CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the Grover Heinrichs Mining Collection

ACCESS STATEMENT

These digitized collections are accessible for purposes of education and research. We have indicated what we know about copyright and rights of privacy, publicity, or trademark. Due to the nature of archival collections, we are not always able to identify this information. We are eager to hear from any rights owners, so that we may obtain accurate information. Upon request, we will remove material from public view while we address a rights issue.

CONSTRAINTS STATEMENT

The Arizona Geological Survey does not claim to control all rights for all materials in its collection. These rights include, but are not limited to: copyright, privacy rights, and cultural protection rights. The User hereby assumes all responsibility for obtaining any rights to use the material in excess of "fair use."

The Survey makes no intellectual property claims to the products created by individual authors in the manuscript collections, except when the author deeded those rights to the Survey or when those authors were employed by the State of Arizona and created intellectual products as a function of their official duties. The Survey does maintain property rights to the physical and digital representations of the works.

QUALITY STATEMENT

The Arizona Geological Survey is not responsible for the accuracy of the records, information, or opinions that may be contained in the files. The Survey collects, catalogs, and archives data on mineral properties regardless of its views of the veracity or accuracy of those data.

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES
FERRY BUILDING
SAN FRANCISCO 11, CALIF.

RETURN POSTAGE GUARANTEED

PROF EDWARD WISSER
DIV OF MINERAL TECHNOLOGY
UNIVERSITY OF CALIFORNIA
BERKELEY 4 CALIF
57

Bulk Rate
U. S. POSTAGE
PAID
San Francisco, Cal.
Permit No. 726

Bristlecone Pine withdrawal, cont·

access, primarily because the terrain is very steep, has always hindered prospecting in the area.

The most recent Division of Mines publications that contain descriptions of mineral deposits in and adjacent to the Bristlecone Pine withdrawal are:

Norman, L.A., Jr., and Stewart, R.M., 1951, Mines and mineral resources of Inyo County: California Jour. Mines and Geology, vol. 47, p. 17-223.

Sampson, R.J., and Tucker, W.B., 1940, Mineral Resources of Mono County: California Jour. Mines and Geology, vol. 36, p. 117-156.

Notice of the proposed withdrawal has been sent to the newspapers and post offices in Mono and Inyo Counties. Final determination of the application for withdrawal will be made by the Secretary of Interior. Although a 30-day period was established for receipt of protests or comments on the proposal, any protests received after September 28, 1958 will be given consideration. If it is determined that a hearing should be held, an additional 30 days will be granted for the filing of written objections which will become a part of the transcript of the hearing. Interested parties should write to the Manager, U.S. Land Office Bureau of Land Management, Bartlett Building, 215 West Seventh Street, Los Angeles 14, California.

GEOLOGIC MAP OF DEATH VALLEY DUE

The first sheet of the new geologic map of California to be lithographed in color is due from the press about November 15. The new map, entitled DEATH VALLEY SHEET, is the first of some 20-odd sheets in the latest edition of the geologic map of California. The sheet covers 2 degrees of longitude by 1 degree of latitude, and is printed on a scale of 1:250,000, or approximately 4 miles = 1 inch. It will be folded in an envelope, which, besides the map, will contain a sheet on which are printed a chart showing the source material from which the mapping was taken, a table showing the stratigraphic nomenclature, an index map showing the U. S. Geological Survey topographic maps covering the area, a list of references used as source material and several photographs.

The map and accompanying sheet are folded in a 9 x 12 inch envelope. Price of the entire assemblage is $1.50; orders will be accepted for the map after November 15. Receipt of the shipment of maps from the lithographer will be announced in a future issue of MINERAL INFORMATION SERVICE.

AGE OF GRANITE MEASURED

The ages of some granitic rocks in California have been measured by a method of radiogenic measurements. Utilizing the potassium^{40} to argon^{40} radiogenic transformation, three geologists, G.H. Curtis, J.F. Evernden, and J. Lipson of the University of California at Berkeley, have determined that the age of the granitic rocks they sampled ranged from 77 million years to 143 million years.

In general, the rocks were from three groups. The most ancient, including rocks from the Klamath Mountains and Sierran foothills, ranged in age from about 143 million to 131 million years. The second group, taken from the high Sierra Nevada, was found to be about 77 to 95 million years old. The third group, representing Coast Ranges rocks, was measured to be 82 to 92 million years in age.

The data for these determinations, together with the conclusions of the authors as to the importance of these measurements in interpreting California geology, are incorporated in the latest publication of the Division of Mines, SPECIAL REPORT 54. Entitled "Age determination of some granitic rocks in California by the potassium-argon method," the report, printed on 8½ x 11 inch format with a slick paper cover, sells for 50¢.

COMING EVENTS

OCTOBER 9-11, OPTICAL SOCIETY OF AMERICA, Annual Meeting, Statler Hotel, Detroit.

OCTOBER 13-17, SOCIETY OF EXPLORATION GEOPHYSICISTS, 28th Annual Meeting, Gunter Hotel, and Municipal Auditorium, San Antonio.

OCTOBER 16-17, AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, SOCIETY OF PETROLEUM ENGINEERS, Southern California Petroleum Section, Fall Meeting, Biltmore Hotel, L.A.

NOVEMBER 6-7, AMERICAN ASS'N. OF PETROLEUM GEOLOGISTS, Petroleum Section, Annual Meeting, Ambassador Hotel, Los Angeles.

NOVEMBER 6-8, GEOLOGICAL SOCIETY OF AMERICA, Annual Meeting, St. Louis.

How to order publications...

To order any Division of Mines publication, such as SPECIAL REPORT 54 listed above, send money orders or checks, made payable to the Division of Mines (no stamps, please!), to DR. GORDON B. OAKESHOTT, CHIEF, CALIFORNIA DIVISION OF MINES, FERRY BUILDING, SAN FRANCISCO 11, CALIFORNIA. If you are a California resident, please add 4% sales tax for all publications except the California Journal of Mines and Geology, or its predecessor, the Reports of the State Mineralogist. You do not need to include postage, but be sure to enclose your name and address.

XLI B-1 II-94 EGH

STATE OF CALIFORNIA
GOODWIN J. KNIGHT, Governor
DEPARTMENT OF NATURAL RESOURCES
DeWITT NELSON, Director

DIVISION OF MINES
Ferry Building, San Francisco 11
GORDON B. OAKESHOTT, Chief

MINERAL INFORMATION SERVICE

Vol. 11 October 1, 1958 No. 10

MINERAL INFORMATION SERVICE is designed to inform the public on the geology and mineral resources of California and on the usefulness of minerals and rocks, and to serve as a news release on mineral discoveries, mining operations, markets, statistics, and new publications. It is issued monthly by the California State Division of Mines. Subscription price, January through December, is $1.00.

DEATH VALLEY

The fascination which Death Valley has held for so many persons is especially strong for geologists, as here, preserved in bold, barren mountain slopes of eastern California is one of the most complete geologic records of any part of the earth's crust. Within Death Valley and the mountain ranges that border it, rocks of an exceedingly great variety, representing virtually every geologic period, are exposed. Equally impressive to the geologist are the effects of severe deformation which these rocks show in many places.

As a topographic feature, Death Valley is part of a great, northwest-trending trough that can be traced for at least 150 miles. (Only the central part of this trough is included on the Death Valley Sheet of the Geologic Map of California, available in November.) The floor of the valley averages about 8 miles in width and is bordered by steep-faced mountain ranges. The Panamint Range forms the west side of the valley for the distance of about 100 miles. Emigrant Wash drains eastward into the valley, dividing the southern part of the range from the northern part which is also known as the Cottonwood Mountains. The southern part of the Range culminates in Telescope Peak, 11,049 feet above sea level, opposite the valley's lowest point--282 feet below sea level, the lowest in the Western Hemisphere. Forming the east side of the valley and opposite the Panamint Range are three mountain masses. From north to south these are the Grapevine, Funeral, and Black Mountains. Although somewhat lower, they compare favorably with Panamint Range, in scenic and geologic interest.

The most-traveled routes into Death Valley are from the west (via State Highway 190 from southern Owens Valley), the southwest (from Trona through Wild Rose Canyon and Immigrant Wash), and the south (via State Highway 127 from Baker). Many who have visited Death Valley recommend a two-day, Trona-to-Baker circuit that could, for example, include the following: (1) a noon-time visit to the area of the old beehive charcoal kilns in Wild Rose Canyon on the west slope of the Panamint Range; (2) an afternoon panoramic view of Death Valley from Aguereberry Point at the crest of the Panamint Range; (3) an overnight stay at Panamint Springs or Furnace Creek; (4) a morning trip, via the historic borax mining camp of Ryan, to Dante's View at the crest of the Black Mountains; and (5) an afternoon journey from Furnace Creek, past Bad Water on the east side of Death Valley, over Salsberry Pass in the southern part of the Black Mountains, and through the oasis-like settlement of Shoshone to Baker. A traveler along this route can observe, from his car window, most of the geological features outlined below.

Precambrian Rocks

The oldest rocks in the Death Valley region are probably best observed in the somber, gray exposures that form most of the west side of the Black Mountains. These rocks are metamorphic in origin and of early Precambrian age. They consist mostly of granitic gneiss and mica schist formed by the recrystallization of sandy and shaly strata. These rocks are comparable in age and character with the very old rocks in the bottom of the Grand Canyon 200 miles

Furnace Creek Inn, Death Valley, California. View eastward at mouth of Furnace Creek Wash. Bluff upon which Inn is built marks a Recent fault scarp. Behind Inn northeast-dipping beds of Funeral fanglomerate overlie similarly dipping strata of Furnace Creek formation. Ridge on skyline is Lower Cambrian strata in fault contact with Furnace Creek strata at Furnace Creek fault zone along ridge base. Spence Air photo.

to the east. The existence of such sedimentary rocks in early Precambrian time, (perhaps 2 or more billion years ago) indicates that, even then, the higher parts of the earth's surface were being eroded away and that the detritus was being deposited in the lower parts. Little is known, however, of the configuration of this ancient land surface.

Later Precambrian time is represented in the Death Valley area by sedimentary rocks that, unlike the older metamorphic rocks, are very evenly layered, variously colored, and only mildly metamorphosed. These strata, the more southerly occurrences of which are known as the Pahrump series, are several thousand feet thick, and are well exposed in Warm Spring and Galena Canyons in the southeastern part of the Panamint Range and on the western slope of the Funeral Mountains. They consist mostly of quartzite, shale, and dolomite and record the entry and prolonged existence in the Death Valley area of a shallow sea. That this sea contained primitive life is shown by the preservation in these rocks of colonies of fossil algae. These strata rest upon the older rocks with a profound unconformity that indicates an interval--probably millions of years in duration--when the area lay above sea level and was being worn down by erosion.

Also in later Precambrian time the lower parts of the Pahrump series were intruded by extensive sills of diabase. Along the margins of the lowest of these sills, dolomite has been altered to large bodies of commercial talc. Most of the mining activity in the Death Valley region today is concerned with the development of these deposits, the white exposures of which stand prominently against the black diabase that borders them.

Paleozoic Rocks

Following the deposition of the later Precambrian sedimentary rocks, the sea withdrew and the land was tilted and again eroded so that these strata and the diabase were stripped from large areas. This interval of erosion, however, was shorter than the earlier interval and the sea waters again spread over the area to remain through most or all of the Paleozoic era. The sea now occupied a broad, northwest-trending trough known as the Cordilleran geosyncline, that extended over much of western North America. The floor of the syncline gradually sank as, for about three hundred million years, it received layer upon layer of sediment. By the end of the Paleozoic era, the strata thus accumulated were 25,000 feet or more in total thickness.

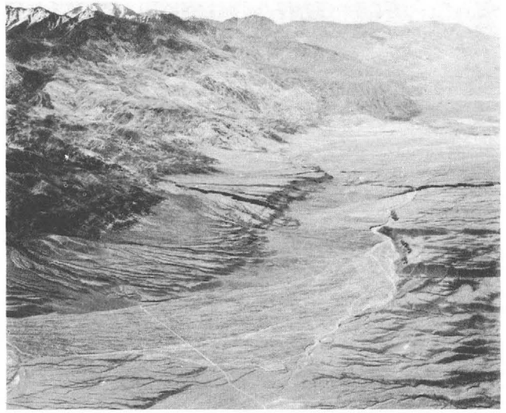
The older of these strata comprise the Noonday dolomite, a massive, generally grayish-yellow, cliff-forming unit, ordinarily about 1000 feet thick. Long after it was deposited, this dolomite became the host rock for most of the lead-silver-zinc mineralization in the Death Valley area--a fact that appears to have been recognized by the early prospectors. Deposited on top of the Noonday dolomite were several thousands of feet of material composed mostly of mineral and rock fragments that later became hardened and compacted into quartzite and shale. These fragments apparently were eroded from land areas that persisted along the border of the geosycline. These source areas, however, as they diminished in size and elevation, ceased to contribute. Instead, during most of the rest of Paleozoic time, carbonate material was laid down on the sea floor which by now was extensive and exceedingly flat. This material, now represented by a thick succession of dolomite and limestone, appears to have formed chiefly by chemical precipitation from the sea water.

Like the earlier Precambrian strata, these younger sedimentary rocks are evenly layered and vari-colored so that they form striped mountain slopes. These rocks underlie most of the eastern slope of the southern part of the Panamint Range and most of the northern part as well. They also are extensively exposed in the eastern and southern parts of the Funeral Mountains and in several areas at the southern end of the Black Mountains.

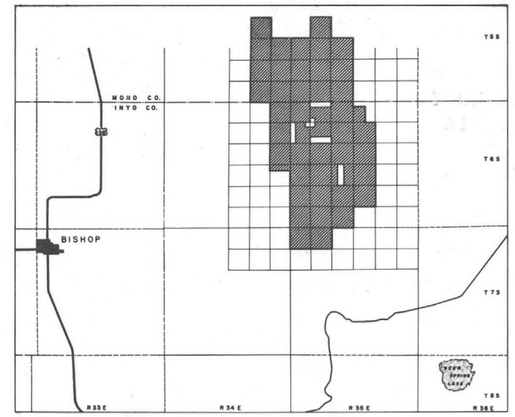
Probably the most intact and complete exposure of this part of the stratigraphic section is at Tucki Mountain at the north end of the southern Panamints. Here, as one travels eastward on Highway 190, past Stovepipe Wells and onto the floor of Death Valley he can observe these strata in an east-dipping section south of the highway. The fossils preserved in them and in correlative strata elsewhere in the region show that life was slowly evolving in Paleozoic time.

Mesozoic Rocks

The presence, in the Butte Valley area of the southern part of the Panamint Range, of early Mesozoic (Triassic) marine strata indicates that the sea lingered in the Death Valley region after the end of Paleozoic time or perhaps returned after a brief withdrawal. But still later in Triassic time the relative quietness of the sea floor was broken by outpourings of flows of andesitic lava, remnants of which also are preserved in the Butte Valley area. These sedimentary and volcanic rocks of Triassic age are presumed originally to have covered much of the



The Wildrose graben and a part of the Panamint Range, as viewed south-southeastward from a point above Panamint Valley. The graben was developed across a series of Quaternary alluvial fans, and beheaded much of the drainage in the area at right. Much of the visible mountain area is underlain by stratified rocks of Cambrian age. Photo is by J.S. Shelton and R.C. Frampton.

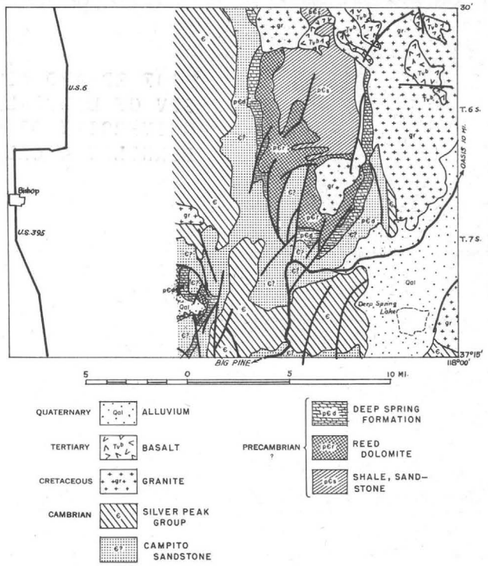


Index map of parts of Inyo and Mono Counties, showing proposed withdrawal of land.

It is believed that the White Mountain Bristlecone pine forest is the largest in existence and probably contains the oldest trees of this species. Some are more than 4,000 years old. This pine is sparsely distributed throughout the Rocky Mountains and Great Basin and good stands are on Telescope Peak in Death Valley National Monument, and at Charleston Mountain, west of Las Vegas, Nevada. The oldest of the pines in the White Mountain forest are believed to be more than a thousand years older than the oldest of any other species in the world, including the Sequoia group.

Because of its great scientific value, efforts to protect the White Mountain forest were initiated in 1953 when 2,330 acres of the Inyo National Forest were set aside as a Natural Area.

As shown on the accompanying geologic sketch map, the area is one in which granitic rocks have intruded older sedimentary rocks including limestone, dolomite, shale, and sandstone, thus creating a geologic environment favorable to the occurrence of mineral deposits such as those that have been prospected.



Sketch map of the area proposed as the Ancient Bristlecone Pine Forest. Geology modified from map by C.A. Nelson, 1956.

Many mineral prospects have been developed within the boundaries of the proposed withdrawn area but production data are not available. Two lead and zinc mines, the Mexican (Reed Flat) and Bull Domingo, have been described in publications of the California Division of Mines since at least 1926 although mining was begun many years before that. Difficulty of

MINING LEGISLATION

A number of bills affecting miners, mining claim holders and mining companies were passed by the 85th Congress of the United States shortly before its adjournment on August 24, 1958. An individual summary of each of these bills is presented below, based on the American Mining Congress newsletter of August 26, 1958.

1. Change in period of assessment work.

Public Law 85-736, approved August 23, 1958, amends the basic mining law to change the period for doing annual assessment work on unpatented mining claims by setting the completion date as September 1st instead of July 1st. The law provides that the current assessment year started at 12 o'clock meridian (noon) on July 1, 1958 and will continue to 12 o'clock meridian on September 1, 1959. Thereafter, the period for doing annual assessment work will run from September 1st of one year to September 1st of the succeeding year.

2. Geophysical assessment work.

Geological, geophysical, and geochemical surveys may now be considered as "labor" with respect to the $100 per year assessment requirement on unpatented mining claims.

Accepted was the House version of the bill which provides that the surveys be conducted by qualified experts and "verified by a detailed report filed in the county office in which the claim is located which sets forth fully (a) the location of the work performed in relation to the point of discovery and the boundaries of the claim, (b) the nature, extent, and cost thereof, (c) the basic findings therefrom, and (d) the name, address, and professional background of the person or persons conducting the work." The bill also provided a limitation of such surveys for not more than two consecutive years or for more than a total of five years on any one claim, and no survey may be repetitive of any previous survey on the same claim. It would also limit such surveys to those made on the ground.

3. Mineral Exploration.

One portion of the Administration's long-range minerals program became effective August 21 when the President signed an Act (S. 3817) authorizing the Secretary of the Interior to allocate funds to private industry for minerals exploration. The program will be administered by a new Office of Minerals Exploration, which will take over the functions of the defunct Defense Minerals Exploration Administration.

Under the new law, the Secretary may determine the minerals eligible for exploration assistance and the proportion of the cost borne by the Government. Maximum Government participation in any one contract is $250,000, and the applicant is required to show that funds for the project are not available from commercial sources on reasonable terms. Repayment of any loan, with interest, is required through payment of royalties on any minerals produced from the project.

Congress has appropriated $4 million for the new agency during the current fiscal year, with a proviso that loans could not exceed 50 percent of the cost of a project.

4. Mineral Stockpiling and Minerals Purchase Bills.

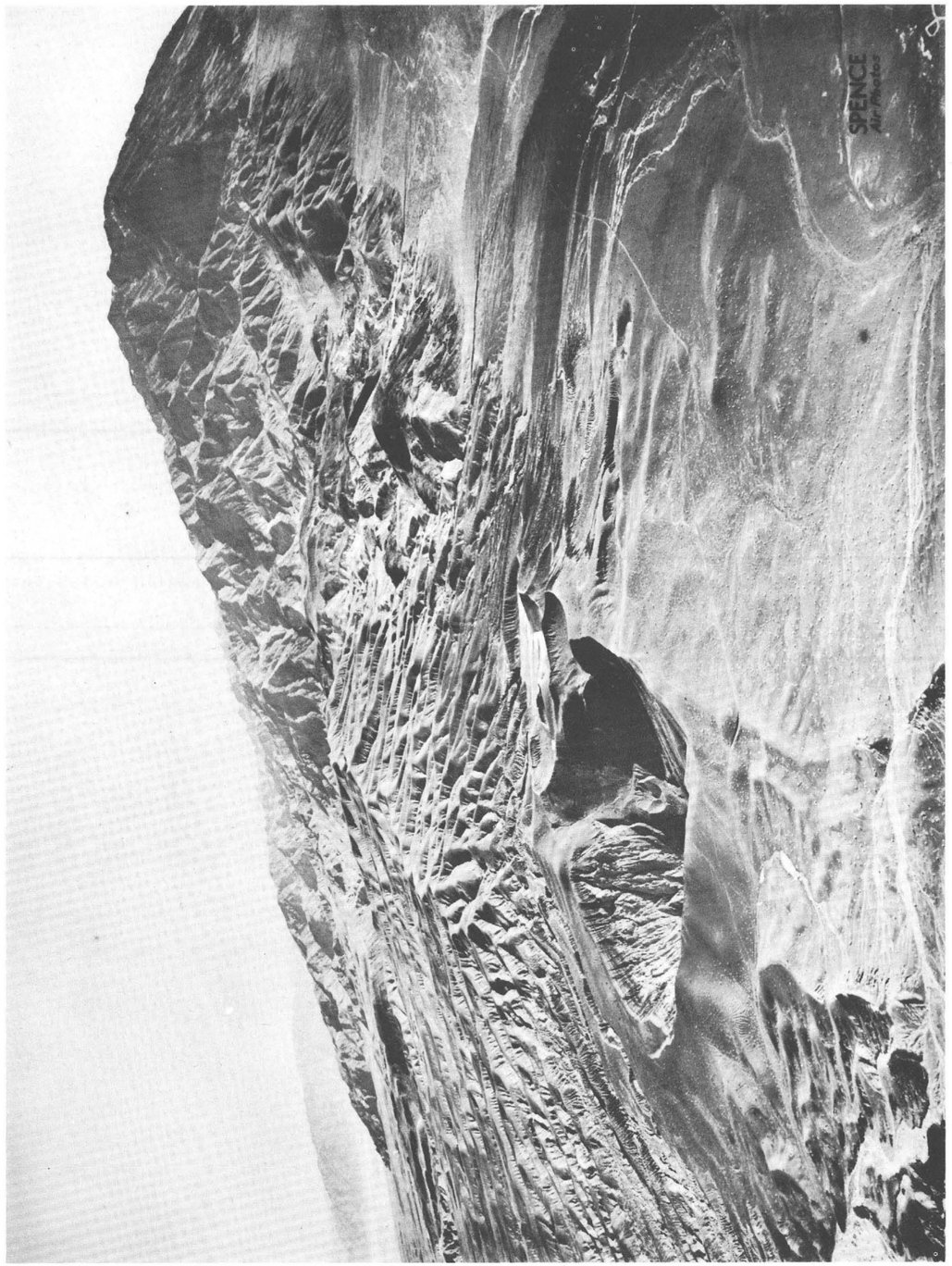
On the negative side of the program was unexpected defeat of the Minerals Stabilization bill (S. 4036) and the extension of the Domestic Mineral Production and Purchase Act of 1956.

The rejection of the former bill opens the door for an immediate request to the President to raise the import duties on lead and zinc, especially.

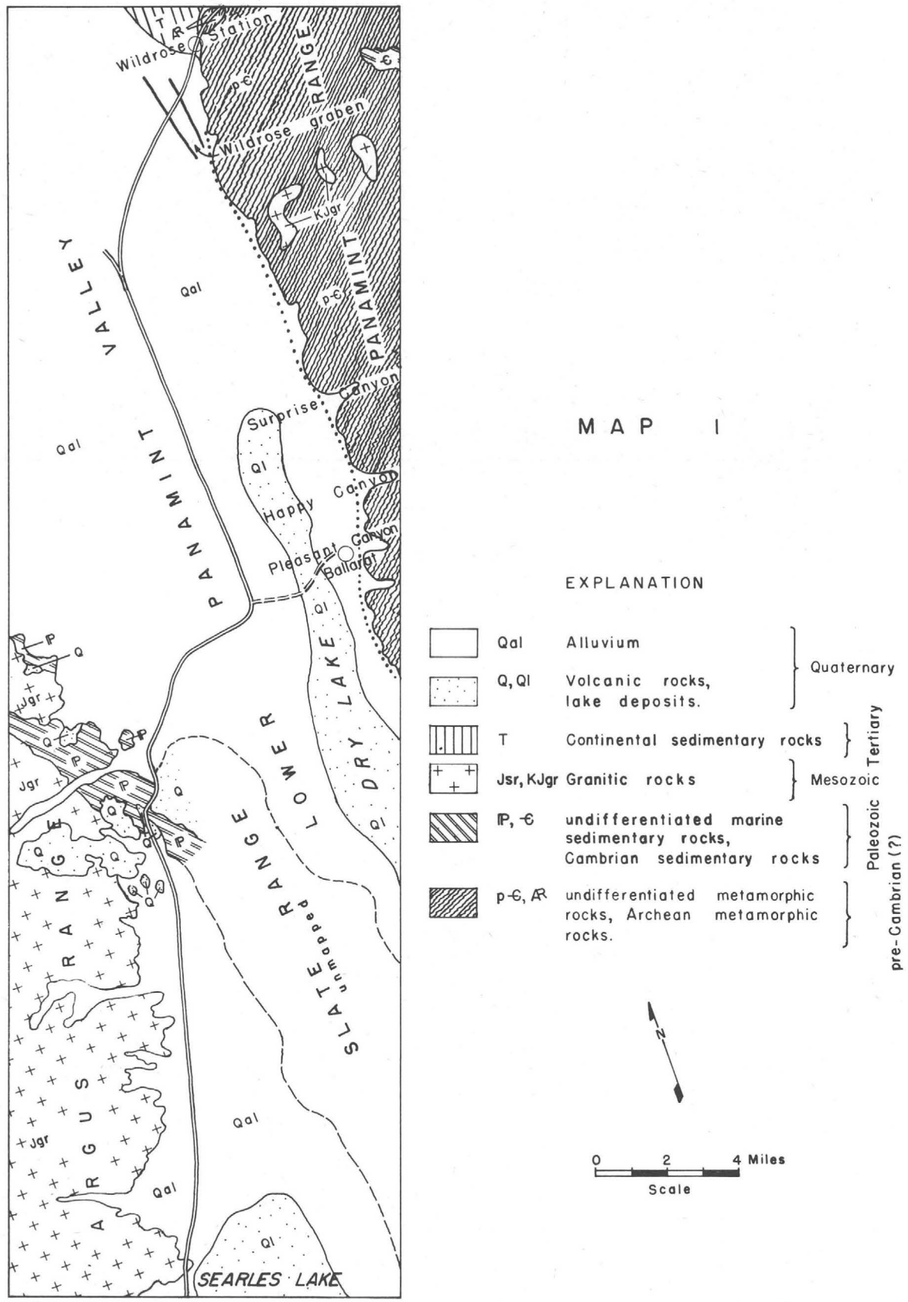
Proposal may withdraw land for Bristlecone Pine Forest

An area containing about 28,000 acres in the crestal part of the White Mountains in north-central Inyo County and southeastern Mono County is subject to a proposed withdrawal as announced in the Federal Register, vol. 23, No. 169, p. 6690, dated August 28, 1958. The withdrawn area would be known as the Ancient Bristlecone Pine Forest, and the land would not be subject to any form of appropriation, including that under the mining or mineral leasing laws. However, the withdrawal would be subject to valid existing rights.

A Bristlecone pine in the White Mountains. This specimen is more than 25 feet high. Photo courtesy U.S. Forest Service.



Ubehebe Crater, Death Valley region, Inyo County. To the right is Tin Mountain; to the left, in the background, is Death Valley. Spence Air Photos.



MAP I

not been established, but which may have coincided approximately with the present positions of Death Valley and Furnace Creek Wash.

As few diagnostic fossils have been described as recovered from the Tertiary rocks of the Death Valley area, the exact ages of the rocks still are largely unknown, but most of the occurrences that can be viewed from the floor of the valley appear to have been deposited in the later part of the epoch (Miocene and Pliocene time). A belt of middle Tertiary (Oligocene) sedimentary and volcanic rocks, however, is extensively exposed along the east slopes of the Grapevine and Funeral Mountains.

The Tertiary lakes of the Death Valley region commonly were undrained and became so reduced by evaporation that saline minerals of various kinds especially salt, gypsum, and borates, were deposited in layers on their floors. The borates later became redistributed and reconstituted into bodies composed mostly of colemanite. During the early 1900's these deposits were the world's principal source of borax as well as the principal source of income in the Death Valley area.

Quaternary Rocks

Most of the present topographic features of Death Valley can be attributed either directly or indirectly to movement along a major fault zone--the Death Valley fault zone--which approximately coincides with the valley. It is joined near the mouth of Furnace Creek Wash by the Furnace Creek fault zone, the trace of which extends southeastward along Furnace Creek Wash. Although both fault zones apparently were active through most or all of Tertiary time, the Death Valley fault zone appears to have been much the more active in post-Tertiary time.

The west face of the Black Mountains, for example, is a fault scarp that has stood at its present elevation long enough to be only slightly eroded. The early stages of erosion are indicated in the steepness and narrowness of the canyon walls, in the presevation of large, relatively undissected areas of low relief high along the crest of the mountains, and in the smallness of the alluvial fans that have formed at the mouths of the canyons.

The surface of these fans and those of the much larger fans that slope eastward from the Panamint Range are broken by numerous scarps from a few feet to several tens of feet high. The traces of these faults are linear and generally parallel with the trend of the valley. These features also are fault scarps and are the most recent visible expressions of movement along the Death Valley fault zone.

One of the most striking features of the valley is the white, saline crust that covers many square miles of its lowest part. This crust is comprised mostly of common salt, but also contains efflorescence of ulexite, also known as cottonball ulexite, which for a few years previous to 1830 were scraped and treated as a commercial source of borax.

The saline crust is but the uppermost layer of saline minerals that formed during the drying up of a once-extensive lake that occupied Death Valley. The floor of the valley is underlain by alternating layers of salt and mud to at least a depth of 1000 feet and perhaps much more. This lake is generally believed to have been the lowest and most southeasterly of a chain of Pleistocene lakes which extended as far northwest as Owens Valley and which during the moist intervals were connected by flowing streams. The lake that occupied Death Valley, now known as Lake Manly, also received water from the area drained by the present Amargosa River which enters the southern part of valley and whose headwaters are near Beatty, Nevada, many miles to the north. The Amargosa, however, now flows discontinuously and feebly and rarely extends on to the surface to the lower part of Death Valley.

Remnants of old shorelines indicate that at one time, Lake Manly was at least 600 feet deep and 150 miles long. These shorelines are especially numerous and well developed on Shoreline Hill at the southern end of the valley. Since the maximum filling of Lake Manly, the climate of the Death Valley area gradually became more arid, so that today only the hardiest of plants and animals survive.

SELECTED REFERENCES

Clements, Thomas, Geological story of Death Valley: Desert Magazine Press, 1954.

Hazzard, J. C., 1937, Paleozoic section in the Nopah and Resting Springs Mountains, Inyo County, California: California Jour. Mines and Geology, vol. 33, pp. 273-339.

Johnson, B. K., 1957, Geology of a part of the Manly Peak quadrangle, southern Panamint Range, California: California Univ., Dept. Geol. Sci., vol. 30, pp. 353-424.

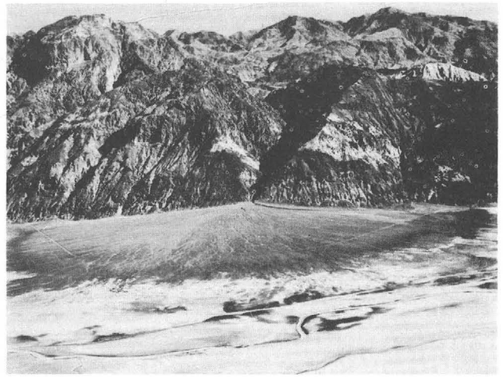
Noble, L. F., 1941, Structural features of the Virgin Spring area, Death Valley, California: Geol. Soc. America Bull., vol. 52, pp. 941-1000.

Noble, L. F., and Wright, L.A., 1954, Geology of the central and southern Death Valley region, California: California Div. Mines Bull. 170, chapt. II, contr. no. 10, pp. 143-160.

Wright, L. A., and Troxel, B. W., 1954, Western Mojave Desert and Death Valley region: California Div. Mines Bull. 170, Geologic guide no. 1, 50 pp.

BOUND VOLUMES OF THE JOURNAL NOW AVAILABLE

A limited number of copies of the 1954, 1955, 1956, and 1957 annual volumes of the California Journal of Mines and Geology, bound in cloth, may now be purchased from the Division of Mines. These volumes (numbers 50, 51, 52, and 53), contain all of the issues of the Journal for each year, some of which are out-of-print on a single copy basis. Price of the bound volumes is $10.00 each.



View east toward the steep, fresh fault scarp of the Black Mountains, with the floor of Death Valley in the foreground. The strikingly symmetrical alluvial fan heads at the mouth of Coffin Canyon, an extremely narrow and precipitous gorge that gives way upstream into somewhat more open country. Photo by J. S. Shelton and R. C. Frampton.

Death Valley region and to have since been largely eroded away. The volcanic activity was a prelude to a series of great crustal disturbances that later produced the Death Valley trough itself and continue to disrupt, though seemingly imperceptibly, the Death Valley landscape today. Concurrent with, or soon after, the Triassic volcanism, the sea apparently withdrew, never to return.

A continuation of the crustal unrest is indicated by the emplacement later in Mesozoic time--probably about 100 million years ago--of bodies of granitic rock. From place to place, these bodies intrude all of the older rocks. They crystallized probably at depths of several thousand feet beneath the earth's surface. These bodies probably are related in time and origin to those that comprise the batholith of the Sierra Nevada, but are much smaller. In the Death Valley area the granitic rocks ordinarily can be distinguished by their uniformly white to pale gray colors, a massive homogeneous appearance, and the "knobby" topography of their weathered surface. Bodies of granitic rocks are widely distributed in the Death Valley area; in the Panamint Range they are especially prominent. An elongated body is along the highway between Wild Rose and Emigrant Canyon. Within this body are the gold deposits at the site of the old mining camp of Skidoo. Peripheral to the body are numerous tungsten deposits. Indeed, most of the metallic mineral deposits in the Death Valley area appear to be genetically related to the granitic rocks.

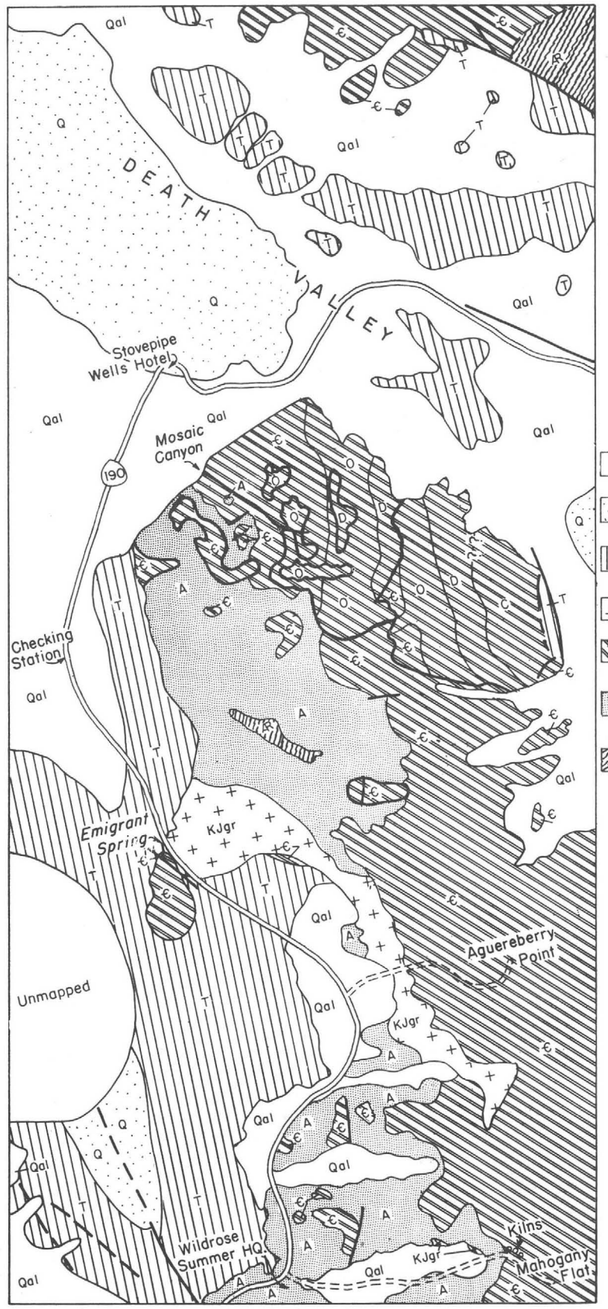
As the Death Valley area and the region that surrounds it contain no sedimentary rocks that have been identified with the middle Mesozoic through lower Tertiary interval, geologists have assumed that during most or all of this time the surface again lay above sea level and that the material eroded from this land was carried well beyond the limits of the present valley. An especially large volume of material, measurable in hundreds of cubic miles, appears to have been removed from the area now occupied by the Black Mountains. Over extensive parts of these mountains, Tertiary rocks rest with depositional or moderately faulted contacts upon the ancient metamorphic rocks. The thick accumulation of later Precambrian and Paleozoic rocks that must have once existed here are missing, and presumably were eroded away before the Tertiary rocks were deposited.

Tertiary Rocks

Tertiary rocks form the most colorful parts of the Death Valley landscape. They are very widespread and are especially well displayed on both sides of the road between Furnace Creek Inn and Dante's View. Here, as elsewhere in the region, the Tertiary rocks can be broadly divided into three types: (1) siltstone, originally laid down in lakes that occupied basins in the Tertiary land surface; (2) conglomerate, deposited mostly in the form of alluvial fans marginal to the lakes; and (3) extrusive and intrusive volcanic rocks, that commonly were emplaced in the high areas between the basins. The siltstone is most easily distinguished as the lightest in color and least resistant of the three; the conglomerate is colored pale gray and is ridge-forming; the volcanic rocks ordinarily are the most resistant and highly colored.

The thickest single succession of Tertiary rocks in the Death Valley area is probably the one in Furnace Creek Wash. This succession, estimated to be about 13,000 feet thick, was deposited in a large land-locked basin the former outline of which has

View west toward east face of Panamint Range, showing Hanaupah Canyon and Telescope Peak (on left skyline). The mountain slopes are underlain by Cambrian strata that dip toward viewer. The large Hanaupah fan is much dissected; the gully in the upper part has a relief of about 200 feet. Spence Air Photos.



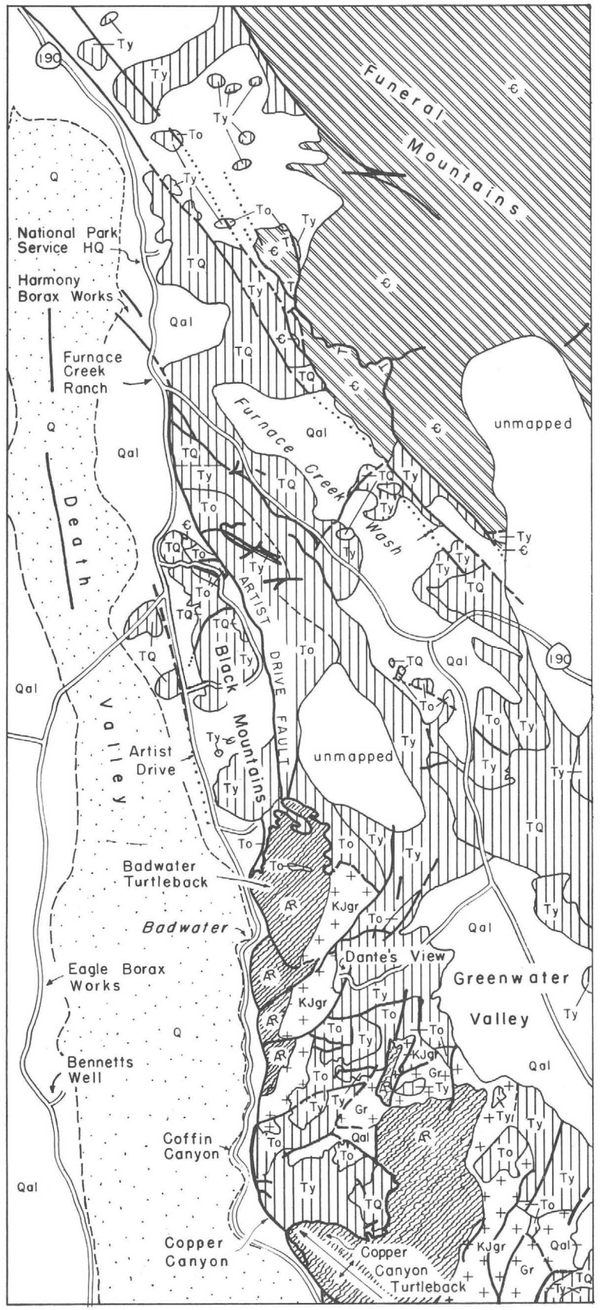
MAP 2

Explanation

- Qal Alluvium
- Q Continental deposits, sand dunes, salt deposits — Quaternary
- T Continental sedimentary and volcanic rocks — Tertiary
- KJgr Granitic rocks — Mesozoic
- C, D. O, € Carboniferous, Devonian, Ordovician, Cambrian marine — Paleozoic
- A Algonkian rocks, sedimentary rocks, metamorphic rocks — Pre-Cambrian
- AR Archean metamorphic rocks — Pre-Cambrian

0 2 4 Miles
Scale

N



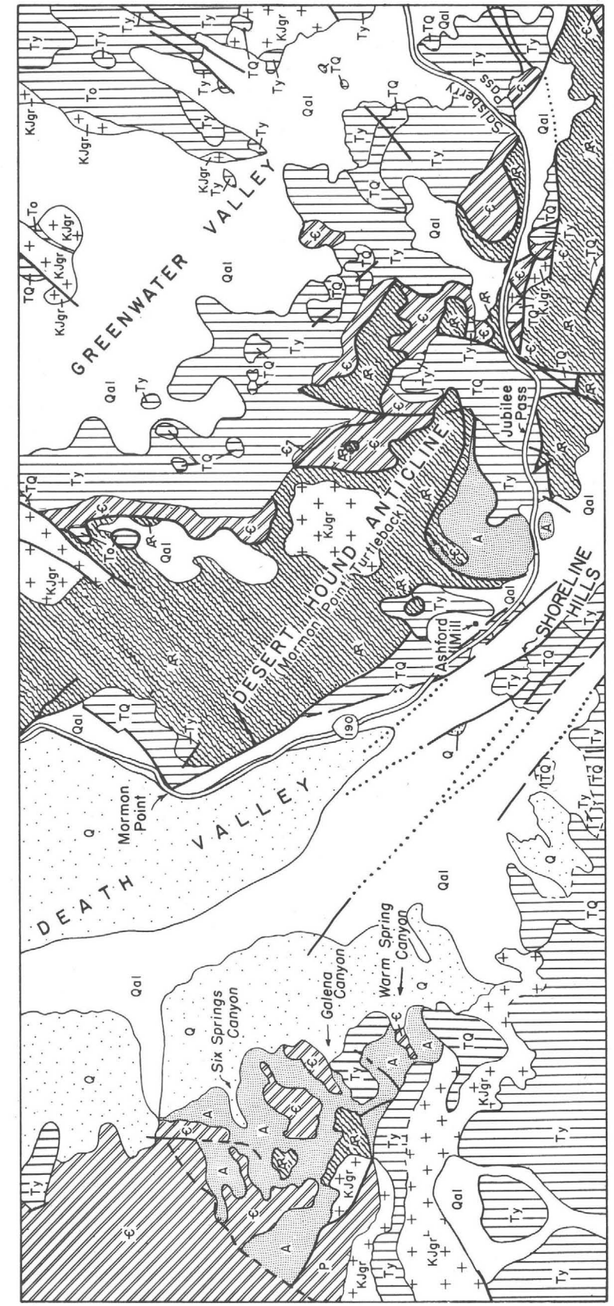
MAP 3

EXPLANATION

Qal	Alluvium	Quaternary
Q	Salt deposits	Quaternary
TQ, Ty, To	Plio-Pleist, younger and older Tertiary continental sedimentary & volcanic rocks	Tertiary
KJgr, Gr	Granitic rocks	Mesozoic
P, Є	Undifferentiated marine sedimentary rocks, Cambrian marine sedimentary rocks	pre-Cambrian Paleozoic
AR	Archean metamorphic rocks	pre-Cambrian

N

0 2 4 Miles
Scale



MAP 4

Explanation

Qal	Alluvium	Quaternary
Q	Continental, salt deposits and volcanic rocks.	Quaternary
TQ, Ty, To	Plio-Pleistocene, younger and older Tertiary continental sedimentary and volcanic rocks.	Tertiary
KJgr	Granitic rocks	Mesozoic
P, Є	Permian and Cambrian marine	Paleozoic
A	Algonkian metamorphic rocks	Pre-Cambrian
AR	Archean metamorphic rocks	Pre-Cambrian

N

0 2 4 Miles
Scale

Goler Canyon Placers—Goler Canyon Mining Co.

Photo by Walter Abel.

o

16258 C 3-35 200

XLI B-1 Dean Frank H. Probert.
WITH THE AUTHOR'S COMPLIMENTS

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES

EGH
II-94

Reprint from California Journal of Mines and Geology,
Report XXX of the State Mineralogist,
October, 1934 (pp. 417–426)

University of California
DEPT. OF MINING & METALLURGY

Geologic Features of the Dry Placers

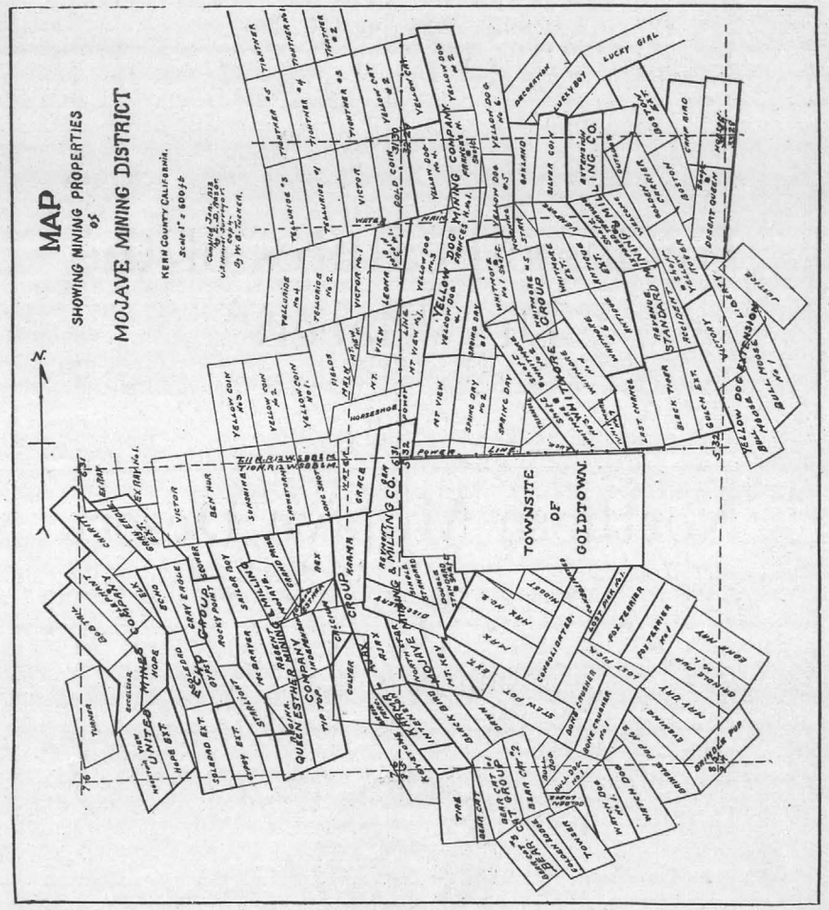
OF THE

Northern Mojave Desert

By
CARLTON D. HULIN

CALIFORNIA STATE PRINTING OFFICE
HARRY HAMMOND, STATE PRINTER
SACRAMENTO, 1935

16258 C



Well, north of Barstow; and at Indian Spring in the extreme eastern part of the Searles Lake quadrangle.

The original source of the gold carried by the basal conglomerates of the Ricardo Series is not known. It may well have been in the Sierra Nevada, far to the north or northwest; or it may have been from gold deposits occurring in the desert ranges east of the Sierras and north or northeast of the Searles Lake quadrangle.

No attempt has been made to determine the actual gold content of the basal Ricardo conglomerates, but it is undoubtedly quite low—probably only a cent or two a yard, if that. The concentration of gold found in the workable dry placers represents the results of reworking of immense quantities of the Ricardo conglomerates by erosional agents operating over a very lengthy period of time. As a result the concentration ratio giving rise to the present placers was at least several hundred to one.

As has been indicated the transportation of sedimentary detritus under the arid conditions existing in the northern portion of the Mojave Desert is done largely by flood waters during times of extreme precipitation. During intervening periods the canyons and washes gradually accumulate a detrital fill—sedimentary detritus washed in by the lighter rains and which the rain water is unable to carry further. This fill may accumulate to a considerable thickness before the next cloudburst. When this cloudburst comes it may sweep out all of the fill from the canyon, or it may carry away only part of it, depending on the intensity of the cloudburst and the depth of the fill. Quite obviously with excessive quantities of detritus available the flood waters will be badly overloaded and the concentration of placer gold will be extremely variable. Moreover the concentration during any given cloudburst will be at the bottom of the channel which existed for that particular cloudburst.

In consequence of these types of action the features of dry placers may be expected to be quite variable. While the best possibility for gold concentrations will always be on bed rock, other concentrations may occur at any horizon in the gravels. And these concentrations, on bedrock or otherwise, may be quite sharp; or the gold may be distributed through some given thickness of gravel.

Nor are all the placer gold concentrations to be found in the present gulches and washes. During the Upper Pliocene and early Pleistocene placer gold concentrations were forming just as they are today, and the bottoms of the canyons of that time were much higher than now and in many cases occupied different courses. With passing time these canyons were cut deeper and locally as this deepening progressed, portions of the old channel gravels were left behind. These are now found as terrace gravels perched high above the bottoms of the present gulches. Many such terrace deposits have been found and mined in Goler Canyon, in Last Chance Canyon, and in other localities in this region.

This paper was written as a progress report covering a portion of the results obtained to date in the study of the geology of the Searles Lake quadrangle. In consequence references, detailed descriptions, and details of geographic occurrence have been largely omitted.

Placer Deposits

Two different modes of origin of placer gold deposits exist in the northern Mojave Desert region, as was intimated early in the paper. The first type of placer gold deposit has been derived directly from the erosion of nearby primary gold deposits. The value of placer gold deposits falling in this group would be dependent among other things on the richness (i.e. the amount of gold available) in the primary deposit; on the coarseness of that gold; on the amount of erosion the primary deposit had undergone; and on a topographic environment favoring the concentration of the gold removed by erosion as contrasted with one which would cause the eroded gold to become admixed with great quantities of valueless rock detritus.

Economic placers falling into this group which are known to the writer are limited to derivation from the bonanza deposits in the vicinity of Randsburg. On the north slope of the Rand Mountains near Randsburg, and on the south slope of the Rand Mountains in the Stringer District and south to below Atolia important dry placers were worked in the early days and a few are still being exploited. The gold in these occurrences was derived directly from the veins near Randsburg and from veins in the Stringer District. These placers carried not only placer gold but placer scheelite as well, and in recent years the scheelite content of the gravels in the placers south of Atolia has been vastly more valuable than the gold content.

Gold from placers near Randsburg examined by the writer was somewhat pale in color, typically angular, and not infrequently gold grains were still intergrown with fragments of quartz. These characteristics are directly the result of the very limited transportation which the gold of these placers has undergone.

Gold placers of this type but of subordinate importance may well exist in connection with the gold-bearing veins of the areas of Eocene mineralization. The writer knows of no case where such placers have been worked, but evidence of early-day small-scale operations might well have been completely destroyed in the intervening years.

The second type of placer gold deposit of this region resulted from the erosion and reworking of the basal conglomerates of the Ricardo Series with a resultant concentration of gold which was originally present in those conglomerates. The widespread distribution of the fluviatile conglomerates of the basal Ricardo has already been described. And in the area so far studied by the writer practically everywhere that these conglomerates outcrop in important quantity the gulches and washes leading from the outcrops either show evidence of dry placer operations in former years or are being actively exploited at the present day. Gold found in these placers, seen by the writer, is slightly darker in color than that found near Randsburg, and shows decided evidence of abrasion and rounding which indicate a lengthy transportation.

As examples to indicate the widespread distribution of placers of this second type of origin may be mentioned the placers formerly or now being worked in Jawbone, Red Rock, Last Chance and Goler canyons in the El Paso Mountains; Summit Diggings; old placer workings near Christmas Camp, southwest of Searles Lake; the Hamburger placer east of Fremont Peak; Opal Camp; Coolgardie and Williams

GEOLOGIC FEATURES OF THE DRY PLACERS OF THE NORTHERN MOJAVE DESERT

By CARLTON D. HULIN *

In the last several years considerable interest has been exhibited in the dry placers of the Mojave Desert. While the more productive placers were largely worked out in early years, the recent rejuvenation of interest in gold mining has resulted in an influx of prospectors so that in many of the better known and more accessible dry placer districts scores of men may now be found sinking shafts and operating dry concentrating machines.

Whatever the economic future for these operations may be, some little interest attaches to the origin of the gold of these dry placers. Widely scattered as they are throughout the desert province, if the gold be of local origin as is commonly believed by many of the prospectors and miners, primary gold deposits would be expected to be as common and as widely scattered as are the placers. Actually this is not the case, and in certain areas intensive prospecting of the country tributary to productive dry placers has proven entirely fruitless.

During recent years the writer has been engaged in studying and mapping the geology of the Searles Lake quadrangle, an area of 3886 square miles located in the northern part of the Mojave Desert province. In the course of this work particular attention has been given to the geologic setting of the various primary metalliferous deposits and also of the various placer deposits which have been encountered in the area so far studied. Work on the Searles Lake quadrangle is still incomplete and in consequence it is not feasible at this time to indicate areas which may be particularly attractive to prospectors; nevertheless the work has advanced sufficiently far as to indicate clearly that two distinct types of placer deposits occur in this region, and the more important factors involved in the origin of each type have been worked out.

Although the work done by the writer has been confined to the Searles Lake quadrangle, it is believed that the placer gold occurrences of surrounding portions of the Mojave Desert are entirely comparable to those of the area which has been studied.

It is believed that a discussion of the origin of these placers will be not only of scientific interest but of direct assistance to prospectors and miners of the desert province as well.

An understanding of the origin of the placer gold deposits calls for a knowledge of the later geologic history of this region. The earlier geologic history will be touched upon only briefly.

* Associate Professor of Geology, University of California.

General Geology

During the Paleozoic the Searles Lake region was receiving more or less continuous deposition of marine sediments. A thick sedimentary column was thus built up, its members ranging in age probably from Algonkian to Permian, and including all of the more common types of sediments—conglomerates, sandstones, shales, limestones and cherts.

Little is known concerning the history of the early Mesozoic. A sequence of lavas is known in the extreme eastern portion of the area which is ascribed to the Triassic or Lower Jurassic. Similar lavas are also known elsewhere in surrounding portions of the Mojave Desert.

In the Middle Mesozoic, at the end of the Jurassic or the beginning of the Cretaceous, occurred the great Sierra Nevada batholithic invasion. The Sierra Nevada of that time can hardly be pictured as being even similar in extent to the present Sierra, since the batholithic invasion involved not only much of the area of the present Sierra Nevada but an almost equally great area in the Tehachapi Mountains and in the desert ranges to the east and south of the present Sierra.

The physical relief of the Searles Lake region at the time of the batholithic invasion can not as yet be reconstructed on the basis of any direct evidence. It may well have been mountainous, but if so its mountainous character was not particularly due to folding. The Paleozoic strata, where folded, show a rather open type of folding; elsewhere the pre-batholithic rocks are nearly flat-lying and may show but little evidence of disturbance. Effects of dynamic metamorphism are in general rather weak in the Paleozoic rocks, though thermal effects, particularly close to the contacts with the granitic rocks, may sometimes be quite pronounced.

The plutonic rocks composing the batholith in the Searles Lake quadrangle are usually rather coarsely granitic in texture and possess a general composition of quartz monzonite, though more acid and more basic variants are known. Cutting the quartz monzonite with extreme abundance are innumerable dikes of aplite, and less commonly pegmatite dikes and dikes or pipes of lamprophyric character are encountered. The lamprophyres in general have the composition of hornblendeite and are typically of extremely coarse grain.

Eocene(?) Intrusives

A second and later group of dikes is encountered in a number of isolated areas in the Searles Lake quadrangle. Within rather sharp areal limits the dikes of this second group may be very abundant, while beyond the limits of each specific area they appear to be entirely absent. The dikes of this group can be naturally subdivided into more acidic members, light in color and poor in ferromagnesian constituents, and into dark-colored ferromagnesian-rich members of lamprophyric type. The dark lamprophyric dikes cut the light-colored acid dikes. Dikes of both types tend to be prophyritic in habit, and possess fine-grained ground-mass textures, the lamprophyric type tending however to be coarser grained than the more acid members.

Dikes of this group are clearly set apart on textural grounds from the older aplites, pegmatites and coarse-grained lamprophyres which are related to the Sierra Nevadan quartz monzonite invasion. The fine-grained groundmass texture of this later group of dikes indicates rather

The first period of mineralization was related to the batholithic invasion of quartz monzonite at the close of the Jurassic. The mineralization of this time is not known to be economic in this area. Veins showing high temperature characteristics occur widely scattered. Usually narrow, a few veins were seen possessing thicknesses of ten to twenty feet. They cut any of the pre-Tertiary rocks and are later than the aplites, pegmatites and lamprophyres which represent the last phase of the batholithic invasion. The quartz of the veins is coarsely crystalline and glassy, and high temperature minerals such as epidote, orthoclase and micas are occasionally to be observed. Prospectors in general have learned to avoid these veins.

Some mineralization has also been locally developed along contacts of the batholith. An example of this in the El Paso Mountains shows minor pyrite and copper minerals in a rather strong contact silicate zone.

The second period of mineralization is related to the intrusion of the dikes which have been questionably assigned to the Eocene. One may travel for miles through country devoid of these dikes and devoid of any evidence of mineralization or of the activity of prospectors. One may then enter an area where the Eocene dikes are present and immediately abundant evidence of mineralization is apparent—usually made so by numerous abandoned prospect holes, shafts and tunnels. On leaving the area where dikes outcrop, the evidences of the former activity of prospectors are likewise left behind.

Regardless of theory, the coincidence of distribution of the dikes and mineralization strikingly indicates an evident relationship between the two.

The veins of this second period of mineralization are later than the dikes which they commonly follow or cut. The veins are usually narrow but sometimes swell out to thicknesses of four or five feet. They are of quartz and show features suggestive of both mesothermal and epithermal characteristics, dominantly the latter. While gold is the economic metal, the presence of pyrite, arsenopyrite, galena, sphalerite, chalcopyrite and molybdenite can be observed in various cases.

The veins of this period have in many cases been productive in a small way, and many are still being actively explored. These veins, however, while in many cases productive of high-grade ore, are inclined to be erratic and to pinch, swell or terminate with extreme suddenness. As a result in very few cases have actual orebodies of consequence been developed.

The third period of mineralization was related to the early Upper Miocene igneous activity of the Rosamond and gave rise to typical epithermal deposits of the bonanza type. The highly productive deposits around Randsburg, at Atolia, at Calico, and south of Mojave in Soledad Mountain are the best known. In the several cases the deposits are of value for gold, for silver, and for tungsten (scheelite). Formed at relatively shallow depths during Rosamond time, and initially possessing a limited vertical range, deposits of this type could easily have been destroyed by erosion if existing in areas subsequently uplifted. Or if formed in areas later depressed, deposits of this type may well exist in this region, unknown, due to burial and protection from erosion.

are overlain by vast thicknesses of poorly sorted arkosic sands and angular gravels which obviously have had a rather local origin.

Post-Ricardo Time

Following the final Ricardo sedimentation, faulting continued, blocks being shoved up (relatively) to give the present fault-block mountains of the region; other blocks subsiding and creating the depressed basin areas. Erosion has accompanied this later fault history (during the later Pliocene, Pleistocene and Recent), cutting into and lowering the mountain blocks and creating the present mountain topography, the detritus removed being carried into the depressed basins, gradually filling them.

In a number of places late Pliocene or Pleistocene gravels have been uplifted by later fault movements and are now undergoing dissection. Elsewhere changes in the power of the erosive agents or local changes in base level have likewise led to the dissection of these later gravels. The later dissected gravels are seldom to be confused with the older conglomerates of the basal Ricardo, since as has been pointed out the later gravels almost invariably carry numerous boulders of olivine basalt and such boulders are strictly absent from the basal Ricardo conglomerates.

During post-Ricardo time, down to the Present, the erosion which has gone on has occurred under strictly arid conditions. In the more elevated portions of the area bare rock exposures were attacked by the various erosive agents, the rock mass being broken down and loose detritus set free. These erosive agents have been quite varied and include not only the abrasive action of wind and running water, but also the effects of temperature change, both daily and annual; the action of freezing and thawing; and the effects resulting from chemical decomposition and hydration of minerals of the rock mass.

The loose detritus set free has continuously tended to move towards the depressed basin areas. In more exposed positions and on the open flats, wind action has been important in moving the finer detritus. In general, however, wind transportation has been of inferior importance as compared to other methods. Gravity has played a part on the steeper slopes.

Transportation by running water has, however, been the dominant mode of movement of detritus in spite of the aridity of the region. The high porosity of the desert soils and sands allows little run-off during normal rainfall, the rain sinking almost immediately into the ground. Occasionally, however, exceptionally heavy rains or cloudbursts occur and during these periods a very heavy run-off is produced. Thus during short periods of exceptional precipitation more detritus may be transported from the higher to the lower parts of the region than is moved during the months or even years that may intervene between cloudbursts.

Primary Metalliferous Deposits

Primary mineralization is known to have occurred during at least three distinct periods in the Searles Lake area. Each period of mineralization was related to a period of igneous activity, the mineralization occurring during the closing stages of such activity.

rapid cooling and hence injection into cool wall rocks. Hence they must be distinctly later than the late Jurassic granitic rocks.

These dikes can be demonstrated as being pre-Middle Miocene, since they are locally capped with Middle Miocene sediments. In age then the dikes may be anything from Lower Cretaceous to Middle Miocene. Tentatively, however, they will be classed as early Eocene and comparable to the supposed early Eocene intrusives known through central and eastern Nevada and western Utah, although this can not as yet be directly demonstrated on field evidence.

Subsequent to the batholithic invasion at the close of the Jurassic or the beginning of the Cretaceous the Searles Lake quadrangle and adjacent areas were subjected to more or less continuous erosion until about the middle of the Miocene. Whatever the relief may have been at the beginning of the Cretaceous, by early Miocene time this relief had been worn down until the surface at least approximated a peneplain. The thickness of material removed by erosion during this lengthy interval can only be conjectured. To judge from the extent of the quartz monzonite now exposed, from ten to twenty thousand feet of rock may well have been eroded away. All of the products of this erosion were removed from the region so that a well-developed external drainage system must necessarily have been in existence. It has been possible to recognize only isolated local portions of this drainage system.

The Rosamond Series

In about Middle Miocene time the northern Mojave Desert region was affected by warping and faulting, with the resultant formation of elevated mountain blocks and depressed basins and a complete destruction of the pre-existent drainage system. Erosion attacked the elevated blocks, the detritus being deposited in the adjacent depressed areas. Of local origin, the detritus consisted dominantly of arkosic sediments derived from the abundant quartz monzonite, though locally detritus from the various Paleozoic and older horizons appears with abundance.

Thus was initiated the deposition of the Rosamond Series, of widespread occurrence in the northern Mojave Desert, though best known at Rosamond, south of Mojave, and in the Barstow syncline, north of Barstow.

The Rosamond sediments were accumulated under prevailing arid conditions quite similar to those existing in the region today. The localized depressed basins became temporary playa lakes into which sediments eroded from nearby hills were carried by cloudbursts, by soil creep, or by wind action. Owing to the usually short transportation involved, the sediments are typically angular, and we now find arkosic sandstones, angular arkosic conglomerates, clays, and occasionally even salines, variously interbedded in this lower part of the Rosamond series. The clays are frequently colored in shades of green, buff, red, brown or yellow and rather commonly are gypsiferous.

The sedimentation of the lower Rosamond was interrupted by a widespread volcanic outburst which apparently affected the whole desert province, and which can unquestionably be correlated with volcanic outbursts of other portions of the Great Basin. The opening phase of the volcanic activity was of the explosive type, and apparently the whole region was blanketed with a thick mantle of tuff. In the

portions of the region which were topographically high at the time of the volcanic outburst, these tuffs are found resting directly on the quartz monzonite or upon the Paleozoic rocks. Traced into adjacent basins, however, pure tuffs are found resting directly upon arkosic sands and clays which contain no trace of volcanic detritus.

Locally the formation of this tuff horizon was accompanied and followed by the accumulation of agglomerates, the pouring out of lava flows, and the injection of dikes and plugs. The volcanic activity appears to have been of the fissure type, no central vents having been recognized, whereas dikes are commonplace and many times can be actually seen to feed flows.

The nature of the volcanic activity appears to have varied from time to time and from place to place, rhyolites, dacites and rather acidic light-colored andesites and their pyroclastic equivalents all being represented.

Following the time of volcanic activity, erosion continued but now the detritus deposited in the depressed basins consisted of admixed volcanic-arkosic materials, dominantly volcanic at the start, but becoming more and more arkosic with passing time. During this third phase of the Rosamond sedimentation the topographically high portions of the region probably had the tuffs completely stripped away except where interbedded or overlying lava flows served as a resistant protective covering.

The age of the middle and upper phases of the Rosamond series can be fixed as early Upper Miocene on the basis of vertebrate fossils occurring in the Barstow syncline. Insofar as the writer is aware, no fossils have as yet been found in the arkosic lower Rosamond. It is, however, continuous with the succeeding phases, and it appears probable that the base of the Rosamond is no older than the Middle Miocene. Until this is checked by actual fossil evidence, however, some slight doubt must exist as to the exact date of inception of the Rosamond sedimentation.

Upper Miocene Andesites

Rather widely distributed through the northern portion of the Mojave Desert, in areas ranging from a fraction of a square mile to tens of square miles, occur flows of basic, dark-colored andesites. These may rest on the Rosamond, or upon any of the basement rocks of pre-Tertiary age. Pebbles and boulders of these andesites occur in the basal portion of the next succeeding group, the Ricardo series of known Lower Pliocene age. The age of these andesites is thus fixed as being between the Rosamond and Ricardo, and hence as Upper Miocene.

The Ricardo Series

The Ricardo series is known to be of Lower Pliocene age on the basis of vertebrate fossils found at the type locality in Red Rock Canyon and its tributaries. While best known at Red Rock Canyon, the Ricardo series is as extensively developed in the northern Mojave Desert as is the Rosamond series. It is to be found in widely scattered localities throughout the Searles Lake quadrangle, and extends on into adjacent portions of the Mojave Desert.

At the beginning of Ricardo time the northern Mojave Desert appears to have been an area of low relief above which rose occasional hills and mountain groups, characterized by the resistant Upper Miocene volcanic rocks. The depressed basins which characterized the Rosamond sedimentation had been largely filled and the present mountain ranges in general had not come into being.

Into this region in early Ricardo time came a large river system which blanketed the lower portions of the country with stream gravels and conglomerates. The course of the stream can not as yet be entirely fixed, but in general it can be stated that it came in from the northward and sought an outlet towards the southeast in the general direction of the Colorado River.

The stream was dominantly depositing and the gravels and conglomerates left behind were of the nature of flood-plain deposits. Undoubtedly at first the stream sought the lowest channel available, but with passing time the earlier channels were filled with gravels and the stream crowded onto adjacent flat parts of the area. Isolated patches of these gravels are to be found widely scattered throughout the Searles Lake quadrangle, and originally a continuous blanket of gravels must have covered all of what was then the lower part of the area.

The basal conglomerates of the Ricardo series are of variable thickness. Poorly developed at Red Rock Canyon, they increase in importance eastward, reaching a thickness of over one hundred feet at Black Mountain. The conglomerates are sandy and poorly sorted and almost unconsolidated in most exposures. The individual pebbles and boulders are all highly rounded and for the most part range from one to two inches in diameter. Occasional horizons, however, show much larger boulders, several horizons being seen carrying perfectly rounded boulders in excess of a foot in diameter. The pebbles and boulders in general are composed of resistant rock types, the more common being various porphyries, granitic rocks, quartzite, chert and crystalline limestone. Many of these are unlike any rocks known in the Searles Lake region. Basalt pebbles and boulders are absent from the basal Ricardo conglomerates, thus distinguishing them from later gravel accumulations of the region.

The extent of the Ricardo gravels, their size range, their highly rounded condition, and the foreign nature of many of the rock types, are suggestive of deposition by a large stream of moderate grade originating in higher country many tens and possibly more than a hundred miles distant to the north, northeast or northwest.

The stream history of the lower Ricardo was shortly terminated by faulting and volcanic activity which disrupted and probably destroyed the pre-existent drainage system. In several portions of the region important accumulations of tuffs, with some interbedded arkosic sediments, agglomerates, and flows of andesite, showing a finely developed flow structure, overlie the basal conglomerates. These grade upwards into more basic tuffs and flows of olivine basalt. Elsewhere in the region, olivine basalt flows rest directly on the conglomerates, the intervening tuffs and andesites being absent.

While at many places the olivine basalt flows represent the present top of the sections exposed, at other places, particularly at Red Rock Canyon, the basalts are still to be seen interbedded in the sections and

XLI B-1

II-94

II-94 XLI B-1 Silverado As

SWEETWATER RANGE, CALIFORNIA-NEVADA

Notes from PhD thesis by J.H.Halsey,1952

Northern Mono Co.,Calif.,& parts of adjacent Nevada. Parts of Wellington, Bridgeport quads.

Abstract

Pre-Nevadan metamorphics: Jura-Trias? Older series,tuffaceous geosyhclinal seds.;younger series,keratophyric volcanics,locally IB withtuffaceous terrestrial and marine seds.amd normal volcanics.

Late Jurassic Orogeny:Above rocks compressed into tight folds,locally faulted,then invaded by intrusives which metamorphosed the rocks to greenschist facies,albite-epidote-amphibolite facies, and amphibolite facies. Two series of plutons:(1) hybrid, qtz-gabbros,QM,G,alaskites,aplites.These were intruded, metamorphosed to the amphibolite facies and metasomatized by (2), QM,GD,aplite pegmatities.

Tertiary,alternating "tension" and "compression". Tension periods:erosion, volcanism;"compression " periods:block faulting.

Volcanic periods: Late Eocene,Late Oligocene,Late Mio-Early Plio,Late Plio, mid-Pleistocene. Each such period followed by a period of block-faulting,succeeded by a long period of erosion,sh wn by sub-peneplain remnants.

Eocene volcanics:only a few small rhyolite remnants.Oligocene,mainly andesitic intrusions,extensively altered both at time of intrusion and during a period of ,iocene Au-Ag mineralization. Most extensive volcanics are late Mio and early Plio andesites,latites,dacites,rhyolites. Welded-tuff member of the latite series extends from MotherbLode east to Mono Lake,120 mi. Late Plio,olivine basalts extruded;midPleistocene,basaltic andesite. Both scanty.

In Pleistocene renewed uplift and block faulting caused intense dissection of the Tertiary volcanics,and development of present topo. Recent fault scarplets show faulting still continuing.

Area east of S.N.crest,in B & R province. Sweetwater Range,reaching 11, 650',is first of the large west-ward tilted Great Basin ranges E of S.N. crest. Range is separated from E side of S.N.summit region,and from the nearby Pine Nut range,Pine Grove range and Wasonic Range by peripheral graben basins filled with thick detritus. Three great fault scarps bo nd greater Sweetwater Range.

Oliøgenene Propylitized Andesites: Former extension E of S.N.crest very large. To 2500' thick. Domes and intrusives predominate,but in places seds., both propylitized and non-p,form substantial part of series. Some flows. Seds and tuffs where present are older than the intrusives. Sedimentation at this time in broad interior basins as w th present Great Basin. Depending on intensity of volcanism in the region these basins were alternately sites of floodplain and lacustrine deposition.

Intrusions form a great sill compex in Mt.Emma district. Laccoliths 800' thick separated by warped septa of tuffaceous seds. At other places andesite as domes and dike swarms.

In each of the 3 propylitized districts the intrusions & domes are aligned along N-S fissures which conform with both the pre-Tertiary structures and the major Tertiary faults.

Mio-Pliocene Andesites: These were part of the eastward extension of the great Mio-Plio andesite plateau that covered most of the central S.N.crest and its W slope. Thickness in area to 3000'. 25 cu.miles of magma in the map-area alone. Both extrusive & intrusive:domes,sills,laccoliths,necks,dikes.

Intrusive centers lie within a swarm of fractures elliptical in shape,major axis of oval subparralel with regional trend of pre-Tertiary fold & joint tr trends,and with trend of Tertiary master faults. Fractures within these swarms also parallel trend,whuch is N10-25W. These zones bear an en echelon relation to the S.N.crest.

Structural Geology

Mesozoic Geosyncline: Trended N or NW;bordered on E,possibly also on W;that on the E,in central Nevada,later became Cordilleran intermontane geanticline of Schuchert(Sites and nature of the North Amerucan geosynclines.GSA Bull. 35(1923),151-230;this reference,137???). This warp remained positive thru entire early Mesozoic;contributed seds.to trough on W which,with IB volcanics reach thickness of 30,000'. The volcanic horizons with persistent pyroclastic debris is the clastic seds.and ls.,show volcanic activity during the whole period of deposition.

In Sweetwater region ~~deposit~~ subsidence kept pace with deposition.From middle Trias to middle Ju basin received pelagic and neritic marine seds. Basin subsided slowly except during periods of volcanism when the rapid accumulation of effusive material was accompanied by an almost equally rapid basin subsidence.

Deformation first hit Sweetwater region in lower Ju Dunlap time,when it c changed from a shallow marine sea to a basin or basins of terrestrial deposition. Dunlap time closed in a prgressive increase in rate and magnitude of folding,with intense volcanism.

Pre-intrusive folding: main period of deformation,but intensity of folding varied greatly.In Sweetwater Range folding varies from broad,open to near-isoclinal.

Inter-intrusive folding: Near some later Nevadan intrusives the pre-Nevadan bedded rocks are deformed increasingly tward the contacts.Micobrecciation in some flows,stretched pebbles in intervolcanic seds.

Great thickness of volcanic rocks folded into subvertical attitudes. In S.N.west foothills great thickness of flows and volcanic breccias tightly folded,but here IB seds.stromgly sheared,drag-folded. Not so in Sweetwater region. No evidence of differential movement between flows.

Also,incompetent siltstone,very thick,foled tightly without internal deformation.

Folding in Thick Limestone: Bedding and chert horizons are intricately contorted by plastic flow;beds less than 100',not so,show only weak foliation parallel to bedding. Toward margins of a thick mass,ls.relatively undeformed but toward center bedding,laminae become increasingly obscure,finally only

marked by discontinuous carbonaceous streaks and contorted strings of chert nodules. Most such deformed limestones are broadly lentocular along the strike and appear to be thickened in zones of max.deformation;some highly contorted limestones lens out completely along the strike,locally. Transfer of mass during deformation toward regions of least stress along the ls.horizon

Curiously,these thick deformed ls. are always associated with fine-laminated pelitic rocks (clay,mudstones etc.)often many times thicker than the ls; these are completely undeformed.

Shearing in Intervolcanic Tuffs:Shearing in tuffs & tuffaceous seds more intense the thinner the beds.Thick tuff beds,only incipient or no shearing. Reason: (1) Welded tuffs,thin,have primary flow structures or rude alignment of frags in case of other tuffs;rock weaker in plane of foliation. (2) Most intensely sheared tuffs 5-20 ft.thick lie between massive flows. Two implications: (a) thick flow moving relative to a thin tuff may impart enough stress to induce a preferred alignment of the frags or to intensift planar structures already present.(b),Competent flows moving slightly with reppect to each other during folding would transmit same am't of shearing stress per unit area to intervening weak beds regardless of their thickness, But shear per unit thickness will be greater in thin than in thick bends.

Fold Trends.-Sweetwater region,most folds trend N.

Mechanics of Early Nevadan Intrusion: Post-kinematic;early plutons intruded under relative tectonic quiescence. Kinematic criteria lacking: foliation, aligned xenoliths,migmatitic border zones,regional metamorphism in CR,conformable reltion wit pre-intrusive structure. In contrast,the early Nevadan intrusiins are shapeless,cut across pre-Nevadan fold structures indiscrominately;no structural control.

Mechanics of Later Nevadan Intrusion: In part forcibly emplaced,have therefore some features of "synchronos" bathos.,but not synchrnous in usual sense they they were emplaced long after major orgenic forces had subsided. Bathos compressed CR only in a well-defined aureole surrounding the intrusive complex. Also,initial stage of forcible emplacement was followed by a stres less stage during which the plutons continued to emplace themselves by quiescent stoping. Close to contact narrow,densely crowded xenolithic zone; both this zone and the inclusions within the zone are oriented parallel with t the contact and the bedding of the CR. Most of the intruded seds show deformation under plastic flow:cgl.,pebbles stretched without brecciation 2 to 5 times original length.Shows stress applied slowly under high T.

Pre-Tertiary Faulting: Not marked;no evidence of thrusting,much for normal faulting. Healed fault-breccia zones in seds.,restructed to steep-dipping rocks. All breccia zones seen are parallel to well-bedded meta-seds dip 60-90. Large size of breccia frags.,small % attrition gouge shows these were tensional fractures of small displacement. Probably 2 cycles of such fissuring,assoaciated with each intrusion cycle.

TERTIARY STRUCTURE

Three periods of block faulting:Early Miocene,middle Pliocene,Quaternary period still in progress. Less certain evidence of faulting at end of Eocene or beginning of Oligocene,following 1st Tertiary volcanism, and another period during or just following the Mio-Plio andesitic volcanic period but preceding the latite volcanism.

Eocene Structure: Cret.-early Eocene platuea or sub-peneplain of S.N.and G.B. was disrupted apparently for the 1st time,in middle Eocene. Fine-graine Ione seds.of Sierran W foothill belt are erosion products of a low land-mass drained by aggrading streams with low gradients.Overlying these are cse cgl,middle or upper Eocene,products of rejuvenate terrane to E.Rejuvenation usually ascribed to epeirogenic upwarp affecting entire S.N. and GB as far E as Wasatch,and followed by "collapse",leaving S.N.& Wasatch standing as s structurally homogeneous blocks. Thinks various elements could have risen by block faulting independently without a preceding period of epeirogenic uplift. In any case by late Eocene much of Great Basin was a region of inrerior drainage:typical intermont basin deposits,late Eocene;associated wirh rhy volcanics which intruded along fissures subparallel to basement grain;possible that loci of these fissures were determined by earlier Eocene fltg.

Oligocene Structure.-Upper Oligocene basin sediments occur in same country which in late Eocene,lay west of the Eocene rhyolitic centers and had exterior drainage.Thus at some time prior to late Oligo the G.B.-Pacific slope drainage was shifted westward to about its present location.Shift probably produced by block faulting fragmented east edge of late Eocene S.N. Shift was 20-40 mi.

Oligocene volcanics largely coextensive with Eocene volcs,having been intruded along fissures subparallel with Eocene rhy fissures. Absence of displacements on these Oligo fissures shows they were produced "during period of relative tectonic stability separating periods of block faulting".

Early Miocene Structure:The Oligo volcanism was followed after relatively short interval by block faulting: great thicknesses of Oligo volcanics preserved in graben, not seen elsewhere;little time to erode volcanics down. Fault displacements large;faults trended nearly N.

Pliocene Structure: Regional block faulting followed Mio-Plio volcanism,again producing a B & R topo which was bevelled in upper Plio by the Markleeville erosion surface.Some of the most conspicuous mid-Plio faults run nearly E-W or normal to the Quaternary structural grain N-S/ to N30W. At least 1/3 of faults shown on map are reactivated mid-Plio flts,which themselves may have been reactivated faults determined during earlier Tertiary distrophic cycles.

Quaternary Structure:Major trends:N15-25W,trend of basement grain. 2nd Order trends: followed by portions of major longit.faults & by branch fault systems:N5-10E, N5-10W. 3rd Order:N40W,N30E,N60W. Less persistent. 4th Order:(Cross faults):Short faults at high angles to regional structural grain.

Pattern of Single Fault Systems:Major faults curve broadly on strike but i in detail consist of many short breaks intersecting at angles 150-175.

Thus have a zigzag pattern. Fault trends controlled by pre-Tertiary structur i.e. bedding in roof pendants of Mesozoic layered rocks and master joints in the intrusives surrounding them. Minor faults probably controlled mainly by cross joints in both the intrusives and the roof pendants. Thus ultimate control of Cenozoic faults has been by Jurassic folding;altho such folds survive only in occasional pendants surrounded by intrusiverock,~~but~~ enough of the intrusives were controlled in their emplacement by the folds so that the regional fold grain was imparted to the intrusives and thus large-ly preserved,in the form of longitudinal master joints and s.t. foliation parallel with the bedding in adjoining pendants.

Regional Fault Pattern: Great blocks outlined by major fault system are rude quadrilaterals,long axes following regional grain N20-25W. Great-est displacements along longit.faults. Gradual decrease in displacements toward the S termini of these faults,the N45W Sierran tectonic crest.

Present major faults probably at least in part reactivated breaks origina lly established earlier in the Tertiary.(early Miocene?).

Displacements simple or compound,step-blocks or slivers,synthetic. No reverse or strike-slip fltg.However,tilting of many fault blocks along their bounding longitudinal faults suggests the dip-slip movements must have has small strike-slip components. Upthrown side on W in 75% of faults in Sweetwater Range. A zone of E-dipping antithetic faults on W flank of range has most blocks bordered on E by upthrfted blocks?

Brick wall fault block pattern,size of blocks varies greatly. Single fault blocks have moved independentaly of neighboring blocks,but their movements are controlled by those of the larger blocks of which they are com ponents. Sympathetc movement.Example: most recent uplift of S.N.was accompan ied by corresponding upift of entire W fringe of Great Basin. But magnitude of uplift decreases eastward. In Sweetwater region, with respect to a given base level blocks of the range cores have undergone greatest net uplif blocks in outer zones uplifted progressively less,basins the least.

Block Tilting:Only small blocks are steeply tilied;the larger the blocks the less steeply they are tilted. Individual blocks seem to have criticial angles of tilt above which they tend to fragment into smaller blocks.

Tilts of large blocks mostly apparent,result of distributed step-like ris rise of smaller blocks along minor faults. Most fault blocks have two tilt c components,1 normal to the fault toward which the block is tilted,the other, smaller,parallel to the fault. 90% of fault blocks have westerly or NW tilts E-tipped blocks confined to narrow zone of antithetic faults along W side of Sweetwater range.

Origin of Basin & Range Structure: H.S.

Metallization: Only metal of any importance is silver:Silverado-Monte Cristo district on E side of Sweetwater Range. Out of total production of $5,000,000,Silverado mine produced $2,500,000. In mineralized area E fron of range is compound fault scarp gashed by deep eastward trending canyons cut thru 2000-3000' Tertiary volcanics exposing granitic basement.Volcs. mid-Tertiary,thock rhyolitic pyroclastics and intrusives intruded by ande-site.Whole complex has been silicified,argilltized,propylitized.

Mineralization along a series of great N fissure systems. Three carry most of mineralization:

1.Cameron belt along base of range,from Monte Cristo mine in Frying Pan canyon to just S of Silverado Canyon.Veins strike just W of N,dip steep E Silver-gold veins mined mainly for gold.

2. Clinton Belt,from Frying Pan Canyon to Cottonwood Canyon, 1 mile W of Cameron Belt.Wide zone in altered rhy.Main ore vein system,includes Kentuck-Silverado lode. At Silverado mine main vein N25W,dips 30-35W. A silver zone.

3. Dore silver belt,toward summit of range;wide,strongly silicified zone. Some gold.

Rhese fissure systems probably represent great B&R normal faults.Trends controlled by pre-Tertiary structure:concordance of faults with pre-Tert. bedding and schistosity of pendants. Pre-mineral displacement along the faults may have been 500-3000'.

Vein-matter: Gangue mainly qtz,with clay minerals,chalcedony,calcite, fluorite,adularia, alunite. Main ore minerals argentite and native Au,with auriferous pyrite. At Silverado ore is brecciated rhy cemented by microcryst qtz containing argentite in dark blue cryptocrystalline masses and dissems. Finely cryst.dissem.py. Post-ore fracturing has locally brecciated the ore which is recemented by saccharoudal and drusy qtz;vigs s.t. partly filled wi with calcite or banded chalcedony.

Sequence of Events: 1.Faulting in Clinton belt.2.Introduction of silica followe by argentite(cryptocrystalline stage).3.Introduction of iron; crystallization of pyrite;silica continues(microcrystalline stage). 4.Faulting in Dore silver belt;Clinton belt locally refaulted;wall rocks still at high T.5.Great increase in silica;silver continues but weak.Minor gold,fluorine;dilution of Silverado ores by brecciation and silicification (drusy qtz stage).6. Hiatus,wall rocks cooled.7.Faulting in Cameron belt; the other belts locally refaulted;new silica;development of chalcedonic breccias in Cameron belt,chcedonic cavity fillings in other belts;silver continues weak,gold decreasing.

Epithermal: textures colloidal to medium crystalline.Vugs lined with coarse clear quartz;rhythmic banding.Open-space fillings,replacement minor. Vertical extent Silverado shoot,300'.