buried range-front faults on the Bristol and Granite Mountains, respectively. The positions of these gradients suggest that the western and southernmost fringes of the study area are underlain by shallowly buried pediments extending out from these ranges. Thus, any mineral potential within these adjacent ranges may also exist at shallow depths in these fringing areas.

Thus, the geophysical data indicate that 1) crystalline basement rocks probably underlie the western and southern fringes of the Kelso Dunes Wilderness Study Area at shallow depths, 2) Jurassic(?) plutonic rocks are very close to the surface in the southeast corner of the study area, and 3) all other parts of the study area are underlain by substantial thicknesses of basin fill. The mineral potential of the basement rocks beneath the western and southern fringes of the study area has not been evaluated; however, the mineral potential of the Jurassic plutonic rocks is low to moderate in the adjacent South Providence Mountains Wilderness Study Area (D. M. Miller, personal commun., 1984).

GEOCHEMISTRY

Sampling and analytical techniques

Geochemical sampling of the Kelso Dunes Wilderness Study Area was conducted by the U.S. Geological Survey in 1982. A total of 29 sites were sampled. Fourteen sample sites were selected within the Kelso Dunes (fig. 4). Eight samples were collected at each dune site; a normal sediment volume and 1 30-liter sample for concentration were taken from the windward face, dune crest, slope face, and trough. In addition, seven sample sites were selected along Cottonwood Wash, which cuts across the east side of the dune field, and eight sites were selected along Devils Playground Wash, which forms the south boundary of the wilderness study area. Two samples were collected at each wash site, one normal sediment volume and one sample for concentration. None of these samples were field concentrated.

Each geochemical sample was semiquantitatively analyzed for 30 elements using an optical emission spectrograph. The nonmagnetic fractions of most concentrate samples were also analyzed for the same 31 elements. Atomic-absorption methods were also used to determine gold concentrations for a subset of randomly selected samples.

The U.S. Bureau of Mines also collected dune sand samples from the Kelso Dunes Wilderness Study Area. A total of 86 dune sand samples were collected from 44 sites. Samples were collected from a 2-mi-square grid and from a few more closely spaced sites (fig. 5). At each sample site all dry sand was removed before sampling, a 3-ft-deep pit was excavated in the moist sand, and a 3-ft-long channel sample with a 6-in.-diameter semicircular cross section was cut in the face of each pit. This sampling procedure was intended to overcome local variation problems. None of these samples were field concentrated. Twenty-seven U.S. Bureau of Mines samples were analyzed by traditional placer evaluation methods (screening and Wilfley table concentration); another 43 samples were evaluated using a modified placer evaluation procedure wherein heavy-mineral fractions were analyzed for their mineral content. Seven additional samples were evaluated for processing feasibility by various separation methods at the University of Idaho, College of Mines, and nine other samples were analyzed by quantitative methods for gold, silver, iron,

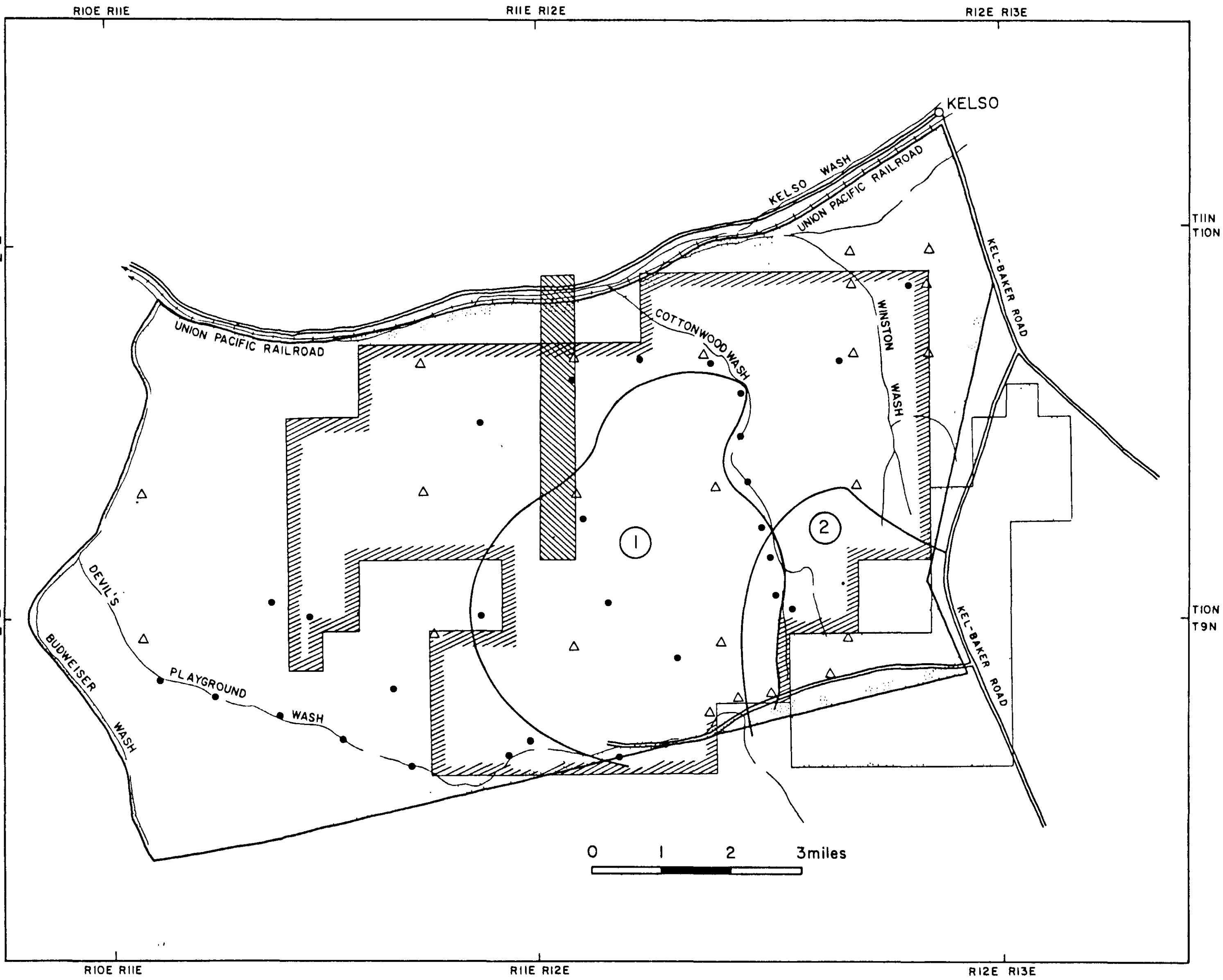


Figure 5.--Locations of oil and gas leases and mining claims in the Kelso Dunes Wilderness Study Area. Also shown are mineralogical and geochemical sample locations and areas of mineral resource potential.

EXPLANATION

AREA OF MARGINAL GLASS AND FELDSPAR SAND RESERVES

AREA OF LOW TO MODERATE MINERAL RESOURCE POTENTIAL-For hydrothermal gold-copper mineralization

ACTIVE OIL AND GAS LEASES AND MINING CLAIMS-Boundaries as of June, 1982. (Only claims and leases in or adjacent to the wilderness study area are shown)

Royal Falcon-Jernberg-Westwind claim group

Crucerro claim group

Current oil and gas leases-No. R0613

GEOCHEMICAL SAMPLING SITES

U.S. Bureau of Mines

U.S. Geological Survey

APPROXIMATE BOUNDARY OF THE KELSO DUNES WILDERNESS STUDY AREA and titanium and by semiquantitative spectrography for 42 elements.

Results

The geochemical populations for all elements within the concentrate data base showed little variability, and therefore meaningful statistical analyses of these data were not possible. The normal sediment-volume data showed somewhat greater variability than the concentrate data. However, statistical analysis of these data did not identify any geochemical associations characteristic of economic mineralization. The most significant factor, explaining about one-third of the variance in the normal sediment volume data, contained large positive loadings for iron, titanium, manganese, cobalt, chromium, copper, niobium, nickel, vanadium, yttrium, and zinc. Samples with high scores in this factor were predominantly collected from dune crests, and field observations showed that many dune crests are significantly enriched in magnetite. Thus, local magnetite concentration within the dune sand is probably responsible for much of the observed variability.

Silver, arsenic, or gold were not detected in any of the concentrate samples. Moreover, gold was not detected at the 0.05 ppm (parts per million) lower atomic-absorption detection level in either dune or wash samples (bulk sediment samples and concentrate fractions). The only geochemical indication of possible mineral resource potential within the Kelso Dunes Wilderness Study Area is the presence of four samples which contain silver that have no obvious spatial relations, and they have no other trace element anomalies. Because of the lack of detectable gold in any samples and exceptionally high background values for silver within surrounding mountain ranges, it is doubtful that these silver values are significant.

Results of the U.S. Bureau of Mines sampling program are, with the exception of gold content, very similar to the results obtained by the U.S. Geological Survey mineralogical and geochemical sampling. The U.S. Bureau of Mines sampling identified very fine (less than 400 mesh size) gold particles with an average concentration of approximately 0.04 ppm. Results of this sampling program are presented in Table 2. Detailed results are contained in Munts (1983), an unpublished report at the U.S. Bureau of Mines Western Field Operation Center in Spokane, Wash.

MINERAL DEPOSITS

Methods of study

The U.S. Bureau of Mines conducted a mineral survey of the Kelso Dunes Wilderness Study Area in 1982. Bureau personnel searched all literature pertinent to mines, prospects, and related geology of the wilderness study area and the surrounding region. Mining-claim records and activities were checked through the San Bernardino County courthouse, U.S. Bureau of Mines production records, the Mineral Industry Location System, records of the state and regional offices of the U.S. Bureau of Land Management in California, and published and unpublished records of the California Division of Mines and Geology. In addition, attempts were made to contact all known claimants and owners of all mining properties in or near the wilderness study area to examine their prospects and to obtain any pertinent scientific or historical information.

Table 2.--U.S. Bureau of Mines sampling program for Kelso Dunes Wilderness Study Area

Sample group	Number of samples	Types of analyses	Value ranges
Initial group	27	Screen and Wilfley concentrate	Gold: 0.0 to 0.05 oz/ton Magnetic fraction: 0.05 to 0.7 percent Non-magnetic fraction: 0.5 to 3.0 percent
Dune grid samples	43	Modified placer analysis	Gold: 0.00013 to 0.035 oz/ton Magnetic fraction: 0.07 to 1.23 percent Nonmagnetic fraction: 6.68 to 40.2 percent
Processing feasibility	7	Various separation methods	Gold: 0.012 to 0.117 oz/ton Quartz: 73 to 87 percent Feldspar: 5 to 20 percent Magnetite: trace to 5 percent
Chemical analyses	9	Quantitative methods	Gold: less than 0.03 to 16 ppm (parts per million) Silver: less than 0.1 to 2.5 ppm Iron (as FE_2O_3): 1.03 to 2.69 percent Titanium (as TiO_2): 0.27 to 0.49 percent

Exploration history

Base- and precious-metal mining and prospecting in the eastern Mojave Desert began in the mid-1860's, and activity increased through the 1890's. Gold was sought in the Kelso Dunes area during this period, but discontinued due to a lack of surface water and very fine particle size. Interest waned until the mid-20th century when several large U.S. companies including U.S. Steel and a mineral exploration arm of the Howard Hughes Company examined Kelso Dunes as a possible source of iron (Arthur Parker, claimant, oral commun., 1982).

In the early 1970's, Sandia Metals Company of Albuquerque, New Mexico, held claims or options to claims covering about 40 mi^2 of the Kelso Dunes. A dune-sand processing plant was constructed at this time and about 1,000 tons of magnetite were produced. This represents the only production from the study area. In 1971, Sandia Metals Company began negotiations with a Japanese company for an iron-ore production contract (Arthur Parker, oral commun., 1982). However, these negotiations were discontinued in 1975 when, according to Parker, Sandia discovered gold in the dune sand. Parker subsequently evaluated the dune sand, primarily for iron and gold; and in the late 1970's, he requested the assistance of Eriez Magnetics of Erie, Pennsylvania, to develop a profitable gold, magnetite and glass-sand recovery system. As of June 1982, this benefication research was still in progress.

Seven claim groups, totaling approximately 1,100 claims have been located within the wilderness study area. Only two groups, the Royal Falcon-Jernberg-Westwind (627 claims) and the Crucerro (approximately 50 claims within the study area), were active in June 1982 (fig. 4). These claims were located for iron in 1966 and 1967, and cover approximately 28,000 acres of the dune field. Subsequent evaluation revealed gold and possible glass-grade sand. The five abandoned groups (Bonanza, Goodell-Glass, Kelso, Kerns, and Micropower) were located for placer gold.

Oil and gas activity

Oil or gas has not been discovered in the wilderness study area. U.S. Bureau of Land Management records indicate all of sections 7, 15, 17-21, and 30, T. 10 N., R. 12 E., S.B.M. (totaling 5,120 acres) were under oil and gas lease during 1965 and 1966. These leases were dropped in 1967, except a total of 1,280 acres in the east halves of sections 7, 18, 19 and 30 (fig. 4). As of August 1982, these remaining leases were still current, but no new oil and gas leases had been listed in U.S. Bureau of Land Management records.

ASSESSMENT OF MINERAL RESOURCE POTENTIAL

The primary Kelso Dune field is estimated to contain approximately 16 billion tons of sand (assuming an average density of 17.3 ft^3 per ton). Of this, about 12.8 billion tons is quartz sand and 2.4 billion tons is feldspar sand (assuming an 80 percent quartz and 15 percent feldspar content). Based on 86 sample analyses, the dune sand averages 1 to 4 percent magnetite, 0.35 percent ilmenite, and 0.045 ppm gold (but locally up to 17 ppm gold). This constitutes marginal reserves of glass sand and feldspar with byproduct magnetite and gold.

Both the U.S. Bureau of Mines and present claimants evaluations indicate that the dune sand has mineral resources and resource potential. Based on the character and quality of the sand and a lack of contaminants, the eastern two-thirds of the study area is considered by the U.S. Bureau of Mines to have a high potential for development of glass and feldspar sand mines with byproduct magnetite and gold. The western third of the study area has only a moderate potential for development because of interlayered zones of gravel, silt, and secondary carbonate minerals.

The potential for oil and gas resources within the Kelso Dunes Wilderness Study Area is unknown but unlikely. Active oil and gas leases cover only 2.5 percent of the study area and no oil and gas has been discovered on, or anywhere near, the study area. Moreover, regional geologic relations give little indication of the possible existence of significant hydrocarbon accumulations in the region surrounding Kelso Dunes (D. M. Miller, personal commun., 1984)

Granitic rocks that underlie the southeast corner of the study area at shallow depths have a low to moderate potential for undiscovered hydrothermal gold-copper resources.

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