

Geology of the Death Valley Region

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GEOLOGY AND MINERAL RESOURCES OF THE AVAWATZ MOUNTAINS RESOURCE AREA, SAN BERNARDINO COUNTY, CALIFORNIA

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SUMMARY

Located in the northeastern Mojave Desert at the southern end of Death Valley, the 276,480 acre Avawatz Mountains GRA encompasses an area of diverse geology and mineral resources. Thick sedimentary sequences of Precambrian, Precambrian-Cambrian, Paleozoic and Mesozoic rocks have been intruded by Jurassic volcanic rocks and Mesozoic plutonic rocks. During Tertiary time extrusive volcanics and hypabyssal dikes and plugs intruded all older rocks in the Soda Mountains. Sediment were again deposited in Tertiary time.

A wide diversity of metallic and non-metallic minerals have been produced and prospected. The most profitable and productive deposits have been iron and talc, although gold and silver have been the most eagerly sought. Commodities known from this area include: iron, gold, silver, lead, zinc, copper, molybdenum, barite, talc, gypsum, salt, celestite, bentonite, and sand and gravel. There is potential for uranium and zeolites. Presently iron is produced and there is renewed exploration for silver in the central Avawatz Mountains.

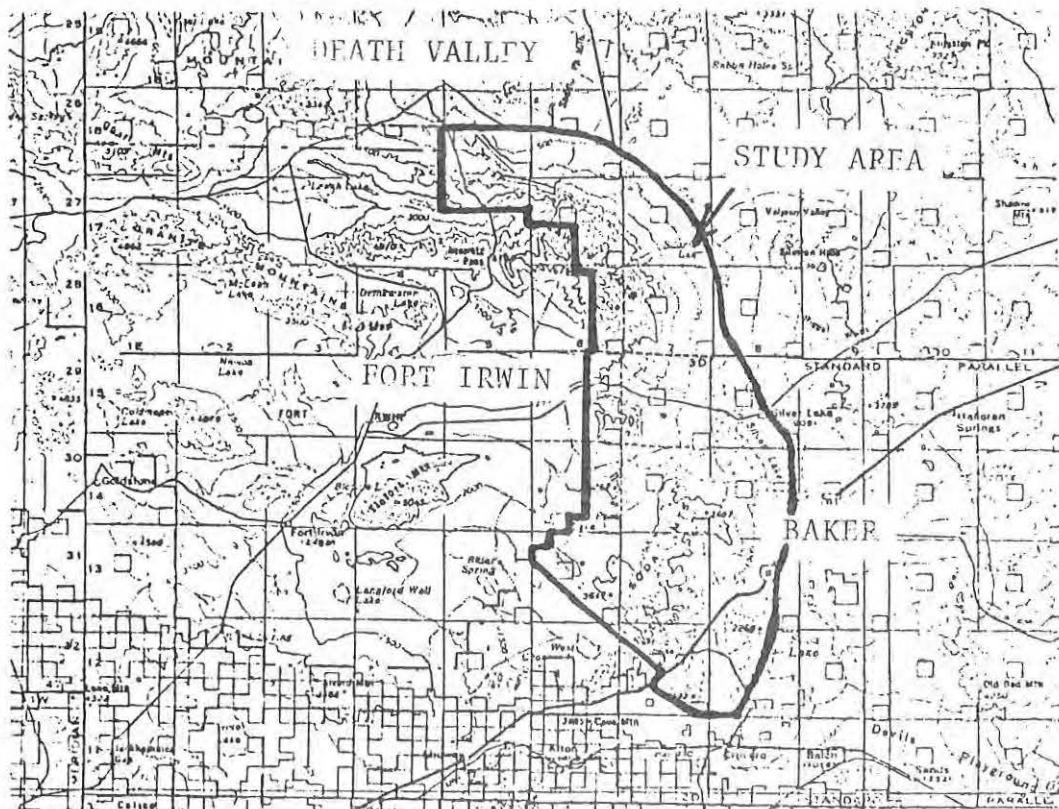


FIGURE 1. INDEX MAP AVAWATZ MOUNTAINS GEM RESOURCE AREA

INTRODUCTION

The Avawatz Mountains Geology-Energy-Mineral Resource Area (GRA) is located in the northeastern Mojave Desert at the southern end of Death Valley, California. This area comprises about 276,480 acres (432 sq. mi., 1,119 sq.km.) and embraces the Avawatz Mountains, Soda Mountains, and Red Pass Range. It includes all or portions of Townships 12-18 north and Ranges 6-8 east and Townships 17-18 north and Ranges 4 and 5 east SBM. It is circumscribed by 116° 30'W Lat. 35° 45'N Long. and 116° 04' Lat. and 35° 04' N Long. Located within the BLM California Desert District and Barstow Resource area is lies in the Owlshead Amargosa planning unit. It is included in California Desert Plan polygons 54,56, and 34 and wilderness study areas 221, 221A and 242. No areas were proposed for inclusion in the wilderness system in the California Desert Plan.

The only town in the area is Baker, located at the junction of California Route 127 and Interstate 15. The town of Silver Lake, a bustling supply center early in this century, is today nothing but crumbling ruins east of Route 127.

Excellent dirt roads lead to the Iron Mountain mine, parallel the high tension lines north of Silver Lake, and emerge from Death Valley on the north end of the area. Poorer quality dirt roads go into the Old Mormon Spring area, Five Point Mountain, Joe Dandy Hill, Sheep Creek, Soda Spring, Denning Spring Wash, Salt Basin and the Jumbo Salt areas. Dunn Siding on the Union Pacific Railroad is about 40 miles southwest of Baker. This siding is an important shipping point for many mines in this region. Talc and borates are also processed here. There is a small airport at Baker.

This large area is virtually devoid of place names and most of the area has never been surveyed. Three neglected names used in old references and readopted for use in this report are Five Point Mountain, Joe Dandy Hill, and Bonanza Mountain. Five Point Mountain is Peak 3497 located at 116° 13' 37" Lat. 35° 18' Long., Joe Dandy Hill is VABM 2849 located at 116° 12' 10" Lat 35° 14'0" Long., and Bonanza Mountain is Peak 3016 located at 116° 18'0" Lat. 35° 18'40" Long. Grose (1959), Noble (1922) and Butler (1979) suggest and use other place names in this area.

PREVIOUS STUDIES

The majority of the mapping and geologic descriptions of the area concern the northern Avawatz Mountains. The principal reports are by Bailey (1902) who described the salt, borax and nitrate deposits, Noble and others (1922) who discussed a sampling program in search of nitrates during World War I, Durrell (1953) who mapped and described deposits of celestite during World War II and Ver Plank (1952, 1957) who described deposits of gypsum and halite. Wright (1968) mapped Precambrian rocks near Sheep Creek Spring and described the talc deposits, Troxel and Butler (1979), Brady, Troxel and Butler (1980) and Brady and Troxel (1981) mapped the range at the intersection of the Garlock and Death Valley Fault Zones, and Clark (1979) mapped the trace of the Garlock Fault.

For the remainder of the area geologic mapping has been much less intense. Troxel (1967) mapped and described the southern Salt Spring Hills, and Gross (1959) mapped the Soda Mountains. Jahns and Troxel have been in the process of mapping the main portion of the Avawatz Range for probably twenty years. Jon Spencer (1981b) recently completed a doctoral thesis at MIT, in which he has mapped the Avawatz Mountains. An abstract of part of his work was published earlier in 1981. Woodburne (1978) summarized information about vertebrate fossils.

Work by geologists in some nearby areas has important implications on the geology and tectonic evolution of the Avawatz Range. Dunne (1977) described Old Dad Mountain, Kupfer (1960) mapped the Silurian Hills, Wright and Troxel (1966) studied the Late Precambrian-Cambrian strata in the area, Hewett (1956) mapped the Ivanpah 30' quadrangle, Marzoff (1980,1981) described the regional distribution of the Aztec Sandstone and Plescia (1981) examined evidence for continuation of the Garlock Fault east of Death Valley Fault zone. Information on mineral deposits is spotty. As noted above the industrial mineral deposits of the northern Avawatz Mountains have been thoroughly described. The Iron King and Iron Mountain mines have been described by Lamey (1948), Wright (1953), Forester (1953), Gay (1957) and Scott and Wilson (1980). The other mines in the area are described by Crosmann (1890) Ireland (1888), Cloudman (1919), Tucker (1921), Eric (1948), Wright (1953), Goodwin (1957), Crowley (1979), Ely (1980), and Henderson (1980).

Mining activity is also described in the following turn-of-the-century news papers and mining journals: Barstow Printer, The Citrograph, The Mining World, Mining and Scientific Press, The Mining and Oil Bulletin, American Mining Review, Mining Science and Mining Review. Additional information was gleaned from mineral survey notes and unpatented mining claim files.

Recent work by the BLM and other government agencies has added to information available on this area. Bushnell and Morton (1980) sampled the area for uranium. Drainage sediments were sampled by the BLM and for the BLM by G.V. Henderson and associates in 1978. The sediments were analyzed for 65 different elements. Aerial gamma-ray and magnetometer surveys were flown by the BLM and the DOE in 1979. Prelat and others (1979), as part of a larger survey of the eastern California Desert, used Landsat data to map tonal anomalies which are presumably areas of hydrothermal alteration. General Electric Co. in a contract with the BLM mapped lineaments.

ACKNOWLEDGEMENTS

Results of exploration work at the Bat Iron deposit was generously made available by J.K. Hayes of U.S. Steel. Robert Wilson with Kaiser Steel was also very helpful. Recent exploration work by other major mining companies may be useful for future workers. Freeport Exploration has mapped their property in the Five Point District and presently Newmont is mapping the Avawatz Crown Mine.

The following persons were generous with their help in the preparation of this report: Ken Shulte, Bennie Troxel, Charles Jennings, Marjorie Bushnell, B.C. Burchfield, Jon Spencer, Marion Ely, Johnny Garrison, Frank Nelson, Neil Hall, Richard Jahns, Louis Atkinson, Vance Echols, Wayne Johnson, Robert Wilson and J.K. Hayes.

GEOLOGY

PHYSIOGRAPHY

The Garlock Fault which runs east-west across the northern part of this area is generally considered the southern boundary of the Basin and Range Province.

The Mojave Block lies south of the Garlock Fault. The Avawatz Mountains GRA embraces three separate mountain ranges. The northwest trending Avawatz Mountains on the north, lying to the southwest, the Red Pass Range and the northeast trending Soda Mountains lying north of Interstate 15. South of I-15 is a distinct separated portion of the Soda Mountains.

The Avawatz Mountains rise abruptly on the east and north to a point 6154 feet above sea level from the lowest point in the area 250 feet above sea level 10 miles to the northwest.

Most of the drainages in the area eventually empty into the chain of playas which were part of a major drainage into Death Valley during Pleistocene time. These playas are Soda Lake, Silver Lake, and Silurian Lake. The Amargosa River was part of that drainage system. Red Pass Lake and Cronese Lake are basins of interior drainage which catch run-off from the Avawatz Mountains GRA.

PRECAMBRIAN IGNEOUS AND METAMORPHIC ROCKS

In the Soda Mountains, Grose (1959) mapped a gneissic complex which consists of fine-grained biotite-quartz paragneiss, biotite schist, amphibolite, quartzite, aplite and silexite. Migmatites involving these rock types with Mesozoic granitic rocks are wide spread. He concluded that this complex was originally "impure sandstone with subordinate layers of calcareous shale and possible basic volcanic rocks."

In the northern Avawatz Range Troxel and Butler (1979) concluded the gneiss was originally crystalline rock. The gneiss has been intruded by pegmatite, lamprophyre and diabase dikes of Precambrian age.

PRECAMBRIAN SEDIMENTARY ROCKS

Rocks of the Pahrump Group, which is comprised of the Crystal Spring Rocks of the Pahrump Group, which is comprised of the Crystal Spring Formation, Beck Spring dolomite and the Kingston Peak Formation are widespread throughout southern Death Valley. However, only rocks of the Crystal Spring and Kingston Peak Formations have been described from the area. The Beck Spring dolomite is conspicuously absent.

Crystal Spring Formation

The Crystal Spring Formation, the oldest formation of the Pahrump Group is stratigraphically similar throughout the southern Death Valley region. Wright (1968) and Kupfer (1960) demonstrated that the stratigraphy of the

Crystal Spring Formation includes sills of diabase and the presence of talc bodies along diabase contacts. According to Troxel and Butler (1979, p. 4):

The stratigraphic succession of the Crystal Spring Formation consists of a lower feldspathic quartzite member (arkose), purple argillite, fine-grained quartzite, a dolomite member with interbedded shaly and quartzitic strata, chert, and an upper sedimentary sequence made up of interbedded, carbonate strata (some of which are algal rich), quartzite, isnltstone, and fine-grained micaceous rock.

Beck Spring Dolomite

Troxel and Butler (1979) suggest the absence of Beck Spring Dolomite is the result of a facies change. The relatively homogenous pale gray dolomite occurs without significant variation in a belt that extends from the Kingston Range to south-central Death Valley. But, it is much more stratified, containing interbeds of siliceous clastic material and tan dolomite beds to the southwest. In the Silurian Hills, the Beck Spring dolomite is absent, but the Crystal Spring Formation is overlain by about 150 feet of limestone. Kupfer (1960) suggests this limestone may be a stratigraphic correlative of the Beck Spring dolomite.

Kingston Peak Formation

In the Death Valley region Troxel (1967) has recognized a northern and a southern facies. The two facies are separated along a norhtwest trending line that extends though southern Death Valley. The northern facies, deep maroon to pale green in oclor, consists of three principal units, a lower shale, a middle conglomerate and an upper quartzite. The southern facies, very dark gray in color, consists of conglomerate and quartzite. The Kingston Peak Formation, exposed in the southern Salt Sparings Hills and Avawatz Mountains are of the southern facies. In the southern Salt Springs Hills the Kingston Peak Formation is about 3,600 feet thick.

LATE PRECAMBRIAN-CAMBRIAN SEDIMENTARY ROCKS

The Avawatz Mountains, southern Salt Spring Hills and Soda Mountains are comprised of thick sections of Late Precambrian to Cambrian sedimentary rocks (Grose, 1959; Troxel and Wright, 1966; Troxel, 1967; Troxel and Butler, 1979; Jahns, pers. comm. November 6, 1980; Spencer, 1981).

In the southern Salt Springs Hills, Troxel (1967) recognized the Johnnie Formation, Stirling Quartzite, Wood Canyon Formation and Zabriskie Quartzite. North and west of Silver Lake Grose mapped sedimentary rocks which he tentatively correlated with the Noonday Dolomite, Johnnie Formation, Stirling Quartzite and Wood Canyon Formation. However, Troxel (pers. comm. March 3, 1981) does not believe these rocks are older than the Wood Canyon Formation.

High in the Avawatz Mountains, Troxel and Butler (1979) recognized the Johnnie Formation, Stirling Quartzite and Wood Canyon Formation. Spencer (1981) has mapped these metasediments in the central Avawatz Mountains,

which occur as pendants, and recognized the entire sequence up through the Sultan Limestone of Devonian age. Fragments of the Noonday Dolomite were recognized at various places in the northern Avawatz Mountains by Troxel and Butler (1979).

The Noonday Dolomite, first named by Hazzard (1937, p. 300) for exposures in the Nopah Range, consists of a lower algal dolomite and an upper sandy and gritty dolomite which commonly shows crossbedding. A clastic basin facies of the Noonday Dolomite first recognized by Troxel in the Saddle Peak Hills and has subsequently been identified in the Siluran Hills and Avawatz Mountains (Troxel and Butler, 1979).

Overlying the Noonday Dolomite is the later Precambrian-Cambrian Johnnie Formation, Stirling Quartzite, Wood Canyon Formation and Zabriskie Formation. These formations were formerly mapped as the Prospect Mountain Quartzite, now an abandoned term (De Courten, 1979). The Johnnie Formation is a heterogenous sequence of shale, siltstone, sandstone, conglomerate, limestone and dolomite. The Stirling Quartzite is a light colored, quartz sandstone and conglomerate with subordinate units of siltstone and carbonate. The Wood Canyon Formation is composed of siltstone and quartzite with minor amounts of dolomite and conglomerate. The Zabriskie Quartzite is a medium to fine grained massive to cross bedded quartzite with subordinate units of sandy shale and conglomerate locally present.

The Carrara Formation of lower to upper Cambrian age which overlies the Zabriskie Quartzite, is generally composed of gray to greenish shale intercalated with gray limestone (De Courten, 1979).

Conformably overlying the Carrara Formation, the Bonanza King Formation is composed of interbedded gray and white calcite marble and tan dolomite marble (Spencer, 1981). Spencer recognized a thinly bedded calc-silicate unit which allowed the division of the Bonanza King Formation into the lower Papoose Lake member (172 meters tectonic thickness) and the upper Banded Mountain member (235 meters tectonic thickness). The conformably overlying Dunderberg Shale member of the Nopah Formation is composed of 5 meters of crumbly, thin bedded, green, maroon and brown calc-silicate and gray calcite marble (Spencer, 1981a).

PALEOZOIC SEDIMENTARY ROCKS

Paleozoic carbonate rocks crop out on the north slope of the Avawatz Mountains, in the central Avawatz Mountains and in the Soda Mountains. Most of the rocks in the Soda Mountains have not been correlated with any other rocks in the region. In the central Avawatz Mountains, Spencer (1981a) has recently recognized the Sultan Limestone. He indicates:

Silicified stromatoporoids of the Devonian Sultan Limestone first occur about 40 meters above the Dunderberg Shale and indicate that a Devonian-Cambrian disconformity occurs within the intervening 40 meters of massive tan dolomite marble. This stromatoporoid bearing tan dolomite marble is correlative with the Ironsides-Valentine (undifferentiated) members of the Sultan Limestone.

In the Soda Mountains, Grose recognized the fossiliferous, Permian Bird Spring Formation. The formation is exposed at Five Point Mountain and Baker Hill. On Five Point Mountain it constitutes a klippe which contains at least 5,000 feet of east dipping beds which may or may not be repeated or faulted. The Bird Spring Formation is a monotonous sequence of thin to medium bedded dark-to light gray clastic limestone with abundant chert nodules, lenses and beds. There is some calcareous siltstone and shale present on top of Five Point Mountain. Spencer (1981b) recognized the Bird Spring and Monte Cristo Formations in upper Sheep Creek. Correlation with these formations was based on lithologic similarities and the presence of fusilinids of Pennsylvanian or Permian age.

TRIASSIC-JURASSIC SEDIMENTARY ROCKS

The Triassic sedimentary rocks which are exposed in the Soda Mountains were first described by Grose (1959). Recently, Marzolf (1980, 1981) and Birchfiel and others (1980) have noted the striking similarity of these rocks with other rock sequences of probable Triassic age. Two different sedimentary units were mapped in the Soda Range. The lower consists of 1,700 feet of gray limestone interbedded with distinctive red, green and gray argillite and shale. A very distinctive limestone pebble conglomerate occurs locally. Tiny (1 mm) gastropod fossils of Late Permian to Triassic age were discovered 650 feet above the base of the exposed section. On paleontological grounds this formation was assigned an age to Lower Triassic. Grose, considered this formation a possible western equivalent of the Moenkopi formation. The overlying formation is an unfossiliferous 7,000+ foot thick sequence of massive andesite flows, flow breccia, pyroclastic rocks, welded tuff and pure quartzite. Grose (1959, p. 1562) named the formation the Soda Mountain Formation, however he and others (Marzolf, 1980) have observed the similarity with the Aztec Sandstone. The name Soda Mountain Formation should be considered obsolete in favor of the Aztec Sandstone.

MESOZOIC VOLCANIC ROCKS

Pre-Cretaceous metavolcanic rocks crop out southwest of Denning Spring, in the Red Pass Range and throughout the Soda Mountains. Southwest of Denning Springs Brady, Troxel and Butler (1980) mapped an elongate body of metasedimentary and metavolcanic rocks. On the Trona geologic sheet these rocks are shown as Pre-Cretaceous metavolcanic rocks.

The Soda Mountain Formation of Grose is interbedded with a thick section andesites with subordinate dacites. Pyroclastic constituents consist of welded tuffs, tuffaceous impurities in the sandstones and flow breccias. South of I-15 he estimated andesitic and dacitic flow breccias are 2,500 feet thick.

MESOZOIC PLUTONIC ROCKS

In the Soda Mountains, east of the Soda-Avawatz Fault zone, Grose (1959) mapped wide spread granodiorite and quartz diorite, with subordinate pod-shaped bodies of granite and a basic complex comprised of diorite, gabbro and hornblende-epidote rock. Near Silver Lake he mapped migmatite and porphyritic granodiorite. West of the Soda-Avawatz Fault Zone the dominant plutonic rocks are quartz diorite and adamellite. The adamellite is petrographically correlative with the Teutonia quartz monzonite of Hewett (1956, p. 61). Lead-alpha dating of a sample south of I-15 by Larsen (1958, p. 50) has yielded an age of 96 million years, or Cretaceous. Other plutonic rocks include granite and altered granite.

The altered granite of the Blue Bell mine area according to Grose (1959, p. 1532) appears, "to have originated by brecciation of quartz dioritic rocks, probably because of movement of subjacent magma, which was closely followed by silicification and epidotization. The presence of lead, silver, and copper mineralization is undoubtedly related to these late magmatic effects."

In the southern Salt Springs Hills, Troxel (1967) mapped hornblende biotite quartz monzonite.

The most common rock in the Avawatz Mountains is diorite composed mainly of medium to coarse grained hornblende and plagioclase with rare quartz. The diorite near Sheep Creek yielded a K-Ar age of 126 my or Cretaceous (Brady, Troxel and Butler, 1980). The second most common rock bears a general resemblance to quartz monzonite in the Owlshead Mountains and to the Teutonia quartz monzonite. Troxel and Butler (1979) have identified several different phases of this rock including: reddish coarse-grained granitic rock, fine-grained rock, coarse-grained, pale-colored quartz monzonite, granodiorite, and garnitiferous quartz monzonite.

TERTIARY EXTRUSIVE AND HYPABYSSAL ROCKS

In the northern Avawatz Mountains the oldest Tertiary rocks are volcanic. These volcanics lie beneath the Tertiary sedimentary rocks, and clasts of the volcanics are contained in the sediments. The volcanic rocks crop out in a discontinuous linear zone, roughly parallel with the central branch of the Death Valley Fault Zone. The most abundant rock type is andesite, that may be a lahar type of flow. Locally associated with it are beds of air-fall ash. Along strike about 7 miles to the southeast, rhyolite and rhyo-dacite crop out in a similar linear manner (Troxel and Butler, 1979, p. 10).

The Soda Mountains west of the Soda-Avawatz Fault Zone have been intruded by innumerable hypabyssal dikes, plugs and irregular masses of diabase and felsite. Over-all the trend of the dikes is N 60°-70°W. In the Blue Bell mine area the dikes constitute nearly half of the exposed rock. East of the Soda-Avawatz Fault Zone intrusions are small irregular, and lacking obvious orientation. However, diabase is also predominate, felsite is restricted to Baker Hill. Porphyritic rocks common in the western area are absent.

In the western-most end of the Soda Mountains andesite intruded Mesozoic granitic rock.

TERTIARY SEDIMENTARY ROCKS

Tertiary sedimentary rocks crop out on the northern and southwestern flanks of the Avawatz Mountains, in the Soda-Avawatz Fault Zone in the Soda Mountains and between the Red Pass Range and the Soda Mountains. The Tertiary sedimentary rocks in the northern Avawatz Mountains are contained within three belts, bounded by lateral-slip fault zones. A fourth belt of outcrops occurs east of Salt Spring Wash and a fifth belt occurs south of the Garlock Fault. There have been no fossils identified in these rocks however south of bench mark 830 feet, hoof prints are preserved in maroon beds which also contain mud cracks, ripple marks and rare worm borrows. The rocks in each belt are distinctive and they all appear to have been deposited in alluvial fan, river delta and lacustrine environments.

The Avawatz Formation which crops out in the southern Avawatz Mountains and Soda Mountains has been divided into three members: a lower boulder fanglomerate member at least 3,200 feet thick, a middle member of sandstone, pebble lenticles and subordinate tuff which totals about 11,000 feet thick, and an upper member of pebbly debris at least 1,100 feet thick (Grose, 1959, p. 1534).

Monolithologic breccia beds and lenses are an unusual component of the Tertiary rocks of the Avawatz and Soda Mountains. In the Avawatz Formation there are lenses of monolithologic purple andesite breccia and isolated masses of monolithologic limestone breccia. The limestone breccia forms irregular tabular bodies 10 to 100 feet thick and up to 2,000 feet long. One 30 foot thick bed is 2 miles long. In the northern Avawatz Mountains discontinuous beds of monolithologic breccia are composed of pale-colored quartz monzonite of Precambrian gneiss, with an occasional minor component of granular trachytic andesite (Troxel and Butler, 1979, p. 13). Lamey (1948) suggested the monolithologic breccia at Red Pass either slid or was thrust into place.

The sediments on the northern end of the Avawatz Mountains contain deposits of gypsum, salt, niter, celestite, bentonite, barite, manganese oxides and iron oxides. Although, the barite occurs in veins and is not of sedimentary origin. Recent analysis by Bushnell and Morton (1980) from the Avawatz Formation on the southwestern flank of the Avawatz Mountains detected anomalous amounts of uranium. In this same area monolithologic breccia contains valuable iron deposits.

PALEONTOLOGY

On the southern and southwestern flank of the Avawatz Range, vertebrate fossil fauna has been found in the Avawatz Formation. The fauna occurs in an upper unit which consists of arenaceous clastic sediments, tuff and coarse-grained sandstone at the top. The tuff beds have been K-Ar dated at 10.7 and 11.0 my. Collected fauna includes: Pseudaelurus intrepidus,

Perognathoides cf. tertius, Peromyscus dentalis, Hypolagus, Gomphotherium cf. simplicidens, Pliohippus, Procamelus coartatus, Merycodus cf. corroensis (Woodburn, 1978, p. 49).

In the Soda Mountains Grose (1959) has identified invertebrate fossils in three sedimentary units. A white and gray limestone of Mississippian-Pennsylvanian age contains crinoid stems. In the Permian Bird Spring Formation Schwagerina, Triticites, Syringopora, tetracorals, echinoid spines, crionid stems, bryozoa, small gastropods and numerous fusulinids were found. Gastropods were discovered in a Triassic formation, possibly correlative with the Moenkopi Formation. Spencer (1981a, b) identified stromatoporoids in the Devonian Sultan Limestone in the central Avawatz Mountains. And in upper Sheep Creek he identified fusulinids in the Bird Spring and Monte Cristo Formations.

STRUCTURE

Faulting

Structure is complex, as rocks of all ages have been folded and faulted. The main faults recognized in the study area are the Garlock, Death Valley, Mule Spring and Soda-Avawatz. The entire area abounds in faults with minor offsets and various trends. Most Pre-Tertiary rocks are shattered or cut by closely-spaced faults.

The left-lateral Garlock Fault is expressed as a south facing scarp south of which are grabens, mostly in young gravel. The Garlock Fault terminates in the Avawatz Mountains, at the intersection with the Death Valley Fault zone. East of the Death Valley Fault the Garlock may have extended beneath the Kingston Wash (Plescia, 1981).

The Mule Spring Fault extends the length of the northern Avawatz Mountains. On the northeastern edge of the Avawatz Mountains it wraps around the range and flattens to a westerly dip as low as 33 degrees. This reverse fault with little or no lateral movement, cuts branches of the Death Valley Fault. In one exposure south of Sheep Creek bedrock diorite is thrust over Quaternary fan gravels.

The right-lateral Death Valley Fault is part of a larger zone that includes the Furnace Creek Fault in the north and the Soda-Avawatz to the south. In the Avawatz Mountains it consists of several branches in a zone about 2 miles wide. In Death Valley the fault has offset Quaternary stream channels.

The Soda-Avawatz Fault cuts the Soda Mountains and is considered by Grose (1959, p. 1544) an extension of the Death Valley Fault. Jennings (1975) indicated that Quaternary displacement has taken place on this fault.

Pre-plutonic thrust faulting occurred in the Soda Mountains during Mesozoic time. In the northern Avawatz Mountains several thrust faults have been recognized (Troxel and Butler, 1979, p. 23). These faults may be Mesozoic in age, although some may be Tertiary in age and related to the lateral-slip faults.

Lineaments

Lineaments identified by remote sensing methods follow the Death Valley, Soda Avawatz and Mule Spring Fault zones. Also, there are three parallel northeast trending lineaments which cross the Soda Mountains. The southern most cuts Joe Dandy Hill, the northern most cuts Five Point Mountain. In the Avawatz Mountains there are two parallel northeast trending lineaments. The northern most intersects with an east-west trending lineament at the Avawatz Crown mine. The northeast trending lineaments at Joe Dandy Hill and Five Point Mountain correspond with mapped faults. It is not known if the lineaments in the Avawatz Mountains correspond with faults. In an portion of the Soda Mountains 4 miles northwest of Crucero siding, there is a mapped northeast trending fault, not identified as a lineament.

Folds

Along faults in the northern Avawatz Mountains folds of limited extent are common in Tertiary silty and gypsiferous units. In the Soda-Avawatz Fault Zone just north of I-15 there is a major anticlinal uplift. South of the anticline is a syncline which has been cut by several high angleaults. On Five Point Mountains there are a few prominent drag folds resulting from thrust faulting.

GEOLOGIC HISTORY

The first geologic event was the intrusion during Precambrian time of granitic magma in the northern Avawatz Range and the accumulation of sedimentary material. These rocks have since been metamorphosed into gneiss.

During Late Precambrian time the Kingston Peak Formation was deposited. However, a widespread unconformity separates it from the overlying Late Precambrian Noonday Dolomite. Troxel (1967) concluded that this regional unconformity, "suggests tectonic activity of undetermined magnitude following the deposition of the Kingston Peak Formation."

During Late Precambrian to Cambrian time sediments were deposited in a north trending trough. To the west and south the sediments thin. Conformably overlying these sediments are the Carrara, Bonanza King and Nopah Formations of Cambrian age. Sediments of Ordovician and Silurian are missing, possibly representing a period of uplift or erosion. The Devonian Sultan Limestone paraconformably overlies the Nopah Formation. Spencer (1981) suggests that the complex facies and isopach trends in the northeast Mojave desert are indicative of a southeast trending embayment and perhaps indicate complex patterns of miogeosynclinal margin subsidence during Paleozoic time.

Marine sedimentation probably continued from Late Paleozoic into early Triassic time. Lower Triassic strata grades upward from limestone into siltstone and fine sandstone of shallow-water environment. These grade into continental sandstone intercalated with andesite breccia.

Continental volcanism and sedimentation lasted until at least the Middle Jurassic. Andesite flow breccia, pyroclastic rocks and nonmarine, possibly eolian quartzite (the Aztec sandstone) represent this episode.

During Mesozoic time, probably during the Cretaceous Period, thrust faulting was followed by intrusion of plutonic rocks. The onset of igneous activity and compressional tectonism is believed to reflect the beginning of an episode of east directed subduction along the west coast of North America (Dunne, 1977, p. 737). Grose (1959, p. 1537) assumed the thrusts were of Laramide age, however now it is believed that no Laramide age or younger compressional structures exist in the northeastern Mojave Desert (Dunne, 1977, p. 737).

Probably shortly after consolidation of the Mesozoic granitic magma hypabyssal dikes and plugs intruded all older rocks in the Soda Mountains. The oldest of these Tertiary dikes is diabase which was cut by younger felsite.

In the northern Avawatz Mountains the oldest Tertiary rocks are volcanic flows. These are overlain by sediments which were deposited in alluvial, fan, river delta and lacustrine environments. The youngest Tertiary sediments in the southern Avawatz Mountains contain an upper tuff unit with a K-Ar age of 10.7 to 11 my or Miocene. This tuff layer may correlate with the extrusion of volcanic andesite, rhyolite and pyroclastic deposits on the western end of the Soda Mountains, and the onset of Tertiary faulting.

From mid-Pliocene through Pleistocene the area was regionally uplifted, folded, faulted and eroded. Movement took place on the Death Valley, Mule Springs, Garlock and Soda-Avawatz Fault zone. At this time a major water course now partially represented by the Soda Lake, Silver Lake and Silurian Lake Playas drained into Death Valley (Lake Manly). Debris from the Avawatz Mountains blocked this drainage north of the southern Salt Springs Hills for a period of time, and sediments were deposited in the basin which formed south of the Salt Springs Hills. Baker (1980) has postulated that prior to 700,000 years ago the Amargosa River flowed south through this drainage to the Colorado River.

MINERAL RESOURCES

Within the Avawatz Mountains GRA there are measured or indicated reserves of salt, iron and celestite (see Table 1). In addition there are deposits which contain gold, silver, lead, copper, zinc, molybdenum, talc, gypsum, bentonite and barite. There is speculative potential for borax, zeolites, uranium/thorium and oil-gas. The most significant production has come from iron and talc deposits. There has been production of gold, silver, copper, lead, zinc, salt, bentonite, sand and gravel (see appendix 1). Continued interest in the minerals in the area is evidenced by the 315 unpatented claims which were located as of January 1981 (see Figure 2). Mines and claims are listed by commodity in appendix 2, and shown on Figure 3.

This section of the report has been divided into four subsections titled, History of Mining, Mining Districts, Metallic Minerals and Non-Metallic Minerals. In the Metallic and Non-Metallic mineral subsections data is presented by commodity. The lode deposits of gold, silver, copper, lead and/or zinc are analyzed by area. Drainage sediment geochemical data, which does not conveniently fit into this outline, is treated separately. Geochemical data from known mineralized areas is examined first then data in areas with no known mineral deposits is examined.

HISTORY OF MINING

The Mohave Indians, long before white-man had explored the region, recognized the intense hydrothermal alteration in the Avawatz Range calling it Avi-Ahwat or red rock. It is highly probable that the 1849 gold discovery by Mormon settlers in the northern Salt Spring Hills tempted others to explore into the Avawatz Range. (The Mormon Trail that skirted the east flank of the range and headed west through Red Pass provided access to the otherwise remote range.) The northern part of the range was in-fact in the Amargosa Mining District, established following the discovery at Salt Spring Hills.

In November 1871 John Moss discovered high grade silver ore and located the San Francisco lode. At the Summit mine, the Mining and Scientific Press (June 8, 1872) reported a 32 foot wide vein yielded \$300 per ton in silver. As of the date 4.5 tons of ore had been shipped from the mines. Work continued until 1873.

The high price of silver and closer rail transportation in the 1880s stimulated interest in the range. In 1885 there was prospecting at the Iron King mine and Five Point Mountain (Calico Print, March 1, 1885). In 1888 Ireland reported that: "Mineral in paying quantities has been found on both slopes, all along the ranges." From high in the range at mines numbered 1, 2, 3, 4, 5, 6, and 7, silver ore was shipped to Barber's mill at Calico. In the late 1880s and early 1890s Joe Dandy Hill was the location of considerable mining interest (Ireland, 1888, p. 502; Crossman, 1890). It was probably at this same time salt was mined from the north end of the range for use in reducing silver ore at the Ibex mine, now in DVMN (Bailey, 1902, p. 128).

Table 1
Identified Reserves and Resources

Measured Reserves and Resources

Salt

Boston Valley (27 drill holes)
1,300,000 tons +92% salt from 0-170 ft.¹

Iron

Iron Mountain (11 drill holes)
5, 175,000 long tons 54% iron ore²
4,600,000 long tons 69% iron³

Bat (6 drill holes)
1.1 million tons 54%⁴
(less 30,000 tons extracted 1967-1969)

Indicated Reserves and Resources

Salt

Jumbo: 1,485,000 tons¹

Salt Basin: 3,960,000 tons¹

Boston Valley (all): 15,000,000 tons¹

King Claims: 99,000 tons¹

Celestite

Jumbo, Salt Basin, Celestite Hills, Cave Springs Wash
250,000-300,000 tons 81% SrO from 0-50 feet.⁵

Iron

Iron King: 375,000 long tons from 0-100 feet. 54% iron^(2,3)

Inferred Reserves and Resources

Iron

Iron Mountain: 1,000,000 long tons 54% iron^(2,3)

Sources: 1) Calzia and others (1979)

2) Lamey (1948)

3) Moore (1971)

4) J.K. Hayes (written comm. March 26, 1981)

5) Durrell (1953)

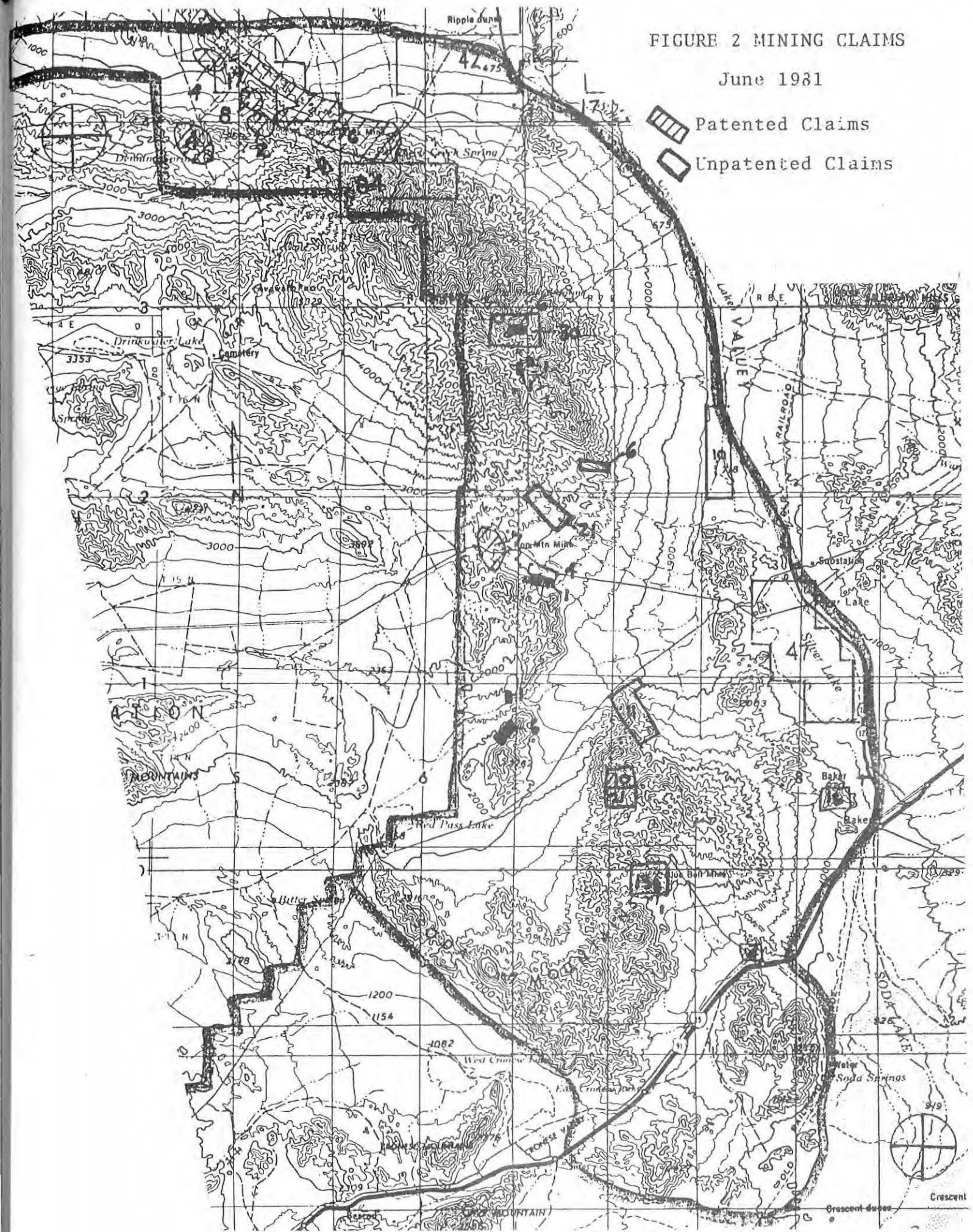


FIGURE 2 MINING CLAIMS

June 1981

Patented Claims

Unpatented Claims

FIGURE 3 MINES
& OCCURRENCES



LEGEND

- mine or deposit, principal commodities shown.
- ? prospect, commodity unknown.

AG-silver
 AU-gold
 BA-barite
 BN-bentonite
 CL-celestite
 CU-copper
 GY-gypsum
 HL-halite
 FE-Iron
 PB-lead

the field. Hydrothermal alteration has stained the rocks bright red high in the Avawatz Mountains. These red rocks were identified using digitally processed Landsta data (Prelat, 1979).

The base metal deposits in the Avawatz Mountains and at Five Point Mountain seem to be associated with negative (-300 gamma) magnetic anomalies. The base metal deposits at Joe Dandy Hill are associated with a positive (zero gamma) magnetic anomaly. The iron deposits at Red Pass are associated with a positive (zero gamma) magnetic anomaly. The most intense magnetic anomaly (+300 gammas) was detected on the north side of the Soda Mountains in a geologic setting similar to the Red Pass iron mines.

Drainage sediment (heavy mineral concentrate) geochemical sampling detected values of Mo, Cu, Zn, and Pb at least above the mean in known mineralized areas. In five areas not known to be mineralized these elements were as high as in the known mineralized areas. Cobalt values were high in the Soda Mountains. However, rare earth values were generally low.

LODE DEPOSITS OF GOLD, SILVER, COPPER, LEAD AND/OR ZINC

Within the Avawatz Mountains GRA the most important lode base and precious metal deposits occur in the Avawatz Mountains, Bonanza Mountain, Five Point District and Joe Dandy Hill. Although there has been intermittent prospecting for perhaps 130 years there has been only minor production. Renewed interest by companies armed with modern methods of exploration and extraction may develop deposits that have tempted prospectors for so long.

Avawatz Mountains

Base and precious metal deposits in the Avawatz Mountains are almost entirely restricted to structurally controlled replacement or fissure filling veins. Several workers (Crossman, 1890; Brady, Troxel and Butler, 1980, Spencer, pers. comm. February 11, 1981; Jahns, pers. comm. November 6, 1980) have independently noted widespread mineralization in the Avawatz Mountains. Crossman noted: "Near the summit of the highest peaks veins of gold, silver, copper and lead occur." Brady, Troxel and Butler observed: "Minor chalcopyrite occurs in the diorite and supergene copper is common along fractures throughout the diorite. Several small copper prospects have been dug in the high Avawatz along the contact between the diorite and the Precambrian marble roof pendants. No ore has been produced from the prospects." Copper prospects were observed by Jahns, from peak 2733, east of Sheep Creek, southward to the Avawatz Crown mine. He also noted considerable prospecting in the Bonanza King Formation in upper Sheep Creek and at Avawatz Peak. Spencer (pers. comm.) confirmed that malachite occurs in Paleozoic carbonates near Arrastre Spring.

According to a July, 1919 Mining and Oil Bulletin article (see appendix 3), the Avawatz Crown mine area has been brecciated by faulting, subject to hydrothermal metasomatism and subsequently leached. Brecciation of the limestone resulted form the movement on high angle faults which presumably cut low angle faults which were "along original bedding planes." Hydrothermal metasomatism subsequently silicified and mineralized the limestone. The deposit is mineralized with gold, cerargyrite, copper carbonates, lead and copper sulfides, silver bearing galena and iron oxides. A

sample from the richest part of the deposit assayed 150 oz. silver, 20% lead, 5.5% copper, 6% zinc. The brecciated zone ran a consistent 4 oz. silver and 8.5% lead. Bright red hydrothermally altered rocks in the Avawatz Crown and Morris A.C. mine area were digitally identified from Landsat data by Prelat and others (1979).

One unusual deposit is reported from the south end of the range. Here the Green Hornet claims have been located in green Tertiary clay which may carry values of silver and gold.

Bonanza Mountain

Bonanza Mountain is the southern most part of the Red Pass Range. It is mapped wholly as Triassic-Jurassic metavolcanic rocks on the Trona map sheet. Grose (1959, p. 526) stated: "The Red Pass Range is largely made up of metavolcanic rocks which are probably part of the Soda Mountain Formation." In an article which appeared in the American Mining Review and quoted in the Citrograph of January 18, 1908, Gilbert E. Bailey described the geology differently.

He described Bonanza Mountain as a monoclinal uplift;

...with the northwest edge tipped up, the strata dipping east and south. The main mass of the mountains is comprised of highly siliceous rocks of sedimentary origin, which are intersected by two systems of veins, the more prominent one striking northeast southwest, standing nearly vertical.

The formation is cut by numerous dikes of diorite and the porphyritic variety of that rock called porphyrite. These dikes have a generally north-south strike.

Gold was discovered on the north slope of Bonanza Mountain in February 1906 by S.S. Worley and W.L. Snodderly. By June 1907 the Crackerjack Bonanza Gold Mining Company had acquired the property and had 400 tons of ore on the dump and 450 sacks of high grade ore ready to ship. The ore reportedly assayed between \$100 to \$500 per ton.

This company located the Goodwater claim in the wash north of the mines and sunk a well. A boarding house and other buildings were constructed and finished by October 1907 and the place began to be known as Bonanza Camp. It was connected to Silver Lake and Crackerjack, by auto stage service.

In December 1907 shipments of ore were made to Salt Lake which ran \$100 to \$300 per ton. In March, 45 tons of ore shipped to a mill at Victorville netted over \$2,000. By April, 1908 there was 400 feet of underground workings including an 100 foot-two compartment shaft sunk on the boundary of the Arizona and Owl claims. The dump contained 3,000 tons of ore in July, 1909 which assayed between \$5 and \$80 per ton. At this time the main shaft was down to 200 feet. F.L. Flourman, who was manager of the property, appears to have continued to direct operations until 1911 and perhaps as late as 1913. Eventually the main shaft was sunk to 250 feet.

In the late 1970s (1979 or 1980) Paul Ottell of the Chelsea Mining Company leased the patented claims from the owner. They began a project in late 1980 to heap leach gold and silver from the waste dump at a rate of 20,000 tons a year (Ely, 1980). The mine operators are using bentonite clay which occurs at this deposit as a liner for their heap leach pads. By October 1982 these operations ceased, due to a disagreement between interested parties.

The ore deposit at the Crackerjack Bonanza mine was described by Bailey in 1908. He observed that:

The veins are well defined, and generally with clay gouge. In the upper portion the veins are iron-stained quartz, but in depth pyrite and chalcopyrite appear. It is thought, from all that has been observed that the permanent water level will be found below 400 feet, and it is expected that the zone of oxidation will extend far below the surface.

The ore is gold-bearing and free-milling ranging from coarse to fine. The quartz is granular and crushes readily by any of the usual machinery used for the purpose.

Ely (1980) also noted the clay when he described: "Extensive hydrothermal alteration has resulted in the production of a large bentonite clay footwall underlying high-grade silver deposits containing some gold."

Joe Dandy Hill

Geology and mineral deposits at Joe Dandy Hill have been described by Ireland (1888), Crossman (1890), Wright (1953), Goodwin (1957), Grose (1959), and Crowley (1979). By far the most complete work is that of Grose (1959). Crowley (1979), who extensively quoted Grose, examined the paragenesis of minerals present at the Blue Bell mine (see appendix 4).

Grose (1959) mapped Mississippian-Pennsylvanian metasediments which have been intruded by an extensively altered Mesozoic granitic rock. Thin limestone beds in the metasediments have been metasomatically replaced by assemblages of garnet and calc-silicates, hundreds of meters from the contact with the granitic rock. The granitic rock was altered by later hydrothermal fluids, fluids which probably deposited metallic minerals. Faulting in the area was severe, and a number of fractures have been partly filled with secondary minerals during oxidation of the deposit.

Oxidation of the ore deposit at the Blue Bell mine is nearly complete. However, the limonitic gossan which frequently accompanies weathered sulfide deposits is poorly developed. Limonitic minerals are present in minor amounts. Minerals which occur at the Blue Bell mine include anglesite, brochantite, calcite, caledonite, cerussite, chlorargyrite, chrysocolla, dioptase, fluorite, hemimorphite, leadhillite, linarite, quartz, roasiste and wulfenite (Crowley, 1979). The intense alteration, fracturing and mineralization are frequently indicators present in porphyry type deposits. Presumably the mineral deposits on Joe Dandy Hill could be the top of this type of deposit.

Five Point Mountain

Five Point Mountain consists of Mississippian-Pennsylvanian limestone, the Permian Bird Spring Formation, a lower Triassic sedimentary formation which resembles the Moenkopi Formation and the Triassic-Jurassic Aztec sandstone which is interbedded with andesite flows. Upper Mesozoic quartz monzonite and Tertiary plugs and dikes have intruded the older sediments.

Low angle east dipping faults have thrust the Permian Bird Spring limestone over the older Mississippian-Pennsylvanian unit. The bottom of the limestone unit is in fault contact with Mesozoic metavolcanic rocks. On the northwest side of Five Point Mountain is a mosaic of fault blocks involving the Aztec sandstone and felsite porphyry.

In the Mississippian-Pennsylvanian limestone, small-scale recrystallized silica and calcite occur widely because of faulting and metamorphic effects of granitic and volcanic intrusion. The Bird Spring Formation being the upper most thrust sheet in Five Point Mountain, is farthest from the intrusive quartz monzonite and is the least altered. On the west side of the mountain Tertiary dikes and plugs have thermally altered lower Triassic limestone and shale (Grose, 1959).

The first mineral locations in the Five Point District were made prior to 1885 for copper and silver (Calico Print, March 1, 1885). Between 1906 and 1914 there were numerous active mines. A mining camp named Day Break is shown here on a 1906 map, near the Break of Day or Three States mine. Two of the most important operations were at the Three States mine and the property operated by the Amos Brothers and later by the Garrison Investment Company (see appendix 2). The geology and nature of mineralization appears to be very similar. Limestone country rock was intruded by chalcopyrite-bearing andesite porphyry, and diorite dikes. Assays reported were equivalent to 23 oz. silver per ton, .6 oz. of gold and 3% copper. The values of silver and copper are in agreement with assays from the Mary-June claims in the late 1970's.

The Mary-June claims were located in May, 1975 by Johnny Garrison of Mina, Nevada. Garrison interested Freeport Exploration in the property, and they leased the claim from him. In November, 1975 Frank Nelson, geologist with Freeport Exploration, located in Tiburon claims.

On this property, a breccia pipe in Tertiary andesite is mineralized with limonite and copper oxides. Soil and rock samples average 9-20 ppm silver, 10-30 ppm molybdenum and .3% copper. The highest values range up to 20 oz. of silver per ton and 3.3% copper. Mr. Garrison also reported that gold occurs here. From the results of drilling it appears the breccia pipe is vertically zoned with highest metal concentrations at the top.

Prior to August, 1980 two holes were drilled in the breccia pipe in an attempt to intersect a hypothesized porphyry copper deposit. The first hole was drilled in a shear zone to a depth of 245 feet before it was abandoned. The drilling of this hole proved very difficult, with very poor core recovery. A second hole drilled to 963 feet also proved difficult. They did intersect an andesite body in the hole, that yielded

dissapointingly low metal values. In addition, 14 airtrack holes were drilled to a depth of 150 feet, probably in the initial phases of exploration.

IRON

Contact metasomatism of limestone during the intrusion of granitic rocks formed iron deposits in various parts of the Avawatz Mountains, and Soda Mountains. The only known deposits of commercial importance may have been complaced as a landslide deposit or thrust into place (Lamey, 1948). A DOE (NURE) airborne magnetometer survey may have located another deposit.

The Iron Mountain, Bat and Iron King iron deposits are unusual in that the iron ore rests on a Tertiary fan-lacustrine sequence (see appendix 5). The iron ore is contained in a body of monolithologic limestone breccia over 200 feet thick. Lenses within the breccia contain iron ore and brecciated igneous and metamorphic rocks that have been tightly cemented with calcium carbonate.

At the Iron Mountain mine magnetite is the predominant mineral but small quantities of secondary hematite and limonite are present. The principal gangue mineral is calcite. Pyrite is present below the oxidized zone. Copper in the form of malachite and chrysocolla is present in minor amounts (Scott and Wilson, 1980). The copper minerals occur along vertical fractures in the ore body, clearly deposited sometime after the iron was emplaced (Wilson, pers. comm. March 13, 1981). Gold has also been reported (U.S. Mineral Survey MS 3923).

Small undeveloped bodies of iron ore occur in the central Avawatz Mountains. While mapping the range, Spencer (pers. comm. February 11, 1981) discovered an iron bearing skarn at the contact of diorite and Paleozoic carbonates along the front of the range 4 miles south-southwest of the Avawatz Crown mine. This is probably the Green Delight deposit, located during 1981. Vredenburgh, (BLM, CDCA notes 19.70.1) discovered a similar deposit about one mile southeast of the Avawatz Crown mine. At the Avawatz Crown mine and to the south, iron rich hydrothermal fluids, probably from the intrusion of the diorite, have stained the rocks bright red.

In the Soda Mountains hematite bodies, of subeconomic importance occur near the contact of limestone and mesozoic granitic rocks at the Buzzard copper mine, and west of the Blue Bell mine. In the Red Pass Range, just north of Red Pass, Dennis Mack, a Baker resident, reported that iron has been prospected by a 20-foot adit.

In an airborne magnetic survey flown for DOE it was determined that an elongate northwest-trending magnetic (zero gamma) anomaly encompasses the Iron Mountain, Bat and Iron King deposits. On the north side of the Soda Mountains in the Tertiary sediments in the Avawatz Fault Zone a strong positive (+300 gamma) magnetic anomaly was detected. It is possible that a similar ore deposit may exist here.

PLACER GOLD

Placer gold has been located and recovered at Denning Spring Wash, at the Iron King mine and along Salt Creek on the northern boundary of the area. At Silver Lake and Soda Lake a large block of claims has been located for an unusual placer deposit. According to Wayne Johnson, the claim holder, gold, silver and mercury occur as an amalgam in the lake sediments.

This is not the first attempt to recover gold from playa sediments in this area. Thompson (1929 p. 556) reported:

Several years ago a project was started to recover gold from the mud of Soda Lake near Soda Station. An elaborate plant was erected, and for a short period as many as 50 men were employed. The promoters of the project claimed that the mud contained large amounts of gold, but it is said that the company spent \$30,000 without obtaining any gold.

Similar deposits are rumoured to exist in Nevada (Troxel, pers. comm.) and at China Lake in Inyo County. This deposit may result from mechanical transport of mill residue, where amalgamation was used.

URANIUM - THORIUM

The U.S. Department of Energy as part of their National Uranium Resource Evaluation (NURE) program contracted to have an airborne gamma-ray and magnetometer survey flown for the Trona and Kingman sheets in 1979. Work for these sheets was performed by Geodata and Aero Service, respectively. To define geophysical anomalies the mean radiometric value of eU, eTh and K for each geologic unit was calculated. Maps showing data points one and more standard deviations above the mean for eU, eTh, K, eU/eTh, and eTh/K were generated.

For the purpose of this report an anomaly was considered to be two or more adjacent data points over 2 standard deviations above the mean. Using the contractors maps, the eU, eTh, and eU/eTh and K anomalies meeting this criteria were transferred onto overlays and subjectively extended into adjacent similar geologic units.

Seven small areas (less than 2 square miles) were anomalous in uranium. Two large anomalies (over 2 square miles) and two of the smaller anomalies were located in Quaternary alluvium. One anomaly located on the west side of Five Point Mountain is associated with a Tertiary intrusive. One anomaly 4 miles south of Red Pass Lake is associated with Tertiary volcanics. There is an uranium anomaly located 3 miles south of Old Mormon Spring. Four miles northwest of Old Mormon Spring an anomaly is located in an intensely faulted zone in which Tertiary sediments, Mesozoic intrusives and Pahrump group rocks are juxtaposed. The claim holder (John Loskott) reports he has located claims for uranium here. Bushnell and Morton (1980) samples clay in Tertiary sediments near the Iron Mountain[#] mine which had high values of U_2O_8 (17 and 21 ppm).

There are six thorium anomalies which are less than or equal to 2 square miles and three larger. Two small thorium anomalies are associated with Quaternary alluvium, three with Quaternary-Pleistocene alluvium.

In the northeastern Soda Mountains one is associated with Tertiary sediments.

A large thorium anomaly encompasses the southern Salt Spring Hills and a portion of the northern Avawatz Range and Quaternary alluvium. Two uranium anomalies are overlapped by the thorium anomaly. The bed of Silver Lake continuing eastward is anomalous, and the eastern margin of the southern part of the Soda Mountains (adjacent to Soda Springs) is anomalous.

Two BLM drainage sediment samples were above the detection limit for thorium. The samples are listed in Appendix 2. The thorium was probably derived from monazite or other thorium bearing minerals in the granitic rock.

DRAINAGE SEDIMENT GEOCHEMICAL SURVEY

Drainage sediment geochemical samples were collected from 1250 sites in the California Desert Conservation Area during Spring 1978 by the BLM and for the BLM by G.V. Henderson and associates. Samples were collected from four large areas. At each site two samples were taken, a sieved sample consisting of the -.5mm (-100 mesh) fraction and a panned, heavy mineral concentrate. If present, black sands were samples exclusively for the heavy mineral concentrate. Both samples were analyzed by the USGS using semi-quantitative emission spectrographic methods. Calculation of statistical parameters including the mean and standard deviation were determined for each of the four areas and for the entire data set by the USGS. Fifty sample sites are located in the Avawatz Mountains GRA; only the heavy mineral concentrate data were evaluated in this report.

Areas of Known Mineralization

Two sample sites are located in drainages on the east side of Five Point Mountain the southern most site (NK724060) is located below the Mary-June claims. This sample is above the mean in Mo, Cu, and Zn (31, 400 and 500 ppm respectively). Lead and cobalt are two standard deviations above the mean (790, 140 ppm). The northern sample (NK724081) is in the wash which drains the Glen/Jo claims. This sample was above the mean for Cu, Zn and one standard deviation above the mean for lead (210, 580, 460 ppm respectively).

Sample NK690257 is located below the Morris A.C. mine and other unnamed prospects. It was above the mean for Mo, Zn (40, 300 ppm) and one standard deviation above the mean for cobalt (91 ppm).

Sample NK635359 located in Salt Spring Wash is over the mean for Mo, Cu, and Pb, over two standard deviations for zinc, and one for barium (30, 230, 190, 1,200 and +9,300 ppm). Sample NK612381 located in New Road Wash was over the mean for Mo, Cu, and Ba (25, 110, and 3,200 ppm). Sample NK582394 located in Sheep Creek Wash is over the mean in Cu, Zn and Ba and over one standard deviation in lead (160, 540, 1,200 and 410 pm).

It is difficult to draw conclusions from this information which can be applied to other geochemical data in this area. In addition, the sieved data and other elements were compared without recognizing any trends or patterns.

Areas of Potential Mineralization

Based on geochemical data, there are five areas in which there are no known mines, but concentrations of metals are as high or higher than known mineralized areas.

One sample NJ785933 located south of I-15 at $35^{\circ}11'$, $116^{\circ}08'$ drains what has been mapped as Mesozoic granitic rocks, although quartzite was found in the drainage sediment. Consistently the data for this sample has the highest concentrations of metals and rare earth elements in the Avawatz Mountains GRA. For this sample copper is above the mean and Mo, Zn, Pb and Ag were over two standard deviations. Gold is present above the detection limit, one of seven samples in the CDCA. The values respectively are 820, 72, 2,900, 910, 26 and 16 ppm. The value of gold is equivilant to .384 oz./ton.

The second area is the southwest end of the Soda Mountains. This area is dominated by the northwest-trending fault which has formed a 1,600 foot high scarp-face. Also, there are discontinuous northwest-trending exposures of Tertiary volcanics. The southeast end of this area (south of I-15) is truncated by a northeast-trending fault zone. In this area 10 samples were collected, three samples are below the mean for Mo, Cu, Zn or Pb. Data for the remaining samples is summarized in Table 2.

The third area is located just southwest of Silver Lake. In this area a complex of Mesozoic granodiorite, quartz diorite, microcline granite, gabbro and diorite has intruded Pre-Mesozoic metasediments and Precambrian gneiss. The Buzzard copper mine is located just to the east of the drainages of interest. However, mineralization may continue into these drainages. Samples NK764070 and NK801078 are located at $35^{\circ}18'19"$, $116^{\circ}09'30"$, $35^{\circ}18'40"$, $116^{\circ}06'30"$. Sample NK764070 is one standard deviation for lead and zinc (500 and 780 ppm) and 2 standard deviations above the mean for Mo, and Co (88, 190 ppm). Sample NK801078 is above the mean for Mo, Cu, and Zn (23, 150 and 230 ppm) and 2 standard deviations over the mean for cobalt (150 ppm).

The fourth area is on the northern end of a group of hills northwest of Silver Lake. Here, microcline granite, granodiorite and gabbro and diorite form an intrusive complex which has intruded late Precambrian-Cambrian dolomite. Sample NK756182 ($35^{\circ}24'22"$, $116^{\circ}10'02"$) was above the mean for Mo, Cu and Zn and over one standard deviation above the mean for cobalt (27, 190, 450, 110 ppm).

The fifth area is northwest of Denning Spring. In this area Mesozoic granitic rocks have intruded pre-plutonic metavolcanic and metasedimentary rocks. The area is highly faulted and less than a half mile east of the site, there is an outcrop of Tertiary volcanic rocks. Sample NK473372 ($35^{\circ}34'41"$, $116^{\circ}28'41"$) is above the mean for copper and zinc (120 and 370 ppm) over one standard deviation for Mo and Pb (47, 420 ppm) and over

two standard deviations for cobalt (170 ppm). At the mines near Denning Spring gold, silver, wulfenite and copper minerals occur in fissure veins. There may be similar mineralization in this drainage.

Table 2
HMC Data for the Southwestern Soda Mountains

<u>Sample Number</u>	<u>Location</u>	<u>Mo</u>	<u>Cu</u>	<u>Zn</u>	<u>Pb</u>
NJ746834	35°05'20" 116°10'50W	90	89	570	120
NJ708906	35°09'16" 116°12'40W	40	150	920	540
NJ654907	35°09'31" 116°16'58"	50	140	460	390
NJ642995	35°09'31" 116°16'58"	26	140	460	230
NJ603945	35°11'20" 116°20'04W	50	290	490	130
NJ574989	35°13'58" 116°21'14W	19	180	450	160
NJ590998	35°15'53" 116°21'14"	18	110	330	130

In the Avawatz Mountains and Soda Mountains there are four values of cobalt greater than one standard deviation (84 ppm) and seven values above two standard deviations (122 ppm). Most of these high values are concentrated in the Soda Mountains and southern Avawatz Mountains. The exception is the sample near Denning Spring. In the Soda Mountains Grose (1959, p. 1532) described abundant diabase dikes. These Tertiary (?) dikes may be the source of the cobalt. Another possible source is the basic complex of diorite and gabbro. However, these rocks are restricted to the area just west of Silver Lake. Probably correlative diorite crops out in the Avawatz Mountains but these rocks do not account for the presence of cobalt in the Soda Mountains. It should be noted that high values of cobalt are not associated with diabase which intruded the Crystal Springs Formation at Sheep Creek Wash.

NON-METALLIC MINERALS

Evaporite and Related Rocks of the Northern Avawatz Mountains

On the northern flank of the Avawatz Mountains there are three fault bounded belts of Tertiary sediments. The southern most belt consists of a succession of gravel and sandstone, with no apparent economic potential. The northern and central belts have long been recognized for their potential for industrial minerals. Among the minerals which occur in potentially economic quantities are salt, gypsum and celestite. Reserves of these are shown in Table 1. Other minerals which have been identified are borax, niter, barite, bentonite and manganese. There is potential for zeolites. Brady, Troxel and Butler (1980) suggest that mineralization of strontium, manganese and barite: "may have occurred along the densely faulted paleobasin floor during periods of Tertiary volcanism."

Salt is most abundant in the northern belt. Indicated reserves or resources exist at Salt Basin, Jumbo Salt Area and the King claims. Boston Valley, in the central belt, contains measured reserves (Calzia and others, 1979, Ver Plank, 1958, p. 82-32).

Gypsum occurs in both belts, however it is somewhat purer and more abundant in the northern belt (Ver Plank, 1952).

At the turn of the century, nitrate deposits in this area were repeatedly investigated. Noble (1922) thoroughly investigated these deposits and summarized previous work. He concluded the size of the area (1,200 acres) was too small and the concentration (1.73-2.12 percent) of nitrate in the caliche was too low to make this area worth consideration.

Celestite is present as small nodules or concretions in gypsum, as spheroidal concretions in clastic sediments and as beds in gypsum and in clastic sediments usually associated with gypsum (Durrell, 1953). Brady, Troxel and Butler (1980) suggest the celestite is a replacement of dense lacustrine limestone.

Veins of massive and crystalline barite penetrate all members of the central belt (Brady, Troxel and Butler, 1980).

In the northern belt gypsum, and in places celestite, is associated with streaks and lenses of manganese oxides and iron oxides (Troxel and Butler, 1979; Durrell, 1953). Durrell noted the presence of manganese oxides: "south of Salt Basin, northwest of Cottonwood Spring and in the Celestite Hills."

Bailey (1902) indicated that: "Borax in considerable quantities has been found in the niter fields...along the flank of the Avawatz range...." A sieved drainage sediment geochemical sample collected from Pipe Line Wash has boron values higher than two standard deviations above the mean. None of the later investigators has noted the presence of borate minerals.

Bentonite is interbedded with gypsum and manganese oxides in the Celestite Hills (Brady, Troxel and Butler, 1980, p. 232). Noble (1922, p. 8) and Troxel and Butler (1979, p. 13) indicate some of the Tertiary sediments may contain beds of volcanic ash. Volcanic ash alters to bentonite and zeolites. Therefore, there is potential for zeolites.

Sodium-Potassium

The USGS has classified the alluvial basins and the Tertiary sediments in the northern Avawatz Mountains as prospectively valuable for sodium and potassium resources (Calzia and others, 1979).

Bentonite

Bentonite occurs in Tertiary sediments southwest of Baker at the Pink Pearl mine (Henderson, 1980). At the Goodwater mine bentonite which occurs in a fault zone is apparently the product of hydrothermal alteration.

Talc

According to Wright (1968, p. 82) the only known talc deposits in the area are in a west-trending, fault-bounded block that forms a foothill in the Sheep Creek Spring area. Within this block the Crystal Spring Formation rests on Precambrian gneiss, and has been intruded by a sill of diabase. A member of carbonate rock in the Crystal Spring Formation has been silicified by the diabase to various degrees. The thickest occurrence of talc extends from Sheep Creek Canyon westward about 1800 feet. To the west of the Sheep Creek Mine there are small irregular talc bodies.

Limestone

Limestone of possible economic quantities and quality has been identified south of Sheep Creek Spring, west of Silver Lake and west of Baker.

Quartzite

Over 2,000 feet of quartzite is exposed west of Silver Lake. Quartzite is used in the manufacture of silica brick and portland cement. It is unlikely that this remote deposit will ever be of economic importance.

Sand and Gravel

The California Division of Transportation has extracted sand and gravel from materials sales sites along I-15 and along state Route 127. Gravel deposits are abundant in the fans along the base of the Avawatz Mountains. However, except for use in local road maintenance, these remote deposits will probably be of no value.

Oil and Gas

The recently recognized importance of the overthrust belt as an oil and gas prospect can hardly be overemphasized. Recently gas was struck southwest of Las Vegas, Nevada. Ertman (pers. comm. February 23, 1981) reported that productive formations are the Moekopi, Kaibab limestone, Bird Springs Formation and Sultan limestone.

The highly fossiliferous Bird Spring Formation is exposed on "Hopeless Hill" about a mile northwest of Baker (Grose, 1959), in the northern Salt Spring Hills south of Sheep Creek Spring and on Five Point Mountain. A formation considered by Grose (1959, p. 1525) to be equilivant with the Meonkopi Formation also occurs at Five Point Mountain. The Bird Spring Formation at Five Point Mountain was thrust into place by east dipping thrust faults (the direction of thrusting is unknown). These formations may be buried to the east of the Avawatz or Soda Mountains. However if there were any hydrocarbon accumulations, it would seem, that Mesozoic intrusions and Tertiary fracturing would have had a deleterious effect of them.

The USGS has classified most of the alluvial basins in this area as prospectively valuable for oil and gas (Calzia and others, 1979).

Geothermal

Sheep Creek Spring and Soda springs have temperatures of 23°C and 24°C respectively (Higgins, 1980). These are not high temperatures and the isolated location of Sheep Creek Spring would preclude any development, although heat from Soda Spring might conceivably be used in heating the facility there.

CLASSIFICATION OF LAND FOR GEM RESOURCES

This section of the report is a classification of the Avawatz Mountains GRA for geology, energy and mineral resources. Specifically the resources which are classified are locatable resources (metallic, non-metallic, uranium/thorium), leasable resources (geothermal, oil-gas, sodium-potassium) and salable resources (sand and gravel). The basis for this classification is the data presented in the Mineral Resources section, Appendix 1: Table of Production, and Appendix 2: Claims and Deposits.

The data which follows is keyed to Figures 4 and 5 (and the 14 series maps in the GRA file) which show the classification of land. Each separate area which is classified is given a number. For example, 1-1C is area 1 and it is classified 1C. The location of the area and a brief rationale why it was classified is given. Table 3 explains the classification scheme.

The classification scheme employed was developed for the California Desert Plan. It is broken into four classes which are further subdivided. Strategic minerals are given extra weight in the classification scheme. In general terms the classification ranges from class 1 where mineral resources are known to occur to class 4 where no mineral resources are known.

CLASSIFICATION OF LOCATABLE MINERAL RESOURCES

Metallic Minerals

- 1-1a. Red Pass. Production from Iron Mountain Mine. 7.65 million tons of indicated reserves.
- 2-1a. Goodwater (C.ackerjack Bonanza) Mine. Production of silver-gold.
- 3-1b. Joe Dandy Hill. Past production of lead, silver, copper, zinc.
- 4-1b. Five Point Mountain. Past production of copper.
- 5-1b. Avawatz Crown Mine. Past production of silver.
- 6-1b. Denning Spring. Past production of gold.
- 7-2c. NW of Baker. Occurrence of lead-silver.
- 8-2c. North Central Avawatz Range. Numerous occurrences of copper, lead-silver.
- 9-2c. NW Denning Spring. 1 Geochemical sample with anomalous values.
- 10-2c. Hills NW of Silver Lake. 1 Geochemical sample with anomalous values.
- 11-2c. SE Soda Mountains. 1 Geochemical sample with anomalous values.
- 12-2c. SW Soda Mountains. 7 Geochemical samples.

- 13-2c. NE Soda Mountains. 2 Geochemical samples. Soda-Avawatz Fault Zone. Positive.
- 14-3b. Soda Mountains. Aeromagnetic anomaly. Possible Iron deposit.
- 17-3b. Salt Creek. Gold Placer reported.
- Areas 18 through 27-3b. Exposures of pre-Tertiary bedrock. Lithologies exposed are no different than in areas of known mineralization. Environment favorable for metallic minerals.
- 28-4b. Quaternary and Tertiary Sediments exposed - these lithologies are not favorable for metallic minerals. Manganese and iron oxides stains occur in the Tertiary Sediments in the northern Avawatz Mountains - but there is no economic potential. Also the monolithologic breccia contained in Tertiary Sediments contains iron, copper and gold mineralization at Red Pass where it is classified 1a. Where the breccia forms large bodies it may have potential for mineralization.

Non-Metallic Minerals

- 1-1b. Sheep Creek Talc Mine. Past production.
- 2-1c. Northern Avawatz Mountains. Reserves and Resources of salt, celestite, gypsum. Occurrence of barite and low grade niter, probable occurrence of bentonite and zeolites. Potential for borates.
- 3-1c. Celestite Hills. Celestite, gypsum, and bentonite occurrence.
- 4-2a. Pink Lady Mine. Past production of bentonite.
- 5-2a. Goodwater Mine. Past production of bentonite.
- 6-2c. Northern Avawatz Mountains. Occurrence of barite.
- 7-2c. West of Silver lake. Occurrence of Limestone and quartzite.
- 8-2a. Baker Hill. Occurrence of limestone.
- 9-2a. Upper Pipeline Wash Canyon. Occurrence of limesonte and delomite.
- 10-3a. Five Point Mountain. Occurrence of limestone.
- Areas 11 through 13-3b. Tertiary Sediments. Favorable environment for bentonite and zeolites.

Uranium/Thorium

- 1-2c. South Soda Mountains. Geochemical sample anomalous in thorium.

- 2-2c. Southwest Soda Mountains. Geochemical sample anomalous in thorium.
- 3-2c. Red Pass. Geochemical sample anomalous in uranium.
- Areas 4 through 13-3b. Anomalous in uranium or thorium as detected by airborne gamma-ray spectrometer.

CLASSIFICATION OF LEASABLE MINERAL RESOURCES

Geothermal Resources (see map 15c)

- 1-2c. Sheep Creek Springs. 23°C.
- 2-2c. Soda Springs. 24°C.

Oil and Gas (see map 15b)

- 1-2b. North Avawatz. Prospectively valuable.
- 2-2b. Silurium Valley. Prospectively valuable.
- 3-2b. Silver Lake. Prospectively valuable

These areas follow the classification by Calzia and others, 1979.

Sodium-Potassium

- 1-2a. Northern Avawatz Mountains. Past production of salt. Substantial reserves.
- 2-2b. Celestite Hills. Occurrence of Salt.
- Areas 1 through 5-3b. Prospectively valuable for sodium and potassium. These areas follow classification by Calzia and others, 1979.

CLASSIFICATION OF SALABLE RESOURCES

Sand and Gravel

- Areas 1 through 3-2b. Materials Sales Sites. Probable past production of sand and gravel.

FIGURE 4

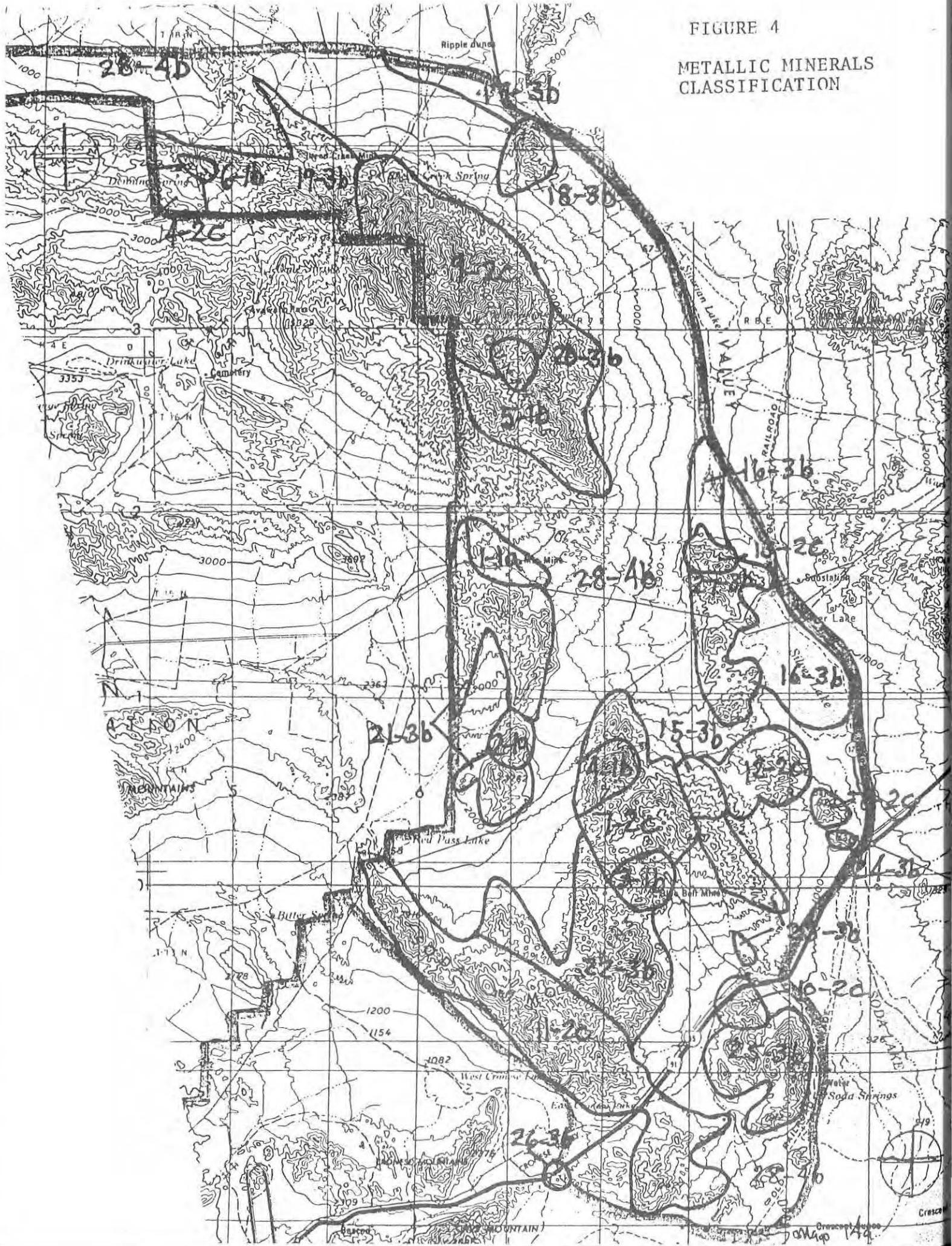
METALLIC MINERALS
CLASSIFICATION

FIGURE 5

NON-METALLIC MINERAL CLASSIFICATION

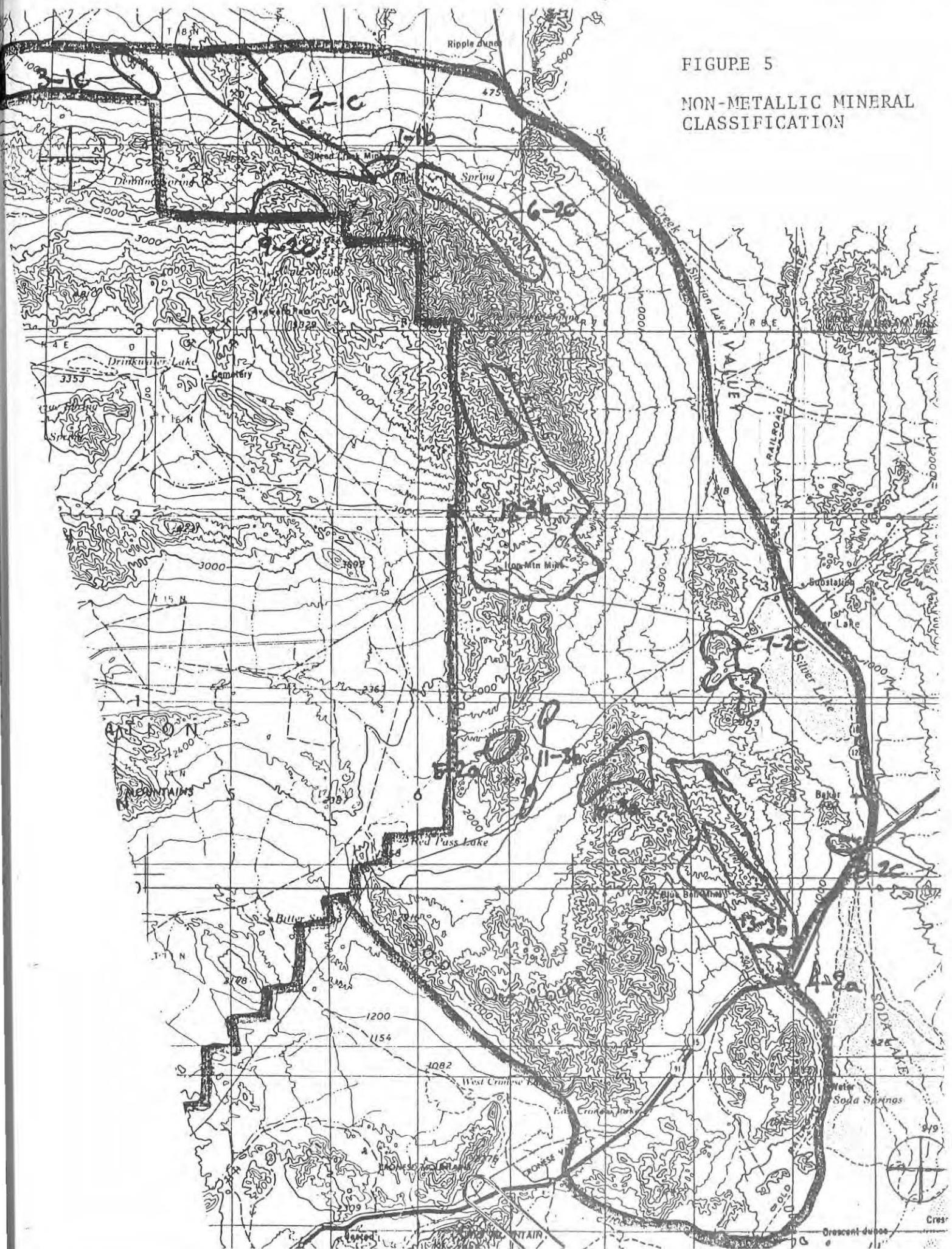


TABLE 3
Mineral Potential Classification

CLASS	LOCATABLE	LEASABLE			SALABLE
		GEO THERMAL	OIL & GAS	SODIUM/POTASSIUM	
	Present or intermittent producer or active development of any locatable mineral, and associated favorable geologic environment. Development means that an ore body has been defined, and work is continuing.	Present producer or development and associated geologic environment.	Same as Geothermal.	Same as Geothermal.	Present producer or development.
	Past producers and/or reserves of any category I minerals and associated favorable geologic environment.	KGRA - favorable for plant siting.	KGS - past producer and/or reserves.	Valuable for Na/K or K reserve, past producer and reserves.	(does not apply)
	Past producers and/or identified resources of any category I minerals and associated favorable geologic environment.	KGRA - less favorable for plant siting.	KGS - past producer and/or resources.	Valuable for Na/K or K reserve, past producer & resources.	(does not apply)
338	Past producers and/or reserves of any category II minerals and associated favorable geologic environment. Does not apply to uranium.	PGRA - favorable for plant siting.	Prospectively Valuable: in Over-thrust Belt, or has shows from wells.	Prospectively Valuable for Na and/or K, salines known present.	Reserves.
	Past Producers and/or identified resources of any category II minerals and associated favorable geologic environment. Does not apply to uranium.	PGRA - less favorable for plant siting.	Prospectively Valuable: other potentially favorable areas.	Prospectively Valuable for Na and/or K, salines not known to be present.	Past Producers
	Occurrences (nonproducers) or direct evidence for occurrence of any category I minerals and associated favorable geologic environment.	Direct evidence for geothermal energy, not in PGRA or KGRA.	Direct evidence for oil and/or gas, not classified by USGS.	Direct evidence for Na and/or K, not classified by USGS.	(does not apply)
	Occurrences (nonproducers) or direct evidence for occurrence of any category II minerals and associated favorable geologic environment.	(does not apply)	(does not apply)	(does not apply)	Favorable geologic environment, may be economic in foreseeable future.
	Favorable geologic environment for occurrence of any locatable mineral.	Favorable geologic environment based on indirect evidence, not in PGRA or KGRA.	Favorable geologic environment based on indirect evidence, not classified by USGS.	Same as oil & gas.	Favorable geologic environment, not economic in near future.
	4a Data insufficient to classify.	Same as locatables.	Same as locatables.	Same as locatables.	Same as locatables.
	Lithologies exposed at surface are unfavorable for locatable mineral occurrence.	Insufficient data, probably unfavorable.	Same as geothermal.	Same as geothermal.	Same as geothermal.
	4b Data insufficient to classify, but potentially favorable lithologies may be present.	Same as locatables.	Same as locatables.	Same as locatables.	Potentially favorable environment. Poor access. May be important in the future.

FURTHER WORK

- Field examination in the 5 areas mentioned in the Geochemical section.
- Detailed geologic mapping of the Red Pass Range with careful attention given to the Goodwater Mine.
- Examination of the mines at Denning Spring.
- Detailed examination of Joe Dandy Hill to determine if the altered granite could be a prophyry deposit.
- Determine the nature and source of the gold-silver-mercury placers reported from Silver Lake.
- Ground magnetometer survey of the magnetic anomaly in the Tertiary sediments in northern Soda Mountains.
- Determine if the copper minerals which fill fractures in diorite in the Avawatz Mountains are indicative of a larger low grade body at depth.
- Determine the nature of borate mineralization in the Tertiary sediments of the north flank of the Avawatz Mountains.
- Determine the source of cobalt in the Soda Mountains.
- Examine Tertiary sediments for zeolites.



Avawatz Resource area looking north toward Avawatz Mountains from above Silver Lakes Iron Deposit. The "strata" dipping to the east (right) appear to control the brecciated structure of iron ore in the deposit. This suggests a thrust or possibly a detachment structure dipping toward the southern extension of the Death Valley Fault Zone (graben) to the east (right) (photograph courtesy of Don Fife, 1983).

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Note: This report was completed in 1981 as a BLM Administrative Report as a result of studies for the California Desert Conservation Area Plan. Since completion of the report active exploration drilling has taken place in the resource area at several localities.