

Cal Poly Geology Club

Death Valley Field Trip – 2004

Guidebook by
Don Tarman & Dave Jessey

Field Trip Organizers
Danielle Wall & Leianna Michalka

DEATH VALLEY

Introduction

Spring 2004

Discussion and Trip Log

Welcome to Death Valley and environs. During the next two days we will drive through the southern half of Death Valley and see some of the most spectacular geology and scenery in the United States. A detailed road log with mileages follows this short introductory section. We hope to keep the pace leisurely so that everyone can see as much as possible and have an opportunity to ask questions and enjoy the natural beauty of the region.

IMPORTANT: WATER- carry and drink plenty. **FUEL**- have full tank upon leaving Stovepipe Wells or Furnace Creek (total driving distance approx. 150 miles).

Participants must provide for their own breakfasts Saturday morning. Lunches will be prepared at the Stovepipe Wells campground before departing. We will make a brief stop at Furnace Creek visitor's center and for fuel etc.

Meeting Points

Saturday morning meet in front at the Chevron station on the north side of the highway a short distance east of the campground (8:30 AM)

Sunday morning (tentative- depending upon what our last stop is Saturday) meet at the Charles Brown highway intersection with 127 just at the south side of Shoshone. (8:30 AM). Get fuel before meeting.

As you know we will be camping Saturday night between the hamlets of Shoshone and Tecopa. If for some reason you become separated from the main caravan during our journey Saturday – and this would be very difficult to accomplish- simply head for Shoshone/Tecopa. Once on highway 127 continue south for about ??? miles to a point a few hundred feet north of the intersection with the paved road to left leading to Tecopa. At this point take a right turn on Furnace Creek Road (gravel) and drive west until you see our vehicles. This is where we will camp and hold the barbeque.

If you wish to visit the hot springs in Tecopa take the left turn on the surface road to Tecopa. At the only stop sign in town turn into the parking lot. This is Tecopa Hot Springs. No charge for use. Mandatory nude bathing. Women's side to the north.

Introduction to the Geology of Death Valley

The geology of Death Valley reflects a series of events spanning almost two billion years of time. The most recent of these, geologically speaking, occurred very recently. Each event added progressively to the complexity of the previous picture. During the trip we will have an opportunity to see features which represent many of these events.

If you've had a geology course previously you may remember that we have names used to tag intervals of geologic time. For the purposes of this course, and to avoid sounding patronizing, the standard geologic terms will be used. Although other time terms may accidentally sneak into the conversation, the trip leaders will attempt to restrict their time designations to these terms (below). The intervals and their duration are:

CENOZOIC	65 MaBP TO NOW (MaBP = million years before present)
MESOZOIC	225 MaBP TO 65 MaBP
PALEOZOIC	544 MaBP TO 225 MaBP
PRECAMBRIAN	PLANET FORMATION TO 544 MaBP

If it is necessary to be more specific- we are dealing with enormous intervals of time- a prefix of 'early' or 'late' can be added to the interval name. For example, some of the material which makes up Tucki Mountain a few miles west from our first camp site is of *early Paleozoic* age.

For any of those of you whose geology is a little rusty trip leaders, upon demand, will quickly and informally review the rock types and the rock cycle. It is hoped that when you have questions during the trip, no matter how basic, you will bring them up.

Geography of Death Valley

Use the maps incorporated within this guide to keep you “located” regionally. Several main physical features define Death Valley (see map). The west side of the south part of Death Valley is primarily formed by the *Panamint Mountains* with the highest point being Telescope Peak (3,368 m/11,049 ft). Tucki Mountain (pron. Tuck-eye), at the north end of the Panamints, near Stovepipe Wells, provides an informal dividing point between north and south Death Valley. Farther to the north and as rough extensions of the Panamints are the *Cottonwood Mountains*. To the southeast of the Panamints, and still on the west side of Death Valley are the *Owlshead Mountains*. The south end of Death Valley is created by the buttress-like *Avawatz Mountains*. The east side of the south end of Death Valley is formed by the *Amargosa Mountains*, *Black Mountains* and *Ibex Hills*. To the north of Furnace Creek the east side of the valley is formed first by the *Funeral Mountains* and then, next to the north, the *Grapevine Mountains*. We will be able to better understand these relationships by viewing the marvelous scale model of Death Valley in the Visitor’s Center mid-day Saturday.

General Geologic History of Death Valley

Much of the information presented below is the result of cumulative labors of a number of geologists, prominent among whom are Levi Noble, Walter Bucher, Harold Drewes, Bennie Troxel and Lauren Wright. Any participants in this excursion who are interested in more detailed information about Death Valley are urged to contact the leaders who will provide citations of useful papers.

We have only the dimmest of records of Precambrian in the Death Valley region. The oldest rocks we can find here are metamorphic rocks, whose original nature cannot be readily deciphered. Some of these ancient rocks appear in the Panamint Mountains to the west. Similar rocks outcrop in the Black Mountains on the east side of Death Valley as well as in the mountains to the east of Tecopa. The best estimates place the age of these old metamorphic rocks at between 1.4 and 1.8 Ga.

The next (second) 'event' is really an extended series of occurrences resulting in, among other things, the deposition of a vast stack of sedimentary rocks, both clastic and non-clastic extending from late Proterozoic until the end of the Paleozoic. It appears that all of the *early* events were located near and were partially controlled by a progressively widening rift which split a progenitor continent called Rodinia into several components one of which North American now resides. The lower part of this section is present only as remnant scraps here and there.

Major units in this stack of stratified rocks have been assigned names based upon geographic features where they were first studied in detail (see attached columnar section -Figure 1- for a partial listing of these formations). Because of metamorphism and extreme deformation/faulting many of these rocks are unrecognizable in Death Valley itself requiring examination at a distant points, for example near Shoshone where they are better preserved.

Although recognition of most the stratigraphic units is difficult at least one unit is unique enough to allow relatively easy identification. At the bottom of this pile of stratified rocks is the *Crystal Spring Formation*. Either during or shortly after its deposition it was intruded by an enormous igneous sill tens of kilometers in length and breadth and tens of meters thick. The metamorphism associated with this intrusion of the magma formed talc in many places. Mining of this talc has left white patches on hillsides where the Crystal Spring Formation outcrops. Thus anytime one see white splashes of color in the distance you are probably looking at the Crystal Spring Formation. Similar sills in Arizona have been dated at about 1.2 Ga.

The geology during Mesozoic time (third event) in the Death Valley region was controlled by the evolution of a convergent plate boundary and a volcanic-magmatic arc to the west with the resultant intrusion/extrusion of large masses of igneous rock. The development of this arc was mainly responsible for the termination of the carbonate (limestone) sedimentation which dominated the geologic scene up through Paleozoic time. Large thrust faults, related to the convergence to the west, cut the crust of the western part of North America carrying enormous thrust slices tens of kilometers to the east. These thrust faults are not well exposed in the Death Valley area. Much better examples are present to the southeast in the Mesquite, Clark and Mescal Mountains, to the east in the Spring Mountains as well as to the north of Death Valley in the Last Chance Range. The amount of shortening may be somewhere in the neighborhood of 75 km. One of the faults in the Clark Mountains had been precisely dated as active 145 ma.

The magnificent mountains and Death Valley itself are manifestations of the operation of an enormous geothermal "engine". This engine moves a giant mosaic of slabs or plates making up the outer one to two hundred kilometers of the earth. These slabs make up the lithosphere. Those of you with some geologic background may remember that the lithosphere is made up of the crust and a small part of the upper mantle. The plates move generally away from, toward or parallel to adjacent slabs. Each sense of movement creates its own distinctive type of geologic response, sometimes causing large faults like the San Andreas and in other places causing the evolution of mountain ranges like the Himalayas. The rate of movement of these slabs is variable but on the average is a few centimeters a year. The engine has been operating during all the countless years represented in the rocks and features discussed above. Only in Cenozoic time do we see effects in sufficient detail to begin to appreciate the magnitude of the forces which the geothermal engine can bring to bear on the lithosphere.

In the Death Valley area the plate movement during the Cenozoic (final events) caused stretching and up-arching of the crust. The uplift eventually resulted in failure of the crust along faults. Large segments of the crust slid slowly down these fracture surfaces leaving high-standing cliffs or scarps behind. The west face of the Black Mountains (Turtlebacks-see below) is an example of one of these scarps.

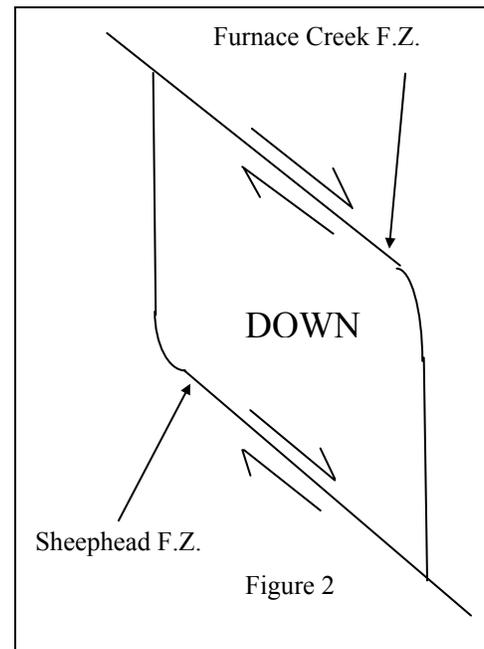
Although the exact relationships are, at present, unclear, several strike-slip faults (horizontal movement along vertical fault planes) are also involved in the formation of Death Valley. These

strike slip faults are the Death Valley fault, the Sheephead fault and the Furnace Creek fault (also called the North Death Valley Fault).

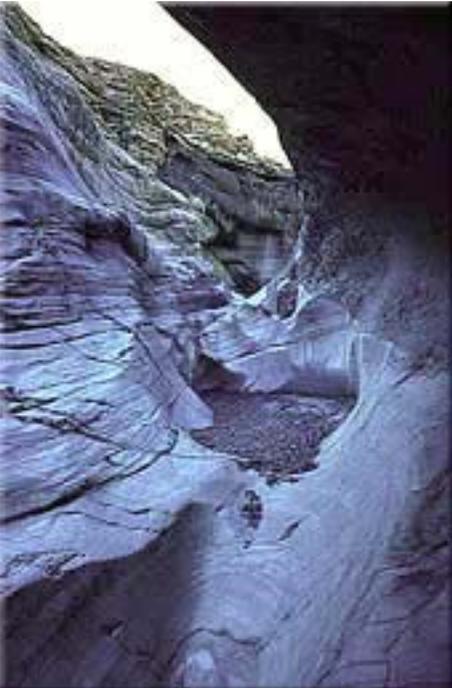
At about 14 Ma movement along the Furnace Creek and Sheephead faults caused the development of so-called “rhombochasm”, a rhomb-shaped region in which the crust is pulled apart (Figure 2). This was the progenitor of the current Death Valley basin. We will stop near Furnace Creek (Zabriskie Point) where we can see rocks which were deposited in the depression formed when the down-dropping was initiated. The oldest of these rocks are called the Artist Drive Formation well exposed along Artist’s Drive. As movement along the two faults (Furnace Creek and Sheephead faults) proceeded the fragmentation of the crust became more severe eventually creating avenues for the rise of magma from sources in the deep crust or mantle. These and related igneous rocks formed the Shoshone volcanic field which today occupies a quadrilaterally shaped region defined by a line east-west thru of Shoshone, Furnace Creek Wash, the east edge of modern Death Valley and highway 127.

In addition to the injection of magma, movement along the two faults also provided an environment in which many of the older rocks were subjected to large-scale gravitational down-slope movement, breaking them into slivers which piled up on one another to form the Amargosa Chaos of L. Noble. We will make one stop to observe examples of these highly deformed rocks. Noble identified three components of the “Chaos” to which he assigned the names, Calico and Jubilee Phases. The Virgin Spring Phase, the oldest, is named for a location a few miles north of the highway. It is composed mainly of Proterozoic Pahrump Group, upper Proterozoic and Cambrian sedimentary rocks, much attenuated in thickness. The Calico Phase is composed mainly of Tertiary volcanic rocks with the upper-most Jubilee Phase mainly of younger sedimentary materials. On the basis of his observations Noble believed that the phases moved independently of one another or at least were not emplaced synchronously with the Virgin Spring Phase more intensely faulted than the Calico or Jubilee Phases. The old, underlying metamorphic rocks are also involved in the faulting.

Perhaps around three million years ago the movement causing the rhombochasm was transferred so that a new fault system formed which, with continued movement, eventually manifesting itself as what we call Death Valley. To understand the relationships between the normal faults and the strike slip faults one must recognize that Death Valley is really composed of three segments: northern, middle and southern. The northern and southern segments are both parallel and trend roughly northwest. The middle segment trends about north-south. Thus Death Valley resembles a deformed letter “Z”. The active faults in the north and south segments are *strike slip faults*- Furnace Creek and Death Valley fault zones- and those of the central segment are *normal faults*. Additionally, the displacement along the normal faults is not purely vertical but is oblique with the down dropped blocks moving down and northwesterly along large, curved fault surfaces called “Turtleback” for their carapace-like shapes which we will observe at one or two of our stops. A simple model thus emerges in which right slip along the Furnace Creek and Death Valley fault zones causes an extensional zone between them where normal faults develop and central Death Valley is formed. The movement picture is similar to one visualized for the formation of the rhombochasm discussed above. Also see Figure 3 below.



Death Valley Field Trip Road Log – Day 1

Mileage	
0.0	From Stovepipe Wells Chevron head west on CA 190.
0.2 (0.2)	Turn left on dirt road to Mosaic Canyon.
2.5 (2.3)	<p>Mosaic Canyon Parking Area (STOP 1).</p> <p>The entrance to Mosaic Canyon appears deceptively ordinary, but just a 1/4 mile walk up the canyon narrows dramatically to a deep slot cut into the face of Tucki Mountain. Smooth, polished marble walls enclose the trail as it follows the canyon's sinuous curves.</p> <p>Mosaic Canyon's polished walls are carved from the Noonday Dolomite deposited during Late Precambrian (about 850-700 million years ago). Later addition of magnesium altered the limestone, a rock made of calcium carbonate, to dolomite, a calcium-magnesium carbonate. The dolomite was later metamorphosed to marble. Recent uplift and subsequent erosion have exposed the metamorphic rocks.</p> <p>Mosaic Canyon derives its name from the angular fragments of many different parent rocks seemingly plastered to the floors and walls of the canyon just south of the parking area.</p>
	
	Return to vehicles and CA 190.
4.8 (2.3)	Turn right (east) on CA 190 toward Furnace Creek.
6.9 (2.1)	<p>Stop beside road to view sand dunes (STOP 2).</p>
	 <p>Death Valley's most accessible sand dunes are just a few miles from Stovepipe Wells. Tucked into Mesquite Flat in the north end of the park, these dunes are nearly surrounded by mountains on all sides. The primary source of the dune sands is probably the Cottonwood Mountains which lie</p>

	to the north and northwest.
12.3 (5.4)	Turn left on North Highway.
12.9 (0.6)	Turn right (east) on Daylight Pass Road.
19.6 (6.7)	Turn right (southeast) on the Chloride Cliff/Keane Wonder/Daylight Pass Cutoff Road.
23.8 (4.2)	Turn left on the dirt road to the Keane Wonder Mine (there should be a sign marking the turnoff).
26.6 (2.8)	<p>Keane Wonder Mine parking lot (STOP 3).</p> <p>The total gold production from the Keane Wonder Mine during its operation was estimated at \$1,100,000. Of that amount, \$625,000-\$682,000 was taken from the mine between 1907 and 1911. The Keane Wonder mine was one of the two largest producing gold mines in the Death Valley area (Skidoo was the other).</p> <p>Gold production came from “quartz veins” that lie within the metamorphosed Crystal Springs Formation. Ore controls are the subject of debate. Some have suggested the lithologic contact between the diabase and carbonate; others the Keane Wonder fault; and most recently regional detachment surfaces similar to the Briggs gold mine in the southern Panamint Mountains.</p> 
	Return to vehicles and paved road.
29.4 (2.8)	Turn left (south) on the Daylight Pass Cutoff Road.
35.1 (5.7)	Intersect CA 190; turn left toward Furnace Creek Ranch.
44.5 (9.4)	Turn right into Harmony Borax Works parking area.
44.6 (0.1)	<p>Harmony Borax Works (STOP 4).</p> <p>W. T. Coleman's Harmony Borax Works was constructed 1882 and the town of Greenland was built. This early outpost was later to become the modern Furnace Creek Ranch. Harmony played a central role in the opening of Death Valley and the subsequent popularity of the Furnace Creek area.</p>

	<p>Borax production began in late 1883. When in full operation, the Harmony Borax Works employed forty men. Hardy workers scraped cottonball borax from the surface of the playa, producing three tons of borax daily. "Cotton ball", an ore made up of the borate minerals ulexite and proberite, was then dissolved in boiling water. As the solution cooled, borax was precipitated. Financial problems caused closure of the Harmony Borax Works in 1888. Borate mining moved to Shoshone/Tecopa for a few years then eastward to the Calico Mountains in the late 1890's. Borate mining returned to Death Valley in 1915 (Furnace Creek Wash) and lasted until 1928. In 1970 mining activity was renewed in Furnace Creek Wash and has continued intermittently to the present (Billie Mine).</p>
	<p>Return to CA 190 and turn right (south) to Furnace Creek Ranch.</p>
<p>/46.0 (1.4)</p>	<p>Turn right into Visitor Center parking area (STOP 5).</p> <p>We will stop here to visit the restrooms and view the Visitor Center. It has displays on the history, climate, and mining of Death Valley and a beautiful relief sculpture of Death Valley that is well worth the stop.</p>
	<p>From the parking area turn south on CA 190.</p>
<p>47.3 (1.3)</p>	<p>T- intersection at Furnace Creek Inn, continue east on CA 190 toward the burgeoning metropolis of Death Valley Junction.</p>
<p>50.9 (3.6)</p>	<p>Turn right into the Zabriskie Point parking area (STOP 6).</p> <p>Our European friends have made Zabriskie Point one of the most popular stops in the park. Their visit marks a pilgrimage to the site of an American cult classic movie of the same name.</p> <div data-bbox="418 1247 1057 1675" data-label="Image"> </div> <p>Looking west from Zabriskie Point you can see Manley Beacon, one of the landmarks of Death Valley. The Beacon is composed of Miocene Artist Drive Formation (the steeply east-dipping colorful rock unit). The Artist Drive Formation interfingers with basalts, from whence the Black Mountains receive their name (note the basalts capping the ridge to the southwest). These rock units are overlain by the more drab brown, Pliocene, Furnace Creek Formation. The most conspicuous feature of the Furnace Creek Formation is the coarse conglomerates you may have seen while driving south up the wash. The Furnace Creek is unconformably overlain by Pleistocene gravels of the Funeral Formation. The pronounced unconformity is one of the most striking geologic</p>

	<p>features in Furnace Creek Wash. To the east, across Furnace Creek Wash, Proterozoic - Paleozoic rocks of the Funeral Mountains are present. The Furnace Creek fault zone marks the boundary between the markedly dissimilar lithologies of the Funeral and Black Mountains.</p>
	<p>Return to your vehicles and turn right (south) on CA 190.</p>
<p>58.0 (7.1)</p>	<p>Turn right on Furnace Creek Wash Road.</p>
<p>61.5 (3.5)</p>	<p>Stop on the right shoulder of the road (Sigma Mine) (STOP 7).</p> <p>The Sigma Mine marks the most recent surface mining venture in Furnace Creek Wash. Little has been published on the property. The deposit lies two kilometers east of Ryan and north of the Boraxo Mine (see write-up). It was a joint venture of Tennaco and U.S. Borax. The borate horizon dips 5-15° to the northeast, has a strike length of 600 meters and down dip width of 300 meters. Average thickness is 20 meters. The ore is similar to that of the Boraxo Mine, a mixture of colemanite and ulexite-probertite. Host rocks appear to be limy mudstones of the Furnace Creek Formation.</p> 
	<p>Continue south on Furnace Creek Wash Road.</p>
<p>65.5 (4.0)</p>	<p>Fork in the road; continue on the paved road to Dante's View.</p>
<p>71.2 (5.7)</p>	<p>Dante's View parking area (STOP 8).</p>  <p>Dante's View provides a spectacular look at Death Valley's remarkable scenery. From this vantage point you can view Telescope Peak (11,049 feet) to the west in the Panamint Range as well as Badwater, the lowest point (-282 ft.) in the Western Hemisphere. This difference in elevation is a staggering 11,331 feet —</p>

	<p>the greatest topographic relief in the conterminous U.S. This striking topography is a product of Death Valley's very active tectonism. The entire region has been pulled apart, fracturing the crust and creating large faults. Along these roughly north-south-trending faults mountains have uplifted and valleys down-dropped, producing the distinctive alternating pattern of linear mountain ranges and valleys of the Basin and Range province.</p> <p>The floor of Death Valley tilts gently eastward. From here, one can see that the alluvial fans on the west side of the valley are far larger than on the east side. This difference results partly from the eastward tilting of the valley floor. On the west side, alluvial material spreads laterally and extends far onto the valley floor because it accumulates on a surface that is gently inclined away from the range; on the east side, the material becomes trapped near the mountain front because it accumulates on a surface that is inclined gently towards the mountains.</p> <p>This eastward tilting of the Black Mountains, the Panamint Range, and the floor Death Valley typifies much of the Basin and Range Province. Through crustal extension, the region broke into a series of tilted fault blocks. In general, these blocks tilted away from the faults along which they rose and towards the faults along which they sank.</p>
	<p>Make the long trek back down (north) Furnace Creek Wash to the T-intersection across from Furnace Creek Inn.</p>
<p>95.1 (23.9)</p>	<p>Turn left (south) on the Badwater Road.</p>
<p>103.7 (8.6)</p>	<p>Turn left into the one-way Artist's Drive (STOP 9). Time permitting me will make the 8.8 mile drive along Artist's Drive. There are numerous stops and overlooks.</p> <p>The winding, one-way, Artist's Drive leads you up to the scarp of the Black Mountains. Artist's Drive rises up to the top of an alluvial fan fed by a deep canyon cut into the mountain. As you make your way up to the mountain face the roadway will rise and dip on the undulating surface of the alluvial fan. The narrow road runs high up onto the fan, with striking views of the barren floor of Death Valley in the distance.</p>  <p>The face of the Black Mountains along Artist's Drive is made up of the multicolored rock of the Artist Drive Formation. Pink, green, purple, brown,</p>

	<p>and black rock debris drape across the mountain front, providing some of the most scenic evidence of Miocene volcanism and lacustrine sedimentation.</p> <p>Weathering and alteration by thermal waters are responsible for the variety of colors displayed in the Artist Drive Formation. Brick-reds and pinks are due to oxidation of dispersed iron to hematite. Shades of yellow result from hydrated iron oxides in variable concentration. Alkaline lakebed environments chemically alter volcanic ash rapidly, producing an array of finely-dispersed new minerals. Among these, clinoptilolite, analcite, nontronite, and (in basaltic debris) celadonite may account for the area's pastel green tuffs and ashy sediments.</p>
112.5 (8.8)	Turn left (south) on the Badwater Road.
116.3 (3.8)	On the left is the entrance to Artist's Drive. If you did not make the detour through Artist's Drive you will need to reset your trip odometer to 0.
124.2 (7.9)	<p>Badwater parking area (STOP 10).</p> <div data-bbox="418 842 1040 1266" data-label="Image"> </div> <p>Beneath the shadows of the Black Mountains, a great flat expanse of shimmering white spreads out before you. You are at Badwater, -282 feet, the lowest point in the Western Hemisphere. Look to the west, the white expanse is made up of almost pure table salt the remnants of a much greener, lusher time in Death Valley's recent past.</p> <p>About 2000-4000 years ago the climate was quite a bit wetter than today. So wet that streams running from nearby mountains gradually filled Death Valley to a depth of almost 30 feet. Some of the minerals left behind by ancestral Death Valley lakes dissolved in the shallow water, creating a brine.</p> <p>The wet times didn't last. The climate warmed and rainfall decreased. The lake began to dry up. Minerals dissolved in the lake became increasingly concentrated as water evaporated. Eventually, only a briny soup remained, forming salty pools on the lowest parts of Death Valley's floor. Salts (95% NaCl) began to crystallize, coating the surface with a thick crust about one to two meters thick.</p> <p>Few people turn and face east toward the Black Mountains. If you do you will immediately notice the Sea Level sign high up on the hillside. The steep face of the Black Mountains is made up of some of the oldest rocks in Death Valley. These 1.7 billion-year-old remnants of an ancient volcanic mountain belt and</p>

flanking deposits of mud and sand have been metamorphosed to gneiss. Eleven million years ago, the gneiss was injected by the Willow Spring pluton. The dioritic to gabbroic composition of the Willow Spring pluton blends well with the dark Precambrian gneiss, so you have to look carefully to see the contact relationship between the two rock types. Badwater is also the northernmost of three “turtlebacks” that lie along the Black Mountains western flank. We will be discussing the origin of the turtlebacks at the next stop.

139.2 (~15) Stop along the road for a view to the north of the Copper Canyon Turtleback **(STOP 11)**. (Note: this is only an approximation of the location of this stop; Don will select a location that best shows the geologic relationships.)



Mormon Point affords an excellent view of the profile of the Copper Canyon turtleback and the overlying Tertiary sedimentary and volcanic rocks that have been transported northwestward over the turtleback surfaces. From Mormon Point the view to the northeast is almost at a right angle to the northwest plunge and trend of the crest of the turtleback surface.

Poorly visible from this viewpoint is the relatively thin skin of carbonate rock directly beneath the turtleback surface. This is because the southwest flank of the turtleback surface has been cut by younger faults along the mountain front. Precambrian foliated gneissic rock and foliated Mesozoic dioritic rock form most of the range front in view beneath the turtleback. Patches of carbonate rock are exposed at the crest of ridge. A few dikes of Tertiary intrusive rocks cross the turtleback at nearly right angles to the trend of the ridge crest.

The turtleback surfaces were first recognized and named by Curry (1938). Since then they have been the subject of considerable debate. Today it is recognized that most of the crustal extension that has occurred in Death Valley can be attributed to low-angle normal (detachment faults). These faults juxtapose, older, strongly metamorphosed, ductility deformed mid-crustal rocks (lower plate core complexes) and younger, largely unmetamorphosed, brittle deformed, volcanic and sedimentary rocks (upper plate). Typically the upper plate rocks are cut by a series of high angle normal faults. The Black Mountain fault zone is an example of a major detachment fault. Death Valley has dropped downward and tilted to the east along the detachment surface. The fault zone remains active today as evidenced by numerous high angle fault scarps that can be seen dissecting the alluvial fans.

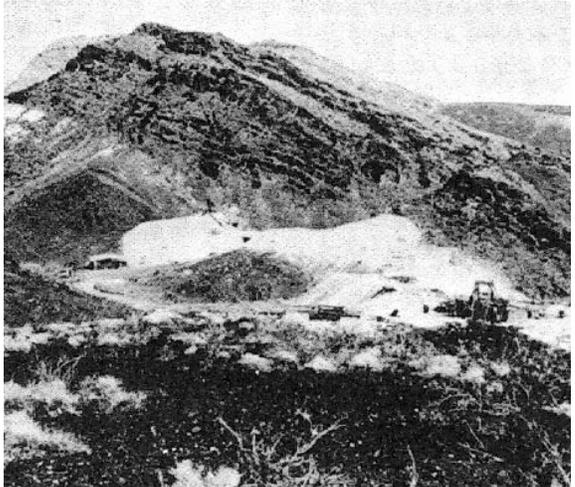
152.8(13.6)	Road forks, stay on the paved road CA 178 (Jubilee Pass Road)
160.0 (7.2)	<p data-bbox="418 279 1096 315">Park on road shoulder; Amargosa Chaos (STOP 12).</p>  <p data-bbox="1128 331 1442 808">Noble (1941) observed a style of faulting in this subject area so intricate and complex that he referred to the faulted rock units as “chaos.” He referred to these, as well as other similarly faulted terranes in the Death Valley region, as the “Amargosa chaos.” The Virgin Spring area in the west-central part</p> <p data-bbox="418 808 1279 844">of the Black Mountains is the type locality for the Amargosa chaos.</p> <p data-bbox="418 861 1442 1297">The geologic features of the Amargosa Chaos record four major deformational events. The first, about 1.7 Ga, accompanied and followed the metamorphism of the crystalline basement. It contributed to the angular discordance in the complex with the overlying later Precambrian sedimentary units. The second began with the deposition of arkosic conglomerate near the base of the Crystal Spring Formation and continued through Noonday time, spanning an interval of probably 400 Ma. This event was accompanied by vertical crustal movement causing facies changes in the Pahrump Group and Noonday Dolomite, and the angular unconformity beneath. Folds preserved in the later Precambrian and Cambrian sedimentary rocks mark a third period of deformation in Mesozoic or Early Tertiary time. The fourth deformational event can be related to faulting caused by crustal extension in late Cenozoic time.</p> <p data-bbox="418 1314 1425 1533">Noble (1941) recognized three phases of the Amargosa chaos and named them the Virgin Spring, Calico, and Jubilee phases. The Virgin Spring phase is composed almost entirely of units of the Pahrump Group and of the overlying latest Precambrian and Cambrian units. The Calico phase consists mostly of Tertiary volcanic units. The Jubilee phase comprises Tertiary conglomerate, finer-grained strata, and bodies of monolithologic breccia.</p> <p data-bbox="418 1549 1442 1696">The best exposure of the Virgin Spring chaos along California 178 occurs at this stop. The chaos underlies the steep north face of a hill about 300 ft high and displays most of the features that are commonly ascribed to the lower part of the chaos in general.</p> <p data-bbox="418 1713 1442 1892">The lower part of this face is underlain by the gray weathering, locally red-stained crystalline complex. Within it are sheared masses of dark green diabase dikes and nearly white granitic pegmatite dikes. All are thoroughly sheared and become progressively more so upward to the nearly horizontal contact with the overlying chaos. The strong evidence of shearing along this contact impressed</p>

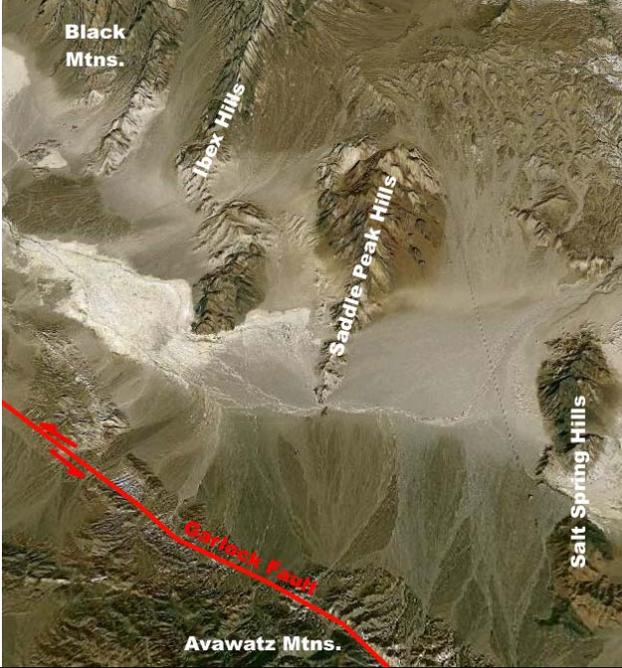
	<p>Noble to the extent that he identified it as his Amargosa thrust (now discredited).</p> <p>The pale gray to dark lavender, fault-bounded lenses at the base of the overlying chaos consist of arkosic sandstone and siltstone of the dominantly clastic lower portion of the Crystal Spring. The dark green lenses higher on the face are slices of the diabase sill that separates the clastic members from the red-brown carbonate member. The ridge-former at the crest of the hill is the yellowish gray dolomite of the Noonday Dolomite. Strata of the Johnnie Formation are exposed on the south side of the hill crest. Both the Noonday and Johnnie occur as fault-bounded lenses and thus also qualify as chaotic.</p>
177.5(17.7)	Intersection with CA 127, turn right (south) to Shoshone.
179.0 (1.5)	Downtown Shoshone, END of Day 1.

Death Valley Field Trip Road Log – Day 2

Mileage	
0.0	Day 2 begins at the junction of the Charlie Brown Highway (CA 178) and CA 127 just south of Shoshone. Head west on CA 178.
3.9 (3.9)	<p>Charlie Brown Highway road cut (STOP 1).</p> <p>This is one of the more famous roadcuts in California geology. It exposes not only a spectacular example of the interior of a welded tuff, with a layer of remelted obsidian, but also a normal fault that has been photographed for many basic geology texts. The fault cuts Miocene tuff and volcanoclastic deposits. The dark brown layer in the footwall rocks is a conglomerate. A prominent black band just to the left of this photo is a welded tuff comprised of volcanic glass and flattened pumice fragments.</p> 
	Return to vehicles, turn around and head back west to CA 127.
7.8 (3.9)	Turn left (south) on CA 127.
13.0 (5.2)	Turn left on the Tecopa Hot Springs Road.

17.4 (4.4)	Turn left (east) on the Spanish Trails Highway.
18.9 (1.5)	Turn right on Furnace Creek Road.
27.1 (8.2)	Turn left on the dirt road just past the cattle guard.
28.3 (1.2)	<div data-bbox="418 409 857 1102" data-label="Figure"> <p>The figure is a geologic map of the War Eagle Mine. It shows a central vertical shaft labeled 'Main Ore Vein' with a 'Raise' branching off to the west. An 'Inclined Shaft' is shown to the west of the main vein. A 'Main Ore Vein' is also indicated. The map shows various mine workings, including 'To additional mine workings' at the top. A compass rose is located in the lower-left quadrant, and a scale bar below it indicates 0 to 300 feet. The map is titled 'Partial Geologic Map of the War Eagle Mine'.</p> </div> <p data-bbox="873 420 1455 493">Follow the main dirt road to the War Eagle Mine (STOP 2).</p> <p data-bbox="873 525 1455 966">The War Eagle Mine is located 8 miles east of Tecopa, California at the south end of the Nopah Range. It operated from 1912 until 1957; the last operator the Anaconda Copper Corporation. Despite the extensive mine workings and obviously large tonnage of ore removed from this mine and the adjacent Columbia and Noonday Mines astonishingly little has been published. However, extensive archival information on the mine is stored at the University of Wyoming and may be examined for a fee.</p> <p data-bbox="873 997 1455 1102">The mine workings are entirely within Noonday Dolomite. Mineralization appears to lie along a nearly north-trending vein</p> <p data-bbox="418 1113 1455 1260">which dips moderately to the east. Examination of the adjacent mines suggests the main ore vein is offset by a post mineral fault system which strikes N 65° W. A series of northeast trending fractures with steep northwest dips are responsible for localization of the ore.</p> <p data-bbox="418 1291 1455 1407">Mine workings extend approximately 500 feet below the existing adit. Access is via a series of raises and an inclined shaft. The main ore zone has been developed for several thousand feet along strike.</p> <p data-bbox="418 1438 1455 1585">Ore mineralization is restricted to argentiferous galena, but traces of chalcopyrite and pyrite were noted in stopes. Native gold occurs in trace amounts. Reportedly, the upper extension of the ore shoot has been oxidized to cerrusite and anglesite.</p> <p data-bbox="418 1606 1455 1795">The main adit to the War Eagle remains open despite vandalism that occurred a number of years ago. Vandals rolled an ore car down the main inclined shaft partially blocking access to the lower mine working and prompting the BLM to threaten closure of the entrance portal. Sealing of the mine never occurred and the vandals were never caught.</p>
	Return to Furnace Creek Road.

29.5 (1.2)	Turn right (west) on Furnace Creek Road.
31.1 (0.6)	Turn left on Western Talc Mine Road.
34.3 (3.0)	<p>Park near the open pit of the Western Talc Mine (STOP 3).</p> <p>Talc was first produced from Death Valley in 1910. Pressure from the Park Service in the form of an asbestos scare closed all mines within the park in 1980. Production outside of the park continued until the late 1990's. In their heyday the Death Valley talc mines yielded 20% of the annual talc tonnage.</p> <p>All talc deposits lie within the Crystal Springs Formation and outcrop along a 50 mile belt from the Panamint Mountains to the Kingston Range. Specifically, the talc ore bodies are the products of contact metamorphism of carbonate layers during intrusion of Proterozoic diabase sills.</p> <p>The Western mine has the most extensive workings and the longest operating history of the talc mines in the southern Death Valley-Kingston Range region. The property consists of seven patented and four unpatented claims, formerly owned and operated by the Western Talc Company.</p> <p>Here, as at numerous other localities in the surrounding region, the talc-bearing zone has formed as an alteration of cherty dolomite at the base of the Crystal Spring Formation. A diabase sill forms the footwall of the talc bodies through most of the mine area, but in the southern part, elongate bodies of green alteration rock separate the talc from diabase.</p> <p>Most of the claims are distributed along two north-striking segments of the same alteration zone that are displaced along a northeast-striking fault. The two segments have a combined strike length of several thousand feet and appear to be the largest intact bodies of commercial talc in the Death Valley region.</p> <p>In mine exposures, the zone of talcose alteration is 30 to 100 feet thick and consists chiefly of saleable material. The zone contains two principal types of commercial talc: (1) laminated tremolite rock (generally referred to as "hard talc") which occurs as a 10-20 foot thick layer in the lower part of the zone, and (2) talc schist (generally referred to as "soft talc") most of which is confined to the upper part of the zone. A thick layer of brown alteration rock ordinarily forms the upper part of the zone, separating talc schist from unaltered cherty dolomite. The brown rock is in sharp contact with the talc schist, but has a gradational contact with the overlying cherty dolomite.</p> 

	Turn around and proceed back to Furnace Creek Road.
37.3 (3.0)	Turn left on Furnace Creek road toward Tecopa.
44.9 (7.6)	Turn left (west) on Spanish Trails Highway
50.3 (5.4)	Turn left (south) on CA 127 toward Baker.
68.6 (18.3)	<p>Pull into Harry Wade Historical Maker turnoff (STOP 4).</p> 
	END OF FIELD TRIP

Keane Wonder Mine

Western mining brings to mind the old prospector and his burro wandering the desert in search of the "mother lode". Death Valley is the image of desert most often conjured up. Not surprisingly, the "mother lode" was never found in Death Valley, but more astonishing is the fact that very little gold has been found in the Death Valley area. Although there are 50 precious metal mines and prospects scattered throughout the monument, none ever reported substantial production and only the Skidoo District in the Panamint Range has shown any significant potential. Total gold production from all mines in Death Valley was probably less than 200,000 ounces (about the annual production of many gold mines in northern Nevada).



The Keane Wonder mine is of interest because it is typical of Death Valley precious metal mines, and the dumps and mill site have been preserved as a historic landmark making the area accessible. Also typical of most gold-silver mines in the Park, little definitive information has been published on the geology. This is not unexpected since the heyday of mining activity was near the turn of the century and a trip to Death Valley was not a coveted assignment for government and academic geologists of that era.

History

Two residents of Ballarat--an Irishman named Jack Keane and his partner, a one-eyed butcher named Domingo Etcharren, were prospecting for silver in the winter of 1903. They had been working on a particular claim for several months, but had discovered nothing of value. In fact, both men were local legends for their ineptitude having found nothing after eight years of prospecting. While returning to Ballarat for supplies, Keane accidentally stumbled across an outcrop of visible gold. The locals felt it was a "wonder" Keane had found anything at all. Hence, the mine became known as the Keane Wonder Mine.

The news of their strike started a gold rush. Keane and Etcharren filed 18 claims and were immediately besieged with offers to buy the mine. Captain J.R. Delmar agreed to pay the partners \$10,000 in cash. In return he received an option to purchase the mine for \$150,000 once the property had been developed. He brought 30 men to the property, built an assay office, a general office building, and a wagon road to within a mile of the mine. Alas, he spent all of his money and had none left to purchase the mine, so the partners took it back.

In 1906, John Campbell purchased the property for \$250,000. A company was set up with Jack Keane as president, Campbell as vice president and Domingo Etcharren as the secretary. Stock was offered to the public and new claims patented despite the fact that only five of the original claims had been explored at this point. Campbell's fortune was

wiped out by the 1906 San Francisco earthquake and within a month the mine was sold yet again. Homer Wilson bought the mine in June of 1906 and began an association with the Keane Wonder that would last ten years. Keane and Etcharren sold their interest in the mine making Wilson the sole owner. Wilson built a 20 stamp mill at the foot of the Funeral Range and the engineering marvel of its day, a 4700 foot aerial tramway. Loaded ore buckets from the mine came down the mountain under gravity and pulled empty buckets back up. The final costs for the mill were estimated at \$85,000. A boarding house was built to house the workers and by Oct. 27, 1907 the mill, with completed tram, began to operate. Twenty-one thousand board feet of lumber were required for the upper tramway terminal, 28,000 for the lower, and 25,000 for the intermediate towers. There were 13 towers in the tram and the longest span between them was 1200 feet. The vertical fall from top to bottom was 1500 feet.

By 1909, 50 men were working at the mill and mine and work had begun on a cyanide mill. In 1911, the Keane Wonder Mine was the only mine still producing in the region. Although it had been plagued by financial problems since the Wall Street Panic of 1907, it continued to operate. In August, 1912 the mine closed for two years. In 1914, it reopened for two years after being sold to new owners. Twenty years later another revival occurred when a new company reworked the old mill tailings by cyanide leaching. In 1937 the mine was sold and the mill dismantled and removed. The tramway was refurbished in 1942 but the mine never reopened. In the 1970s it was purchased by the National Park Service.

The total production of the mine during its operation was estimated at \$1,100,000. Of that amount, \$625,000-\$682,000 was mined between 1907-1911. The Keane Wonder mine was one of the two largest producing gold mines in the Death Valley area (Skidoo was the other). The scope of the operation, the duration of production and the story of two incredibly lucky miners add up to a mine that ultimately surpassed even the grandeur of the name "Keane Wonder Mine."

General Geology

The Chloride Cliff Mining District (sometimes termed the Bullfrog South) lies on the west flank of the Funeral Mountains, approximately 30 kilometers east of Stove Pipe Wells. The Funeral Mountains consist of strongly metamorphosed Late Proterozoic and Paleozoic sedimentary rocks overlain by weakly metamorphosed late Proterozoic, Paleozoic and Tertiary rocks. The contact between the two sedimentary packages is marked by a series of low angle range-front (detachment?) faults.

No outcrops of basement rock have been mapped in the central or western Funeral Mountains, however some have suggested that the gneisses which floor Monarch canyon may be basement rock. The oldest identified rocks consist of interbedded schist, marble, quartzite and amphibolite, which represent high-grade metamorphic equivalents of the Pahrump Group (Figure). The Pahrump Group is in turn overlain by the Johnnie Formation, which consists predominantly of schist and quartzite. The Stirling Quartzite comprised of quartzite and minor marble overlies the Johnnie Formation. Argillites and

quartzites of the Wood Canyon Formation overlie the Johnnie. Smaller outcroppings of Cambrian rocks occur locally. The Paleozoic section is capped by middle and late Tertiary volcanics and lacustrine sediments.

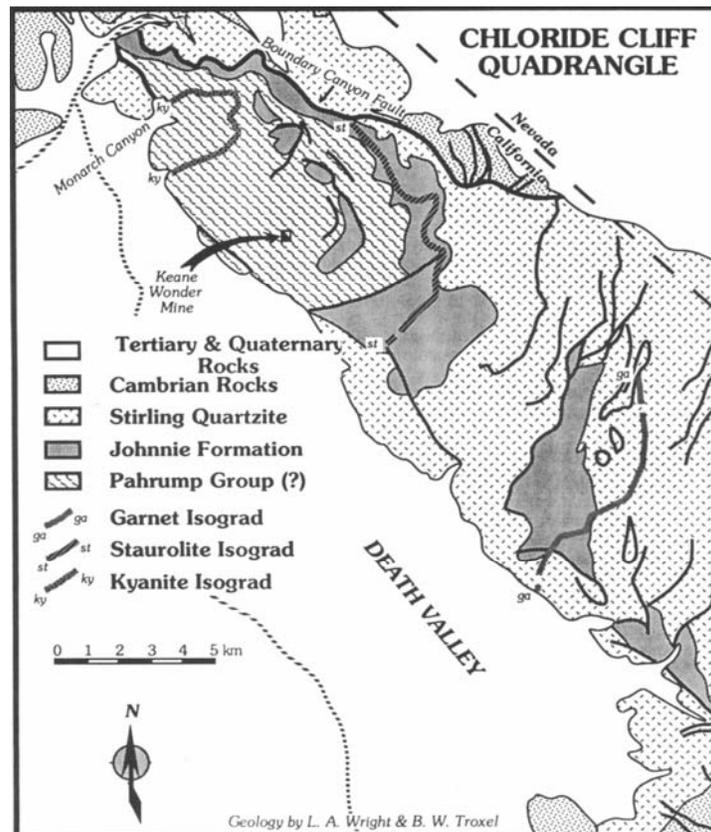
The structure of the Funeral Mountains is dominated by a doubly plunging anticline consisting of a core of high grade metamorphic rocks overlain by low grade metasedimentary rocks. The contact between the two rock assemblages is marked by the Boundary canyon fault system, a gently undulating surface that dips to the north.

Geology of the Keane Wonder Mine Area

The Chloride Cliff Mining District is a geologically complex area and as such it is difficult to do justice to the geology. This discussion will be largely a generalization for the sake of simplicity.

The prominent Chloride Cliffs are comprised of Beck Spring Dolomite, underlain by the Crystal Spring Formation. Much of the rugged slope from the Chloride Cliffs to the valley floor is Crystal Springs, however, complex faulting also results in small isolated outcrops of Kingston Peak, Johnnie and Stirling Formations. The following description is given to allow some differentiation:

:



Geology of the central Funeral Mountains

- Stirling Quartzite - Pale gray, medium-to-coarse-grained sandstone (orthoquartzite), locally conglomeritic.
- Johnnie Formation - Greenish-gray, pelitic schists.
- Kingston Peak Formation - Upper member is a conglomerate with clasts of quartzite and marble in a dark fine-grained groundmass. Lower member is pelitic schist, generally silverish in color with a bright luster.
- Beck Spring Dolomite - Pale white, gray or cream marble.
- Crystal Spring Formation - Upper member is a pelitic schist and micaceous quartzite with lesser marble and amphibolite,; Middle member is mostly pale marble and interlayered schist; Lower member is pelitic schist with abundant amphibolite (diabase), layers and minor carbonate.

In the vicinity of the Keane Wonder mine the dominant rocks are middle and lower Crystal Spring Formation with marble, pelitic schist and amphibolite, common. Most of the central portion of the southern flank of the Funeral Mountains is bounded by the Keane Wonder fault. The fault, which is poorly exposed, dips 20° to the southwest. Proterozoic and Paleozoic rocks lie above the fault, while folded and strongly metamorphosed Proterozoic strata lie beneath the fault plane.

The gold ore occurs in two discontinuous, lenticular quartz veins which appear to follow bedding planes, particularly the contact between marble and amphibolite; the latter the metamorphic equivalent of diabase. The quartz veins can be traced for 500 meters along their N 25° W strike. The veins dip 20° E and vary in thickness from 2 to 8 meters. Ore minerals include free gold, minor pyrite and galena. Iron-staining is common, an indication of near surface oxidation of pyrite to hydrated iron oxides.

Ore grades are reported to have been about .25 oz/ton and total production from the 1908-1916 period about 35,000 ounces of gold. The development consisted of a 75 meter deep shaft and over 2000 meters of underground workings, most of which are now inaccessible. There has been no activity on the property since it was abandoned in 1916, but rumored sampling by the Park Service in the 1980s indicates there is significant recoverable gold remaining in the mine dumps.

Harmony Borax Works – Twenty Mule Teams

The first form of borax to be found in Death Valley was white crystalline ulexite called “cottonball”, which encrusted the ancient Lake Manly. Cottonball of this kind had been found earlier at Columbus Marsh and at Teel’s Marsh, in western Nevada.

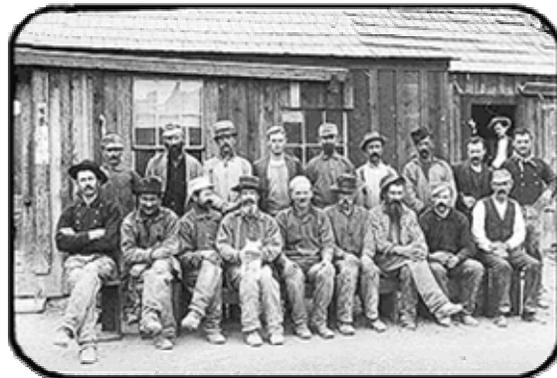
The first man to try to market Death Valley cottonball was an unsuccessful gold prospector named Daunet. In 1875 he could interest no one in his discovery. Fate made him six years too early.

In 1881 Aaron Winters, who lived in Ash Meadows with his wife, Rosie, offered a night’s lodging to a stranger, Henry Spiller, who was prospecting through the desert. His hospitality was well rewarded. The stranger spoke of the growing interest in the mineral borax and showed him samples of cottonball. One look told Winters that he saw the same crystals every day, covering acre upon acre of the floor of Death Valley.

The next morning, as soon as his visitor left, Winters rode off to the Valley, scooped up a bagful of cottonball and rode back to Ash Meadows. The stranger had told him about the test for borax: pour alcohol and sulfuric acid over the ore and ignite it. If it burns green, it’s borax. At sundown, Aaron and Rosie tried the test on the bagful of sample: “She burns green, Rosie”, shouted Aaron, “We’re rich, by God!” And they were. Winters sold his Death Valley claims to William Tell Coleman, a prominent San Francisco financier for \$20,000.

Word of the Valley’s cottonball quickly spread. Daunet came back in 1882 and set up the Eagle Borax Works, but quit the business when he found that borax could not be processed by simple recrystallization during the intense summer heat. By the time operations could resume in the fall, the price of borax had fallen and he was never able to make the operation profitable.

In 1882 Coleman began construction of the Harmony Borax Works. In 1883 he hired Chinese laborers to scrape borates from the ancient lake bed for \$1.50 per day. In full operation, the Harmony Borax Works employed forty men. "Cotton ball", an ore made up of the borate minerals ulexite and proberite, was then dissolved in boiling water. As the solution cooled, borax was precipitated. The hardy workers (notice no Chinese labors in the photo to the right) produced three tons of borax daily. Finding



that summer processing in the Valley was indeed impossible, he built the Amargosa Borax Works near Shoshone, where the summers were cooler. The ruined remains of these three early borax plants still stand in the desert. The borax was hauled to the nearest railroad by the use of Twenty Mule Teams hitched to ponderous wagons. Coleman was

producing about 2 million pounds of borax per year from his Death Valley and Amargosa facilities.

In 1882 the Lee brothers discovered a new form of borax along Furnace Creek Wash. This new mineral was named colemanite after Coleman. A quartz-like ore, it demanded far more complex mining methods than cottonball, but it was far richer in borax. Coleman added these borax deposits to his holdings but he never developed them. His financial troubles in 1888 closed the Harmony Borax Works, and they never reopened.

In 1890 Coleman sold his properties to an energetic and successful borax prospector from Teel's Marsh named Francis Marion "Borax" Smith for \$550,000 giving Smith a virtual monopoly on domestic borax production. Smith consolidated these properties with his own to create the Pacific Coast Borax Company.

The Twenty Mule Teams



The twenty mule teams solved a transportation problem: between 1883 and 1888 they hauled more than twelve million pounds of borax from remote and inaccessible Death Valley to the railroad at Mojave.

When the Harmony Borax Works was built in 1882, teams of eight and ten mules hauled the ore. But with increased production, the first teams of twenty mules were tried. Stretching out more than a hundred feet from the wagons, the

great elongated teams immediately proved a dependable means of transportation.

The borax wagons were large and well built. The rear wheels were 7 feet high, the front wheels 5 feet high. Each wheel had a steel tire 8 inches wide and an inch thick. The hubs were 18 inches in diameter and 22 inches long. The spokes were of split oak, the axle-trees were solid steel bars. The wagon beds were 16 feet long and 6 feet deep, and could carry 10 tons of borax. Fully loaded, the wagons, including the water tank, weighed 36.5 tons.

The distance to Mojave was 165 miles. Traveling fifteen to eighteen miles a day, it took ten days to make the trip. After leaving the Valley the teams had to cross 100 miles of empty desert, where many of the overnight stops were at dry camps. Water tanks were therefore attached to the wagons, to supply the men and animals between springs. Three men operated these twenty mule teams – in actuality eighteen mules and two horses – the driver who wielded a formidable whip; the teamster, who harnessed and unharnessed the mules, rode one of the horses, and handled the brake of the lead wagon; and the swamper, who rode on the rear wagon, operated its brake on the downgrades, and

was chief cook and dishwasher.

When borax was discovered in the Calico Mountains early in the 1890's, twenty mule teams hauled the ore from Borate to the railroad at Daggett. Except for the brief interlude when the traction engine "Old Dinah" attempted the job, borax was carried solely by these teams until the Borate & Daggett Railroad was built around 1895.

History of Borate Mining

On October 12, 1872 Francis "Borax" Smith discovered borax at Teel's Marsh, Nevada and until 1881 the marsh was the center of the United States borax industry. In 1881, Aaron and Rose Winters identified ulexite in the playa at the mouth of Furnace Creek Wash in Death Valley. The Winters sent samples of their discovery to W.T Coleman and Co. who purchased the property and in 1882, built the famous Harmony Borax Works near the discovery site and began processing the ulexite or "cottonball" as it was called. That same year a new borate mineral, later named colemanite, was discovered further to the south along Furnace Creek Wash.

The process Coleman employed to produce borax from "cottonball" was simple. He dissolved the material in boiling water, allowed the solution to cool and the borax to precipitate. The only problem lie in the fact that summers in Death Valley were too hot to allow the solution to cool sufficiently for the precipitation of borax. Fortunately, another borate discovery was made near Tecopa. Here summer temperatures reached a maximum of only 11 0⁰F and borax could be produced all year round. In winter, the richer deposits in Furnace Creek Wash were processed and in summer operations were moved to Tecopa.

Coleman and Co. was thus owner of two borax deposits, but they were an arduous 250 kilometer trek from the nearest railhead in Mojave. Coleman decided the only solution for economical shipment of the borax to railhead was a fleet of large wagons pulled by mule teams, the 20-mule teams that were to become a Death Valley legend. From 1883 to 1888 the teams made the 20 day round trip without a single breakdown.

In 1883, colemanite was discovered near the present site of Barstow and Coleman began purchasing claims in the area. Unlike ulexite, colemanite was not readily soluble and the mines were costly underground operations. Coleman went bankrupt in 1888 and sold his claims to "Borax" Smith who consolidated his Nevada holdings with those he acquired in California into the Pacific Coast Borax Company, later to become U.S. Borax.

Smith closed the Harmony and Tecopa operations and began mining at Borate north of Bar-stow. With depletion of the Borate deposits in sight Smith purchased the Lila C property in 1902. To reduce costs Pacific Coast Borax constructed the Tonopah and Tidewater Railroad from Ludlow to Death Valley Junction and in 1907 began shipping ore from the Lila C mine. Borate operations were suspended. The Lila C produced until 1914 when operations were moved to the upper Furnace Creek Wash near the town site of Ryan. Deposits in Furnace Creek Wash produced from 1915 until 1928 when the famous Boron deposit was discovered in Kern County. Since Boron was a sodium borate,

processing costs were lower and shipping costs to the port of Los Angeles were also lower since the shipping distance was reduced.

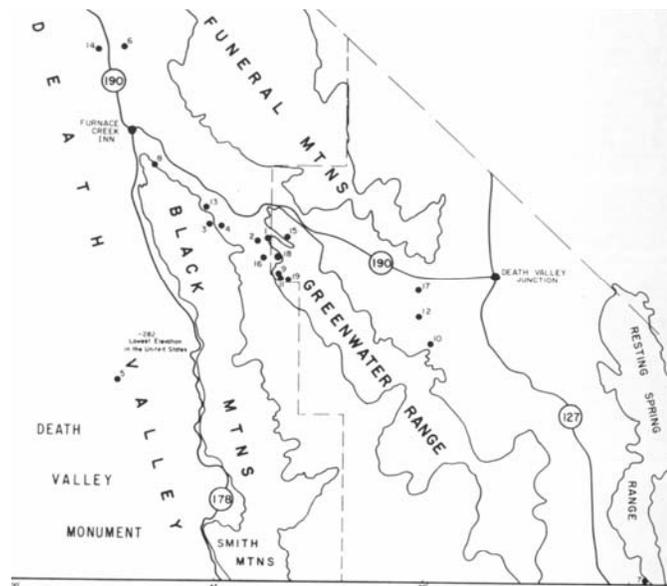
Borate mining ceased in the Death Valley area until 1970 when Tenneco Oil began production of colemanite from the Boraxo mine, later to be joined in 1976 by American Borate from the Billie mine. Passage of Public Mining Law in 1976 placed severe restrictions on mining in National Parks and Monuments, essentially eliminating surface mining. The result was the closure of all surface mines in Furnace Creek Wash. However, the Billie mine, an underground operation, remains in intermittent production.

General Geology

Borate deposits of Death Valley (Figure) are of two types: (1) accumulations of ulexite and associated minor borate minerals in Holocene playa lake beds that occupy the floor of Death Valley and (2) colemanite, ulexite, probertite and associated minor borate minerals in bedded lake sediments in the Pliocene Furnace Creek Formation in the Furnace Creek Wash area. All of the more recent mining has been from Furnace Creek Wash.

The Furnace Creek Formation lies between the Oligocene (?) to Pliocene Artist Drive Formation and the Plio-Pleistocene Funeral Formation. These units have been folded into a broad syncline cut by steeply dipping faults with small displacements. On the east, these formations are separated from the Paleozoic rocks of the Funeral Mountains by the northwest-trending Furnace Creek fault and on the west they are separated from the volcanics and sediments of the Black Mountains by a frontal fault system.

The Furnace Creek Formation is comprised of 2500 meters of interlayered lacustrine sediments, pyroclastics, and basaltic volcanics. Deposits of colemanite and ulexite/probertite are found several meters to hundreds of meters above the base of the formation. The main borate deposits are interstratified with mudstone, shale, limestone and conglomerate. Most major deposits are truncated by steeply dipping faults.



BORATE MINES AND DEPOSITS IN DEATH VALLEY NATIONAL MONUMENT

- | | |
|--------------------------|------------------------------------|
| 1. Billie | 11. Lizzy V. Oakley |
| 2. Boraxo-Inyo (Tompson) | 12. Mena |
| 3. Cortacrew | 13. Monte Blanco |
| 4. DeBely | 14. Old Harmony Borax Works |
| 5. Eagle Borax Works | 15. Played Out |
| 6. East Coleman | 16. Sigma |
| 7. Gansley | 17. Terry |
| 8. Gower Gulch | 18. Upper and Lower Biddy McCarthy |
| 9. Grand View | 19. Widows No. 3 and No. 7 |
| 10. Lile C | |

The borate mines and properties of the Death Valley region.

It is generally thought that borates were formed from hot springs emanations into shallow playa lakes. Boron is discharged into the calcium-sodium enriched waters where it accumulates until evaporation causes the precipitation of sodium and calcium borates. Probertite is formed by burial dehydration of ulexite. Some colemanite also appears to have been deposited by secondary remobilization of original borates due to ground water circulation. Evidence for this comes from secondary veinlets of colemanite which cross cut the existing mineralized zones and the deposition of colemanite along fault planes.

Boraxo Mine

The Boraxo mine lies 3 kilometers southwest of the mining camp of Ryan at an elevation of 800 meters. The property was originally claimed by Pacific Coast Borax in 1915. Kern County Land Company acquired the property in 1960 and when the company was merged with Tenneco Inc. in 1967 the property was turned over to the Tenneco Oil and Minerals subsidiary for development. Initial pit excavation began in 1974, production in 1975 and abandonment in 1977.

The Artist Drive and Furnace Creek Formations in the mine area have been folded into an anticline the axis of which plunges to the east (Figure). Several steeply dipping faults with small displacements cut the section. The Furnace Creek Formation is comprised of 400 meters of interlayered tuffaceous mudstone and sandstone with abundant limey laminations. The rocks are yellow to green on weathered surfaces. Minor basalt occurs locally 150-300 meters above the base of the formation.

The ore body is lenticular and is situated on the south limb of the anticline within a few meters to tens of meters above the base of the Furnace Creek Formation. It is cut on the north by the Pit fault and pinches out on the south 300 meters below the present surface. The deposit ranges in thickness from a feather-edge to about 40 meters, averaging 15 meters. Maximum east-west strike length is 1000 meters and width 200 meters. The ore body dips approximately 40° to the south. After minimal processing at the mine site ore was either trucked to Lathrop Wells, Nevada for calcining if it was primarily colemanite, or shipped to Dunn Siding west of Baker for grinding if it was ulexite-probertite.



EXPLANATION FOR MAP

QUATERNARY

Recent alluvium

- Talus and slope wash
- Undifferentiated alluvium
- Older alluvium

UNCONFORMITY

TRIASSIC

Furnace Creek Formation

- Tf calcareous mudstone and sandstone, limestone laminations common, minor limestone. contains major basaltic deposits
- Tfb and differentiated basaltic flows and intrusions; may be sh. and fragmental; local basaltic veins
- Qa = columnar sand
- NO = metasite and protuberant zone

UNCONFORMITY

ARTIFIAL DRIVE FORMATION
(Internal members after McAlister, 1978)

- T0a middle sandstone member; lacustrine mudstone and conglomerate, some silt and sandstone
- T0b lower pyroclastic member; massive silt breccia
- T0c and differentiated lacustrine conglomerate, silt, minor ls
- T0d lower sandstone member; lacustrine mudstone, cong. and some sandstone

GEOLOGIC SYMBOLS

Contact
Solid where approximated, dashed where recessed, dotted where uncertain

Fault
Shows dip and sense of lateral separation, dashed where approximated, dotted where recessed, dotted where uncertain, T, upthrown, D, downthrown

Anticline
Shows sense of trend, strike and direction of plunge, dashed where approximated, dotted where recessed, dotted where uncertain

Bedding
Shows strike and dip

Joint
Shows strike and dip

Landslide
Shows direction of movement

Figure 7. Geologic map and cross section of the Boraxo mine.

Talc Deposits

Talc production was first reported from Death Valley in 1910, although the presence of large talc bodies had been noted as early as the late 1800's. From 1910 until 1978, Death Valley was a significant producer, accounting for 10-20% of the annual U.S. total. Pressure from the Park Service closed the last mines in 1980, although substantial talc reserves remain. Talc mining outside the National Park has continued to the present day, although only one mine remains in operation.

Talc deposits occur in the Crystal Springs Formation of Late Proterozoic (Precambrian) age at the south end of Death Valley (Fig. 1). The belt of deposits, encompassing 50 mines and prospects stretches eastward to the Kingston Range. The most productive areas were within the National Park in the adjacent Warm Spring and Galena canyons.

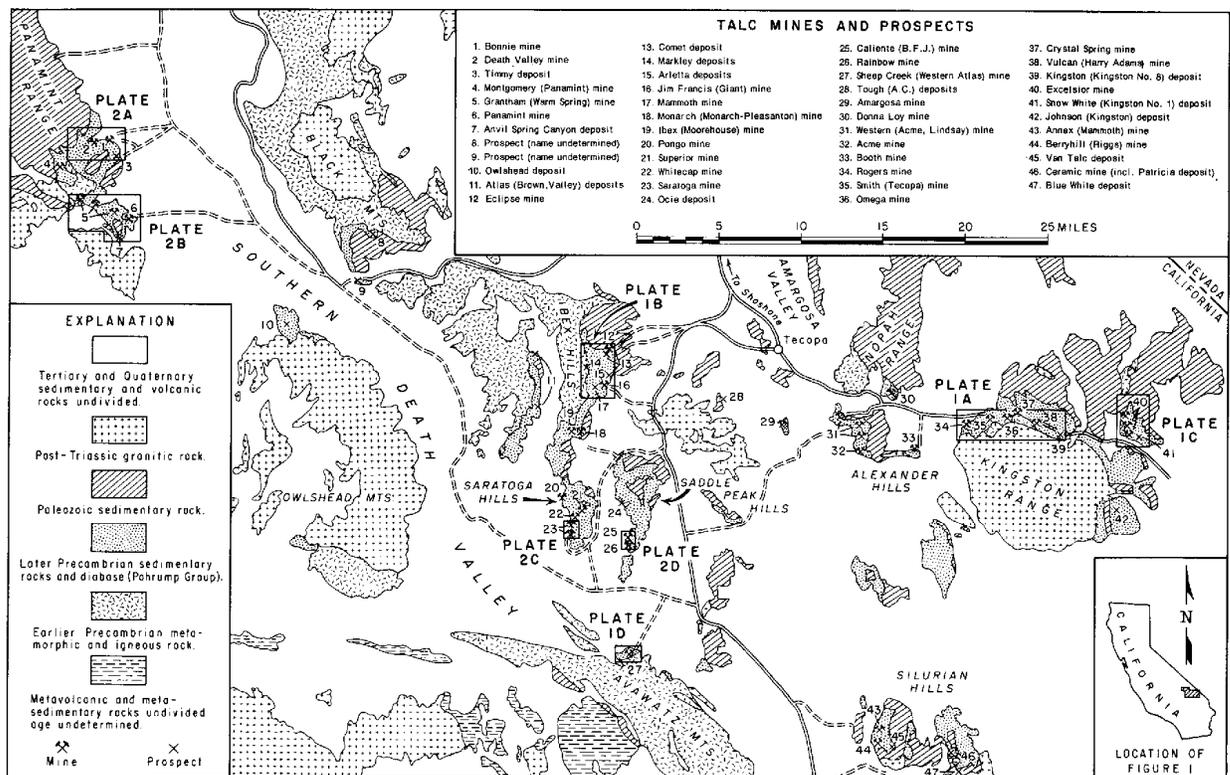


Figure 1. Index map

Mineralogy and Uses of Talc

Talc is a hydrous magnesium silicate ($Mg_3(Si_4O_{12})(OH)_2$) containing 63.5% SiO_2 , 31.7% MgO and about 5% water. In nature, talc rarely occurs in pure form but rather is intergrown with other silicates such as tremolite chlorite, epidote and diopside. This results in commercial talc of widely varying composition. In general the compositional range does not deter from the marketability of the talc.

Commercial talc falls into four categories:

- Steatite: Compact, massive and fine-grained: can be sawed, drilled or machined to required shapes. Usually it is heat treated to convert the talc to clinoenstatite which is used as insulation.
- Soft platy talc: An alteration product of dolomite with chlorite as a common accessory. This is the most important type of talc and is used in wide variety of ceramic, paper, roofing and plastic products.
- Tremolite talc: Massive or laminated rock with varying percentages of tremolite, anthophyllite, calcite and dolomite. It is characterized by a high CaO content, and is often in demand for products which require a greater cohesive strength.
- Mixed talc: Various types of talc; usually any type which is not characterized as one of the above. Used for applications that are less selective in terms of oxide mineral content.

Most commercial talc products are a blend of two or more types specifically designed to meet the specifications of the buyer. For example, the ceramic industry prefers hard massive, white talc while the paint and plastics industries prefer soft, foliated talc. Death Valley talc, because of its purity commanded a premium price and was much in demand for specialized applications requiring higher purity, such as cosmetics.

General Geology

Talc in southern Death Valley-Tecopa area occurs only in the Crystal Spring Formation, the stratigraphically lowest member of the Pahump group of Late Proterozoic age. The Crystal Spring Formation is 1000 to 1400 meters thick and consists characteristically of: (1) lower unit-interbedded quartzite and shale (50-400 meters thick); (2) middle unit-massive dolomite and limestone with minor chert (10-200 meters thick); (3) upper unit-intercalated shale, quartzite and carbonate (100-400 meters thick) and (4) intrusive sills of diabase (100-500 meters thick). The most persistent of the diabase sills lies immediately below the middle carbonate unit of the Crystal Spring.

Contact metamorphism of the carbonate unit during intrusion of the diabase sills has produced the talc mineralization as well as widespread silicification of the Crystal Spring Formation. Typically, zones of silicification range from a few centimeters to 100 meters in thickness. The persistent diabase sill at the base of the middle carbonate unit mentioned above, has produced the best talcose alteration and most of the mines have exploited this zone.

Geology of the Southern Nopah Range and Alexander Hills

The Alexander Hills, which form a southerly extension of the Nopah Range consist mostly of later Precambrian and Cambrian formations (Fig. 2). These have been arched into a very broad, east-plunging anticline, about three miles wide and bordered on the

north and south by major, east-trending faults. The more northerly of the faults occupies the gap that separates the Alexander Hills from the Nopah Range proper.

The Crystal Spring Formation, containing all of the typical members, is exposed for a distance of about 2 3/4 miles along the lower part of the west face of the hills. The formation contains a talc-bearing zone which has formed along the upper margin of a diabase sill and is an alteration of cherty dolomite at the base of the carbonate member.

At the southern end of the Alexander Hills, the Crystal Spring Formation is successively overlain by the Beck Spring Dolomite and Kingston peak Formation to form one of the few essentially complete occurrences of the Pahrump Group west of the Kingston Range. From this locality, for a distance of about seven miles northward, successively lower units in the Pahrump Group are progressively cut out along the contact with the overlying Noonday Dolomite, so that in the southern end of the Nopah Range, strata of the Crystal Spring Formation wedge out northward, and the Noonday Dolomite rests directly upon earlier Precambrian metamorphic rocks. Most of the talc that has been mined in the area of the Alexander Hills and southern Nopah Range has been obtained from two north-trending segments of the talc-bearing zone, each on the west side of the hills. The more southeasterly segment about 1 1/2 miles long, contains most of the workings of the Western mine and the Acme mine. For a distance of about half a mile between the two mines the zone lies unexposed and unexplored beneath Tertiary conglomerate. The other segment of the zone, which appears to be at least 2700 feet long, contains the remaining workings of the Western mine. Movement along a northeast-trending fault has separated the two an apparent horizontal distance of about 4000 feet so that the southern segment has moved northeastward with respect to the other.

Another talc deposit is contained in highly faulted rocks at the southeastern tip of the Alexander Hills and is the site of the Booth mine. This deposit occurs along a nearly horizontal fault-contact between earlier Precambrian metamorphic rocks and dolomite of the Crystal Spring Formation, In a similar geologic setting is the talc deposit at the Donna Loy mine, which is near the tip of the wedge of Crystal Spring strata in the southern part of the Nopah Range.



Figure 2. View looking northeastward of Alexander Hills, showing the Western mine area.

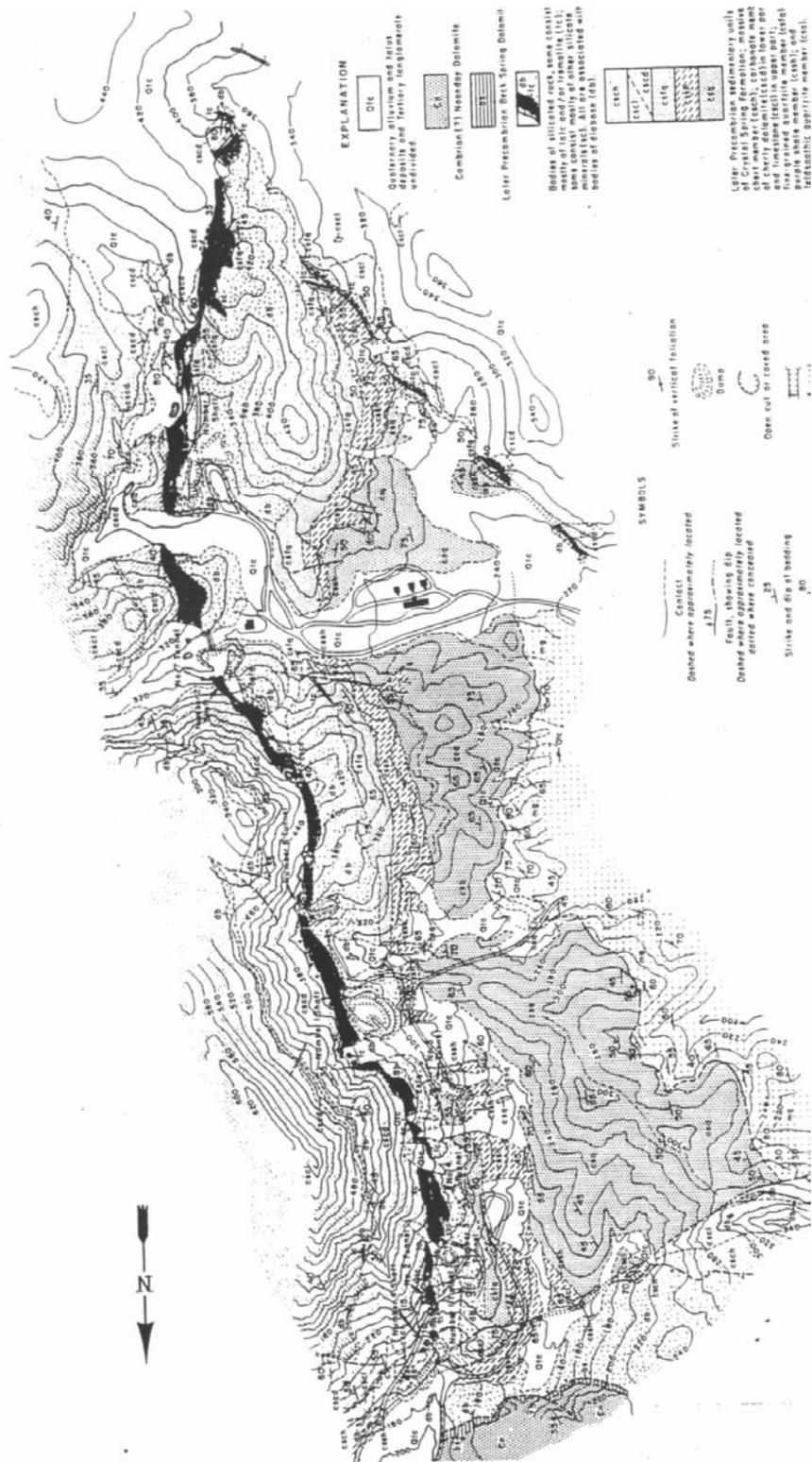


Figure 3. Geology of a portion of the Western Talc Mine

The Western Mine

The Western mine has the most extensive workings and the longest operating history of the talc mines in the southern Death Valley-Kingston Range region. The property consists of seven patented and four unpatented claims, formerly owned and operated by the Western Talc Company.

The talc bodies at this locality were being worked as early as 1912 and may have been opened one or two years before then. The claims of the Western mine cover all of the talc-bearing exposures in the northwest quarter of the Alexander Hills and in the low area to the northwest of the hills. Here, as at numerous other localities in the surrounding region the talc-bearing zone has formed as an alteration of cherty dolomite at the base of the Crystal Spring Formation. A diabase sill forms the footwall of the talc bodies through most of the mine area, but in the southern part, elongate bodies of green alteration rock locally separate the white rock from the diabase.

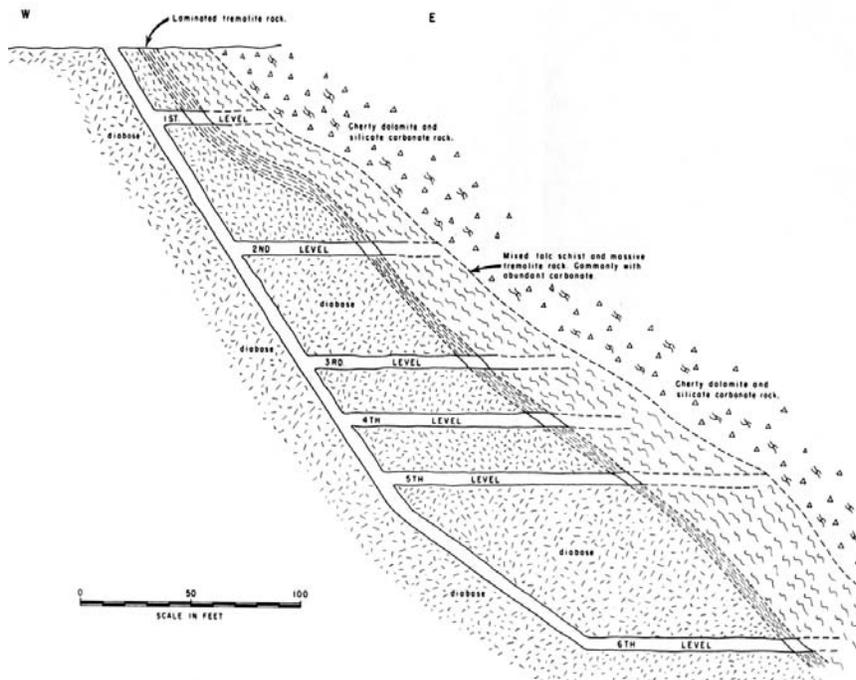


Figure 4. Cross section through a portion of the Western Talc Body.

War Eagle Mine

The War Eagle Mine is located 12 kilometers east of Tecopa, California at the south end of the Nopah Range. It operated from 1912 until 1961, the last operator the Anaconda Copper Corporation. Despite the extensive mine workings and obviously large tonnage of ore removed from this mine and the adjacent Columbia and Noonday Mines astonishingly little has been published. Much of this can be attributed to the untimely death of the Chief Mine Geologist in 1957.

The mine workings are entirely within Noonday Dolomite, although the contact with underlying basement rocks is reportedly exposed to the north in the Gunsight mine. Mineralization appears to lie along a nearly north-trending vein which dips moderately to the east. A brief examination of the mine suggests the main ore vein is offset by a post mineral fault system which strikes N 65° W. A series of northeast trending fractures with steep northwest dips are thought to control localization of the ore bodies.

Although little information is available on the mine workings, levels are thought to have been developed to at least 175 meters below the existing entrance adit. Access to lower levels is via a series of raises and an inclined shaft. The main ore zone has been developed for several thousand feet along strike.

Ore mineralization is restricted to argentiferous galena, but traces of chalcopyrite, sphalerite and pyrite were noted in stopes. Native gold has been reported, but recent assay work in the late 1970's suggests gold ore grades are subeconomic. Reportedly, the upper extension of the ore shoot has been oxidized to cerussite and anglesite. Typical gangue alteration minerals such as siderite, jarosite and iron and manganese oxides are common throughout the mine workings. Figure 5 is a geologic map of the southern portion (about 1/4) of the War Eagle mine workings. Note that the main ore body, near the top of the map follows a vein system that strikes approximately N 50E. Mineralization has been stoped both above and below the level of this map.

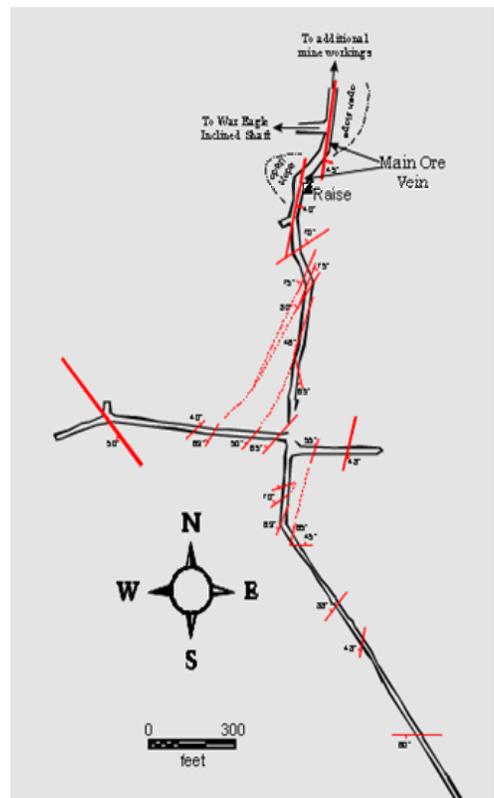


Figure 5. Geologic map of the southern War Eagle mine.

Geology and History **of the Resting Springs Mining District**

Suzanne Baltzer

Location and History

The Resting Springs Mining District is located at the southern end of the Nopah Range one and a half miles from the Resting Springs Arabian horse ranch and seven miles south of Tecopa. This district encompasses several mines. The main ore producers were the Gunsite, Noonday, Columbia, Grant and War Eagle mines. The ore produced by these mines was chiefly lead and silver. The Gunsite workings, located north of the War Eagle, are the oldest. The Gunsite was located and developed in the spring of 1875 by two brothers, William D. and Robert D. Brown. The Browns were also responsible for the discovery of the Darwin silver district located in the Inyo Mountains. The two brothers laid out the Willow Springs town site located six miles southeast of Resting Springs in anticipation of what they hoped would be a new “boom” camp. In September of 1876 the town was renamed Tecopa (after a local Paiute leader) by the new owner of the mines and township Jonas D. Osborne, a former mining superintendent from Eureka, Nevada. Osborne located several investors in Los Angeles and they incorporated the Los Angeles Mining and Smelting Company.

In the beginning the operations looked promising. The wood used in development of the mines was brought in from a sawmill in the Spring Mountains 35 miles away. Initially, the ore was easily processed and during its first night of operation the smelter turned out 67 bars of bullion. The ore was richer in silver than galena (a lead sulfide), however processing it turned out to be more difficult and expensive as most of it was in the form of lead carbonates, instead of the softer, easier to process galena. During the next several years the mines were worked intermittently depending on funding and new refining processes but finally in May 1881 the Los Angeles Mining and Smelting Company closed its operations.

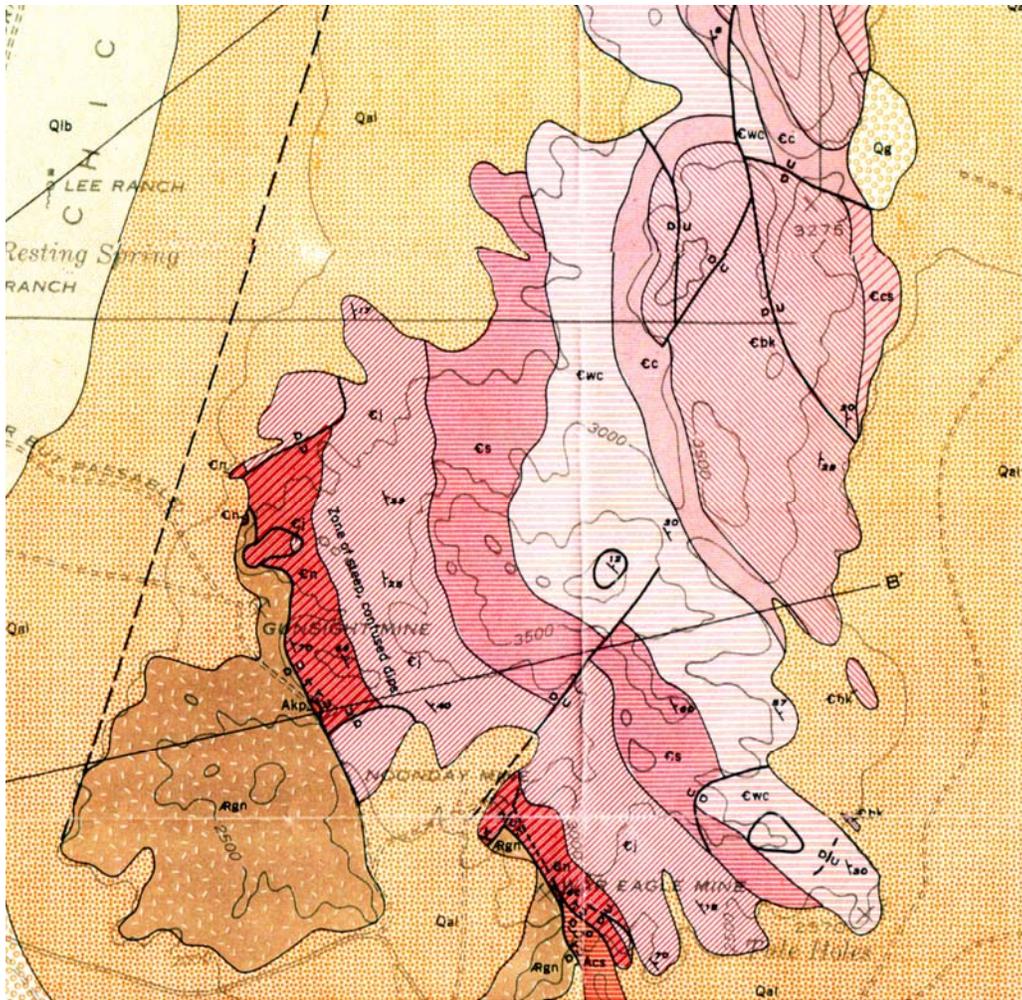
In 1906 the Tonopah and Tidewater Railroad was built within a few miles of Resting Springs, assisting mining operations by lowering transport costs. During the period 1912 to 1928 nearly \$3,000,000 of lead-silver ore was produced, primarily by the Tecopa Consolidated Mining Company. In 1947 the Anaconda Copper Company purchased the mines and called them the Shoshone Mines. The principle mines within this group were the Noonday (2/3 mile northwest of the War Eagle), the Columbia (1/4 mile southwest of the Noonday) and the War Eagle. The Gunsite deposit was not worked by the Anaconda Company. During the period 1947 to 1956 almost \$4,000,000 of silver-lead ore was produced by the Shoshone Mines. The richest ores of the group were produced from the War Eagle workings. Ore production of the Shoshone Mines Group discontinued in 1957.

Geology

The mine workings lie entirely within the Proterozoic Noonday Dolomite, a massive, highly weathered, cream-colored dolomite. Rusty weathering sand grains, especially in the upper part, locally makes cross bedding evident. Fracturing and brecciation is common, forming fissures for ore deposition. The mines lie above the unconformable contact between a granite gneiss and the Noonday formation. The Proterozoic Johnnie formation lies in conformable contact above the Noonday. This contact is well exposed near the Gunsite mine, northwest of the War Eagle mine. The ore lies within a series of steeply dipping (sometimes vertical) north-south trending faults. The ore consists chiefly of lead carbonates with some unoxidized galena. Argentiferous galena was the primary ore mineral, but oxidation has produced cerussite and anglesite. In 1951 the War Eagle was the most important producing mine of the Shoshone Mines group. Lateral workings of the War Eagle are quite extensive. This field trip stop is actually the “back” side of the workings. These workings continue through to the other side of the hill we are facing, however this connection has recently collapsed and you are no longer able to walk through the mine workings to the “front” side of the War Eagle. The road to the “front” side of the mine is nearly undriveable, thereby making the “back” side of the mine much more accessible.

Summary

The history of the Resting Springs Mines was sporadic and not as “colorful” as other mining districts in the area. However, in terms of lead and silver production it was considered one of the three largest lead producers within the state of California. Between the discovery of the district in 1876 to its final days of operations in 1957 the Resting Springs Mining District was responsible for production of more than \$7,000,000 worth of lead-silver ores. Today, all that is left are mine workings and memories to be explored by rockhounds, mineral collectors and history aficionados.



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