U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Mineral Resources of the North Algodones Dunes Wilderness Study Area (CDCA-360), Imperial 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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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 their mineral values. 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 Algodones Dunes Wilderness Study Area (CDCA-360), California Desert Conservation Area, Imperial County, California.

SUMMARY

The potential for undiscovered base and precious metals, and sand and gravel within the North Algodones Dunes Wilderness Study Area is low. The study area has a moderate potential for geothermal energy. One small sand-free area between the Coachella Canal and the west edge of the dune field would probably be the only feasible exploration site for geothermal energy. The study area has a moderate to high potential for the occurrence of undiscovered gas/condensate within the underlying rocks.

INTRODUCTION

The North Algodones Dunes Wilderness Study Area is located on the southeast edge of the Imperial Valley in east-central Imperial County, California. The study area encompasses 20,482 acres of the 45-mi-long, 3- to 5-mi-wide Algodones dune field, also referred to as the northwest part of the Sand Hills on some maps. It is bounded on the south by California Highway 78, on the northeast by the Southern Pacific railroad lines, and on the southeast by the Coachella Canal (fig. 1). Although graded dirt and gravel roads run along the east and west boundaries of the study area, access within the area is limited to foot travel. Brawley, the nearest population center, is located 28 mi west and Blythe lies 60 mi north. Glamis, a small settlement of eight inhabitants, lies adjacent to the study area near the southeast corner.

GEOLOGY PERTAINING TO MINERAL RESOURCE ASSESSMENT

Geomorphology

The southwest margin of the dune chain is sharply delineated and rises abruptly from East Mesa as a granule-armored plinth, whereas the northeast margin is irregular and embayed along a series of low dunes that extend 1 to 4 mi northeastward from the core of the dune chain.

Distal alluvial fan deposits cover the northeast fringe of the area (fig. 2). Based on a general absence of rock varnish and stone pavements, segments between active fans appear to be no older than late Holocene. Downfan drainage is blocked by the main rib of the Algodones dune chain, although fan channels penetrate 1 to 2 mi southwestward into the low dunes along the northeast fringe of the chain (fig. 2). The sumps of these fan channels are dune-surrounded oases of vegetation and playa sediments (Norris and Norris, 1961; Sharp, 1979). The low dunes surrounding these sumps are southeast-trending ridges 10 to 20 ft tall crossed by fainter northeast-trending ridges supporting scattered large perennial plants (for example, mesquite and creosote bush). These plants do not grow on the main dune crest to the southwest.

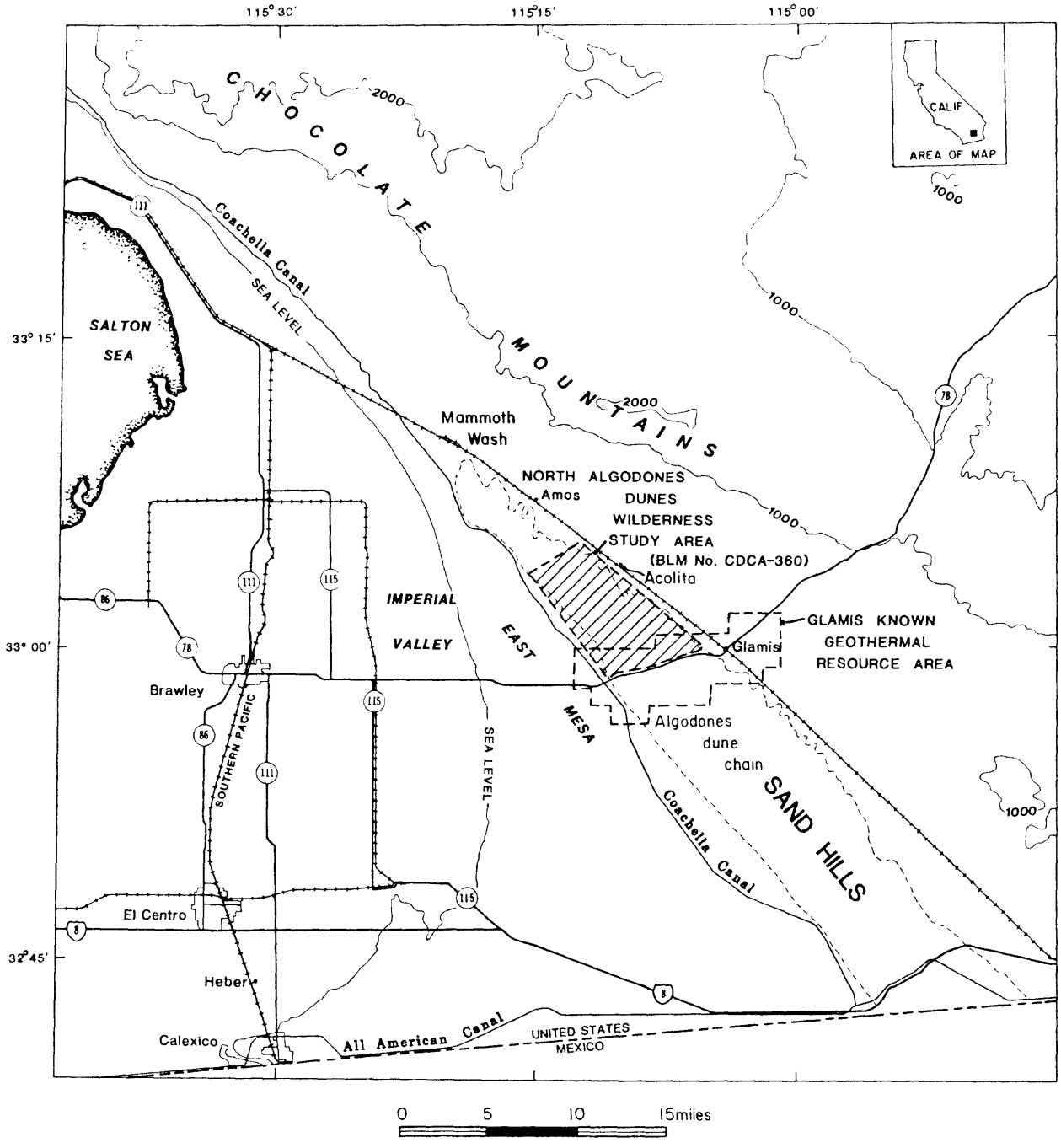
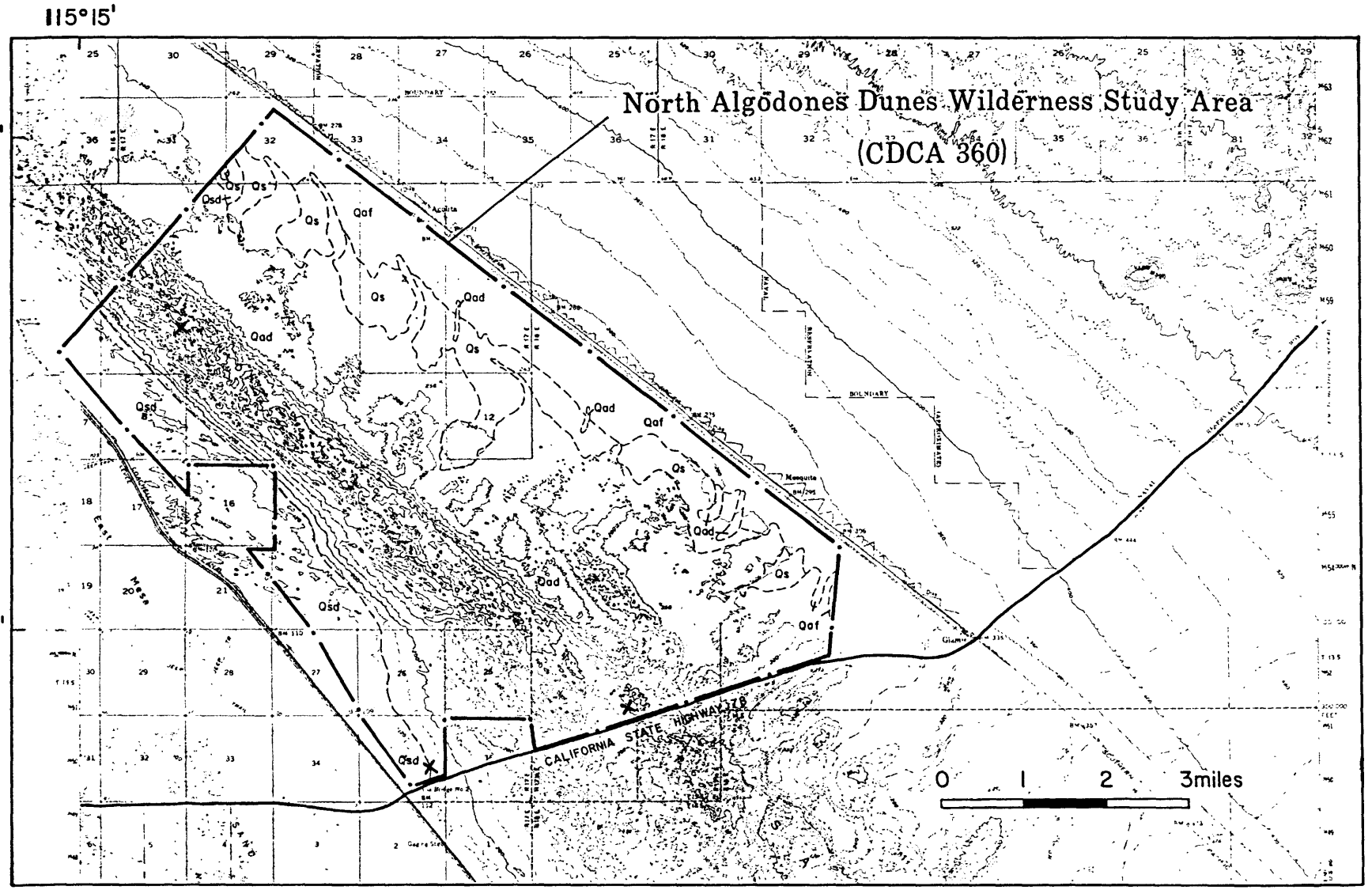


Figure 1.--Index map showing the North Algodones Dunes Wilderness Study Area, Imperial County, California.

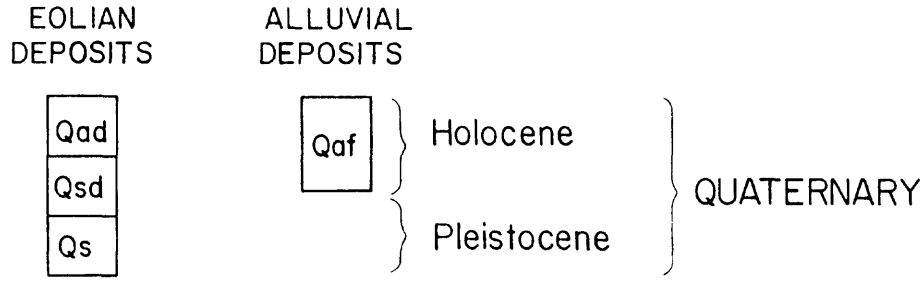


Base from U.S.Geological Survey
Glamis,1955; Acolita,1953

Geology mapped in 1983
by Warren Yeend

Figure 2.--Surficial geologic map of the North Algodones Dunes Wilderness Study Area, Imperial County, California.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Eolian Deposits

Qad ACTIVE DUNES (HOLOCENE)--Medium to fine sand with sharp dune forms. Vegetation is sparse. Dunes exist as sinuous ridges 0.5 to 3 mi long and 300 ft apart and are 20 to 60 ft tall. Dunes change position and shape with the prevailing winds

Qsd STABILIZED DUNE SAND (HOLOCENE AND PLEISTOCENE)--Well-sorted medium to fine sand. Dune forms are subdued and of various shapes. Vegetation is more common than on the active dunes (Qad). The unit is most prominent along the southwest boundary of the wilderness study area. Dunes are stabilized by vegetation and do not change shape with the active winds

Qs SAND SHEETS (PLEISTOCENE)--Medium to fine sand lacking dune form. Vegetation is present, especially creosote bush. This unit is present on the northeast side of the wilderness study area

Alluvial Deposits

Qaf ALLUVIAL FANS (HOLOCENE)--Small boulder and cobble gravel and sand. Moderately well vegetated. Fans are present along the northeast boundary of the area and penetrate 1-2 mi southwestward into the dune field. Sumps of these fan channels are dune-surrounded oases of vegetation and playa sediments

CONTACT--Approximately located

APPROXIMATE BOUNDARY OF NORTH ALGODONES DUNES WILDERNESS STUDY AREA

SAMPLE LOCALITY

About one-third of the wilderness study area is occupied by the main rib of the dune chain rising abruptly 150 to 200 ft above the field of fringing dunes on the northeast (fig. 2). Subparallel sharp-crested dune ridges follow along the crest of the main dune rib. These sinuous ridges, typically 0.5 to 3 mi long and 300 ft apart, are 20 to 60 ft tall but locally break up into pyramidal dunes with 80 to 120 ft of local relief.

The southwest margin of the main dune rib, a ramp largely devoid of sharp-crested dune features, descends 200 ft to East Mesa. The surface of this ramp is largely armored by granules and is sufficiently stable to support creosote bushes, which are absent on the crestal dunes. Low ridges trend S. 65° E. up the ramp to feather into the S. 45^{0} to 60^{0} E. trend of the crestal ridges. These low ridges, steepest on their south sides, are composed of interbedded sand and granules and, on aerial photographs, display a characteristic "zibar" pattern of wavy alternating bands of light and dark tone. These low ridges parallel, and locally are distal continuations of, the inactive sand ridges that cover most of East Mesa.

East Mesa slopes gently west and appears to be an inactive surface of sand, silt, and clay on which little soil is developed. This surface, which becomes gravelly to the south, may represent a large Pleistocene fan delta of the Colorado River. Loeltz and others (1975) describe evidence for a deformed late Pleistocene shoreline that descends northwestward along the southwest margin of the Algodones dune chain. This shoreline is about 37,200 years old (1) if it correlates with deformed shorelines on the west side of the Salton basin, as radiocarbon dated by Hubbs and others (1963), and (2) if age determinations on aragonitic shells are valid.

Geologic history

The history and age of East Mesa and the Algodones dune chain are not well known; therefore their relation to the alluvial fans of the Chocolate Mountains piedmont is uncertain. Drilling logs indicate that a very thick section of mostly fine-grained sediments underlies East Mesa (Loeltz and others, 1975). Sediments throughout most of the Imperial Valley appear to have been mainly derived from the Colorado River, 25 mi to the east (Muffler and Doe, 1968). The sediments beneath East Mesa must have been transported northwestward into the Salton basin. They probably interfinger with coarser fan deposits from the Chocolate Mountains along a northwest-trending line that roughly follows the trend of the Algodones dune chain. This line may also coincide with down-to-the-west faults recognized beneath the dunes on the basis of geophysical data (Kovach and others, 1962).

The origin of the dune chain is, likewise, poorly known, except that the sand came ultimately from the Colorado River (Merriam, 1969; van de Kamp, 1973). This sand may have been (1) blown directly off Pleistocene beaches along the margin of the present dunes (Loeltz and others, 1975; Sharp, 1979), (2) blown across East Mesa from the Holocene shoreline of Pleistocene Lake Cahuilla (Brown, 1923), (3) deflated from East Mesa and the Imperial Valley (van de Kamp, 1972), or (4) blown southeastward from beaches near Mammoth Wash (Norris and Norris, 1961; McCoy and others, 1967).

East Mesa appears to be the oldest geomorphic unit, the Algodones dune chain intermediate in age, and alluvial fans the youngest unit in the study area. Southeast of the area, intradune flats are floored by a surface similar

to that of East Mesa (Sharp, 1979), implying the Algodones dune chain accumulated on the preexisting surface of East Mesa. The modern alluvial fans appear to be younger than the dune chain, and are blocked by it north of State Highway 78. Topographic profiles show clearly that the surface of East Mesa projects beneath the dunes to intercept the alluvial fans about 100 ft below the present land surface. These relations suggest that the dune chain blocked southwestward migration of the fans onto East Mesa and forced the fans to aggrade about 100 ft since the dune chain formed. Although interfingered eolian sand may form a significant part of that thickness, the volume of impounded fan material must be large and must have taken a long time to accumulate.

Part of the difference in elevation between East Mesa and the Chocolate Mountain fans may be the result of possible Quaternary downfaulting of East Mesa along faults beneath the Algodones dunes chain that bound the eastside of the Salton Trough. The absence of fault scarps and the continuous longitudinal piedmont profile just northwest of the study area indicate a pre-late Pleistocene age for any such faulting. Evidence for faulting along the trend of the dunes is limited to geophysical data (Kovach and others, 1962), but some low, down-to-the-west scarps have been described on East Mesa (Heath, 1980).

Using assumptions about Pleistocene winds and lake currents in the Imperial Valley area, McCoy and others (1967) calculated that it would have taken about 160,000 years for lake currents to deliver enough sand to the vicinity of Mammoth Wash, on the north boundary of the study area, for the entire dune chain to have blown to the southeast. However, demonstrated derivation of the sand from the Colorado River (Merriam, 1969; van de Kamp, 1973) requires that this model be revised. Evidence that the dunes are as young as 37,000 years (Loeltz and others, 1975) is equivocal.

Mineralogy and textures of the sand dunes

Three bulk sand samples were collected from the North Algodones Dunes Wilderness Study Area and analyzed for heavy minerals. The sand samples contain no gold, very little magnetite (0.2 to 0.3 percent), and few heavy minerals. The heavy minerals are poorly sorted, and include: magnetite, epidote, zircon, biotite, garnet, tourmaline, and hornblende. The magnetite grains are well rounded and generally 0.04 to 0.08 in. in diameter. Quartz makes up 70-80 percent of the dune material, feldspar 10-15 percent, and rock fragments 5-15 percent. The heavy fraction generally makes up less than 1 percent of the sand by weight. Sand grains are slightly to completely frosted. Sand fragments are subangular to rounded and generally fall in the size range of 0.01 to 0.06 in. in diameter.

Subsurface geology

The North Algodones Dunes Wilderness Study Area lies on the northeast margin of the Salton Trough, an elongate northwest-southeast trending basin extending from the Salton Sea to the Gulf of California. The Salton Trough is bounded on the northeast by the San Andreas fault zone, and on the southwest by the San Jacinto-Superstition Hills fault zone. These faults separate thick sedimentary deposits in the basin from igneous and metamorphic basement rocks that occur at or near the surface west and east of the bounding fault zones.

Sediments underlying the study area vary from less than 2,000 ft along the northeast boundary to possibly as much as 13,500 ft at the southwest corner. Well data from exploratory wells in the eastern and southern parts of the Salton Trough indicate that these sediments are probably Miocene and lower Pliocene marine deposits, and upper Pliocene to recent deltaic, lacustrine, and alluvial deposits.

At Acolita, on the northeast boundary of the study area, an oil test well penetrated metamorphic rocks at a depth of 2,060 ft (Ajax Oil and Development Company, "U.S.L. Phyllis" 1, Oct. 1955, T. 13 W., R. 17 E., sec. 2; Morton, 1977). At Amos, 6 mi northwest of Acolita, a 1,550-ft well penetrated gravel with sand and some clay without reaching basement. Ten miles northwest of Acolita, near the railroad crossing of Mammoth Wash, a well penetrated 1,000 ft of interbedded sand and clay without reaching igneous or metamorphic rocks (Loeltz and others, 1975). If sediment thickness is related to distance from the mountain front, sediment thicknesses in excess of 2,000 ft probably occur along the entire northeast margin of the study area. This margin lies 3 to 7 mi from outcrops along the front of the Chocolate Mountains mapped by Morton (1977) and by Loeltz and others (1975).

Geophysical data and well-log data indicate that these sediments thicken abruptly toward the southwest across several major faults beneath the study area (Kovach and others, 1962; Terra Resources, written commun., 1984). Prairie Eagle seismic reflection line HHK-8 shows acoustic basement at a depth of 8,500 ft at the Texaco No. 1 Grupe-Engebretson well in T. 16 S., R. 16 E., sec. 8, approximately 40 mi southeast of the study area. This well, completed in 1945, was drilled to a depth of 12,313 ft in Pliocene strata (3,800 ft below the acoustic basement reflector) without encountering crystalline basement. Shell seismic reflection line 82-147-787, located along California Highway 78 on the southeast boundary of the study area, shows the acoustic basement reflector dipping southeast to a depth of over 5,000 ft at the southeast corner of the study area. If (as comparison of the Prairie Eagle line HHK-8 and the Texaco No. 1 well log indicate) the acoustic basement reflector is not the actual base of the sedimentary section in this area, then the southwest part of the study area may be underlain by as much as 13,500 ft of sedimentary strata. Shell seismic line 82-147 787 also indicates that the southeast part of the study area is underlain by at least three down-to-the-southwest faults and the southwest part of the area is underlain by at least three down-to-the-northest faults (Terra Resources, written commun., 1984).

MINING DISTRICTS AND ENERGY RESOURCES

Methods of study

The U.S. Bureau of Mines conducted a mineral survey of the North Algodones Dunes Wilderness Study Area in 1981 and 1982. No evidence of any mining activity or mineralized areas was found during field investigations in or within 1 mi of the area; therefore no samples were taken. In addition to field investigations, the mineral survey included a review of pertinent published literature and unpublished data. All mining-claim records and current oil and gas leases were examined at the U.S. Bureau of Land Management's state office in Sacramento and at the bureau's district office in El Centro, Calif.

Petroleum exploration

Mineral and petroleum activity within the North Algodones Wilderness Study Area has been limited to petroleum exploration. Oil and gas lease applications cover the entire study area; however, as of February 1983, the U.S. Bureau of Land Management had not issued any oil and gas leases within the study area (S. E. Hagerty, oral commun., 1983). In 1955, Ajax Oil and Development Company drilled the only exploratory oil and gas well within the wilderness study area. The California Division of Oil and Gas (1955) compiled a well summary report for this well (U.S.L. Phyllis #1, sec. 2, T. 13 S., R. 17 E.). The well reached metamorphic basement at 2,060 ft and was discontinued at 3,315 ft. Electric logs did not detect the presence of hydrocarbons in the well.

In early 1982, two seismic-reflection survey lines were shot along the southeast and southwest boundaries of the study area. One of these reflection lines, Prairie Eagle line HHK-14 was shot along the Coachilla Canal by the Prairie Eagle Company for the Amoco Production Company. The other line, Shell line 82-147-787 was shot along California Highway 78 by the Shell Oil Company for a joint Terra Resources/Shell Oil Company project. The acoustic basement reflector at the southwest corner of the study area, as determined from the records generated by these seismic-reflection surveys, is interpreted to lie at a depth in excess of 5,000 ft. Comparison of the records for these seismic lines with the records for other intersecting seismic lines and with exploration well logs indicates that perhaps as much as 10,000 ft of late Tertiary marine and continental strata lie below the acoustic basement reflector in the eastern part of the Salton Trough. Therefore, the southwest part of the study area may be underlain by as much as 13,500 ft of sedimentary section (Terra Resources, written commun., 1984).

Mineral extraction

Lode and placer gold deposits are found east and north of the study area in the Mesquite mining district on the west flank of the Chocolate Mountains. Native gold occurs in quartz veins and fracture zones within Precambrian(?) gneiss and schist. Dry placer-mining activities were centered on the alluvial washes along the southwest base of the range. These placer deposits occur in Quaternary gravel overlying highly weathered and fractured gneiss (Sampson and Tucker, 1942; Morton, 1977). Prior to military withdrawal from the Chocolate Mountains in 1942, only one mine and two prospects had been located upfan from the wilderness study area, and these operations removed about 522 tons of ore, mostly gold (Morton, 1977). Drainage from these sites does not enter the study area. Moreover, neither lode nor placer-gold deposits are known to extend into the area.

In 1981, sand and gravel were being excavated at approximately 35 sites in the vicinity of the North Algodones Dunes Wilderness Study Area (S. E. Hagerty, unpub. data, 1981). All 35 sites were located outside of the study area. Most excavation sites are located 4-8 mi west of the study area along the east shoreline of Pleistocene Lake Cahuilla. These shoreline deposits have been a significant source of high-quality sand and gravel for more than 20 years; providing more than 20,000 yd^3 of material each year for local construction and agriculture (S. E. Hagerty, unpub. data, 1981). Developed deposits contain a sand to gravel ratio of 50 to 70 percent (Goldman, 1968). The deposits form a low ridge, 500 to 1,000 ft wide and 15 to 20 ft thick,

that extends for more than 80 mi along the eastern flank of the Imperial Valley. However, these lacustrine shoreline deposits do not extend into the study area.

A few sand and gravel operations are located east of the wilderness study area on the western piedmont of the Chocolate Mountains. Although the deposits in which these operations are located, cover about 50 mi^2 only 200-300 yd^2 of land have been mined (Goldman, 1968; Morton, 1977). Until 1962, material was intermittently excavated and processed with a portable crushing plant (Morton, 1977). This sand and gravel was primarily used as road base and bituminous aggregate (Goldman, 1968). These alluvial sand deposits extend into the study area, but lie beneath a significant thickness of dune sand.

Geothermal resources

The southernmost part (approximately 15 percent) of the North Algodones Dunes Wilderness Study Area lies within the Glamis Known Geothermal Resource Area. The Glamis resource area was established in 1970 as a result of the Geothermal Steam Act. Establishment of the known geothermal resource area boundary was based on a higher than normal geothermal gradient (8^0-10^0 F per 100 ft) determined from a geothermal investigation conducted by the University of California, Riverside (Meidav and Rex, 1970). The location of the positive geothermal anomaly under the Glamis Known Geothermal Resource Area corresponds with the location of a positive Bouguer gravity anomaly, suggesting that a hydrothermal system does exist beneath this area (Kovach and others, 1962; Mase and others, 1981). As of January 1983, no geothermal leases had been issued for the Glamis Known Geothermal Resource Area by the U.S. Bureau of Land Management (S. E. Hagerty, oral commun., 1981).

The feasibility of generation of electricity and recovery of dissolved salts (sodium, calcium, potassium, and lithium chloride) and metallic minerals (iron, lead, manganese, and zinc) from geothermal brines are currently undergoing examination within the geothermal province. Electricity is generated nearby from geothermal plants at Cerro Prieto, Mexico (150 MW; megawatt); Brawley, Calif. (10 MW), and East Mesa, Calif. (10 MW); and Chevron Resources has planned a geothermal plant south of El Centro at Heber, Calif. (Koening, 1967; Mase and others, 1981; and S. E. Hagerty, oral commun., 1982).

ASSESSMENT OF RESOURCE POTENTIAL

Oil and gas resources

Prior to the discovery of a significant gas resource near the mouth of the Colorado River in Mexico in 1981 (Pemex no. 1, Extremeno well), the oil and gas potential for the Imperial Valley was judged to be insignificant (Scott, 1983; Tarbet, 1971; Frizzell, 1984). All previous estimates of the hydrocarbon potential of the Salton Trough were at a disadvantage because of the absence of data pertaining to the potentially hydrocarbon-rich Pliocene and Upper Miocene marine sediments in the deep portion of the trough. The North Algodones Dunes Wilderness Study Area has a moderate to high potential for the existence of undiscovered gas/condensate accumulations, supported by (1) the discovery of a significant accumulation of gas (Pemex no. 1, Extremeno well) 60 mi to the south in a geologic environment similar to that which may exist in the wilderness study area, and (2) subsurface data collected from both existing wells and seismic reflection profiles within and adjoining the wilderness study area that imply an adequate thickness of favorable rocks with

potentially favorable structural traps (Terra Resources, written commun., 1984).

Mineral resources

The wilderness study area has a low potential for undiscovered placer deposits. The area of East Mesa and the Algodones dunes have a low potential because these sediments have been reworked from deposits of the Colorado River. Although claims and mines are located in the Chocolate Mountains and recent exploratory drilling has occurred east of the area along California Highway 78, drainage from these sites does not enter the study area. The one mine and two prospects located upfan from the wilderness study area, prior to military withdrawal of the Chocolate Mountains in 1942, removed about 522 tons of ore, mostly gold (Morton, 1977). If all potential source areas are equally barren and directions of sediment transport have been steady, then accumulation of placer deposits in fans within the study area seems unlikely.

The potential for sand and gravel resources within the wilderness study area is also low. The eolian dune sand that covers the area is too fine and well sorted for local use. Most of the local demand for sand and gravel requires a product with a 50 to 70 percent sand to gravel ratio. Material from the dunes is much too fine and would require extensive screening and processing to produce the required local product. As of 1981, few requests had been made for the fine sand found in the study area (S. E. Hagerty, unpub. data, 1981). Moreover, similar sand deposits are abundantly available outside of the study area.

Geothermal resources

The potential for geothermal resources within the wilderness study area is moderate. Generation of electricity and recovery of dissolved salts and metallic minerals would be the products of this potential resource. However, the presence of a substantial thickness of dune sand over most of the area would hinder geothermal exploration. One small sand-free area between the Coachella Canal and the west edge of the dune field would probably be the most feasible exploration site within the study area.

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