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GUIDEBOOK ALONG THE EAST-CENTRAL FRONT  
OF THE SIERRA NEVADA

ANNUAL FIELD TRIP OF THE GEOLOGICAL SOCIETY  
OF SACRAMENTO, JUNE 18, AND 19, 1966

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J. R. Evans, California Division  
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# CONTENTS

|  | Page |
|--|------|
| Geological road guide, junction U. S. 50 and<br>California State 80 highways near Lake Tahoe<br>to Junction U. S. 50 and U. S. 395 in Carson<br>Valley, D. B. Slemmons, J. Lintz, and A. E.<br>Jones ..... | 1    |
| Geology and structure of the Mono Basin, Mono<br>County, California, Charles W. Chesterman,<br>and C. H. Gray .....  | 11   |
| Mono Lake tufa pinnacles, David W. Scholl .....  | 19   |
| Geology of Mono Lake, David W. Scholl, Roland<br>von Huene, and Pierre St.-Amand .....   | 22   |
| Islands of Mono Lake, Mark Twain .....   | 37   |
| Mammoth-Minaret Summit-Convict Lake-Rock<br>Creek-Owens Gorge area, Inqua Guide<br>Book .....  | 45   |
| Geomorphology of the Reversed Creek Recreation<br>area, N. E. A. Hinds .....   | 62   |
| Leviathan mine, J. R. Evans .....  | 63   |
| Zaca mine, J. R. Evans .....   | 69   |

## Plates

|  |           |
|--|-----------|
| Geologic map of the Carson Valley area, California<br>and Nevada .....                                 | In pocket |
| Bathymetric chart of Mono Lake .....   | In pocket |
| Geologic map of Mono Basin, Mono County, California .....  | In pocket |
| Plan distribution of sulphur mineralization Leviathan<br>sulphur mine, Alpine County, California ..... | In pocket |
| Composite level map of the Zaca mine, N. E. Alpine<br>County, California .....                         | In pocket |



## LEVIATHAN MINE

James R. Evans, California Division  
of Mines and Geology, Sacramento

### History

About 500,000 long tons of sulfur valued at  $14\frac{1}{2}$  million dollars have been produced from the Leviathan mine (Figure A, and Table 1). Nearly all the production came in the period 1953 to 1962 when the mine was owned by the Anaconda Company.

Discovery of the mine came in 1863 by Comstock Lode miners and prospectors who apparently were seeking a source of blue vitriol or chalcantite ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) for processing silver sulfide ore by the Patio process at Virginia City, Nevada. At this time an adit was driven about 400 feet into silicified and mineralized rock in search for a concentration of chalcantite. It occurred, however, <sup>only</sup> as coatings, seams, and cavity fillings.

By 1869 miners had given up any possible idea of extracting chalcantite, but had become interested in the showings of primary copper minerals. A copper smelting furnace and other mine machinery were shipped from Reno, Nevada in 1869 by San Francisco investors who hoped to attract English capital to Alpine County. They were successful as Edward Dorsett of London gained control of the mine in 1869 (Alpine Chronicle, October 1869). By 1870 two adits were driven and 500 (?) tons of 30-50% (?) copper ore was extracted (Alpine Chronicle, July 1870). In 1872 the mine was leased to Captain Bennett, and reports were still glowing about high grade copper ore (Alpine Chronicle, March 1872). A significant point here is the first printed note about the mine "bottoming" in sulfur. In July 1872 the sulfur deposit was described as immense (Alpine Chronicle). Edward Dorsett died in late 1872 or early 1873 and information about mine ownership and operation is lacking until about 1900. At this time the mine was owned by D. Bari of Silver Creek, Alpine County, but reported idle (Aubury 1905, p. 199). Exploration work consisted of a 400-foot adit driven through a ledge 250 feet below the outcrop, and a 700-foot adit 200 feet below the upper adit. The adits were connected by a winze.

Apparently the mine was idle until 1931 when it was optioned from Mr. Brune, Markleeville, to Western Clay and Metals Co., Los Angeles. The "old" workings were being reopened by 5 miners (Logan 1931, p. 491). In 1935 the mine was leased to Texas Gulf Sulfur Co., and then subleased to the Calpine Corp., Los Angeles. An experimental plant was erected for recovery of sulfur by steam liquidation, and about 5000 long tons of sulfur were produced, all from underground workings. The main adit was at the top of the sulfur body, and 3000 feet long. It had several drifts, raises, and stopes. Underground mining was extremely hazardous because of the highly inflammable nature of the sulfur. In 1941, Calpine Corp. gave up its sublease, and in 1945, Siskon Mining Corp. (subsidiary of Texas Gulf Sulfur Co.) acquired the mine.



| Year  | Crude Ore<br>(long tons)* | Sulfur Content<br>(long tons)* | Estimated<br>Value |
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| 1953  | 151,549                   | 37,887                         | \$ 757,740         |
| 1954  | 185,085                   | 53,175                         | 1,507,429          |
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| 1962  | 146,448                   | 39,395                         | 1,413,223          |
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\*2240 lb.

Table 1. Sulfur Production from the Leviathan Mine (Courtesy of Anaconda Company).

Anaconda Company purchased the property in 1951 with the idea of developing an open pit mine. They needed sulfur to manufacture sulfuric acid for leaching secondary copper ore (chrysocolla) at their newly opened Weed Heights mine near Yerrington, Nevada. Stripping of overburden was done in 1952 and early 1953 by Isabel Construction Co., Reno, Nevada. Open pit mining of the sulfur ore was begun in July 1953 and continued until 1962. Sulfur ore was trucked 60 miles to Weed Heights in 17 (23 cubic yard) belly dump trucks. Hauling was done under contract by Wells Cargo Co., Reno, Nevada. The mine was closed in 1962 for several reasons. Ore away from the existing open pit is under an increasingly thick overburden, and mining costs were certain to rise. Also, the walls of the existing pit were caving and needed shaving to shallower slopes. To add to these problems the mine at Weed Heights had been worked down into primary sulfide ore (chalcopryrite) which does not require acid leaching. Even with these problems if a nearby demand for sulfur could have been found, the mine might have been kept in operation. In January 1963 the property was sold to Chris Mann, County Clerk, Markleeville, Alpine County.



## Geology and Mineralogy

The sulfur ore body occurs as a flatish NW trending elliptical lense about 90 feet in maximum thickness and at least 2400 feet long (Plate 1, and Figures 1, and 2). As described in the History section, sulfur does not outcrop at the surface, and was first discovered through underground mining and about 200 to 300 feet below the ground surface.

Sulfur has impregnated the lower part of a lake deposited (?) tuff bed, and part of the underlying rock called andesite (?) by Anaconda Company geologists. The tuff is white to yellowish brown and locally bedded. Tuff visible in the walls of the present pit is mostly white and massive. Locally it is replaced by highly irregular shaped areas of gray opaline material several feet in length. Part of the tuff contains fine grain sized crystals of kaolinized feldspar. These crystals are more obvious in the gray replacement areas as relicts. Possibly the andesite (?) is completely opalized tuff. It is remarkably similar to those areas in the white tuff.

Tuff is very porous and provided an excellent sponge for mineralization. In this unit most sulfur was distributed uniformly, although it locally occurred in clots and veins. Sulfur in the andesite (?) or opalized tuff is less uniformly distributed. Mineralized rock exposed in the west wall of the main pit is broken and bright yellow sulfur fills fracture planes rather than pores as in the tuff. Marcasite, pyrite, and chalcopyrite occur in discontinuous bunches mostly along the upper and lower margins of the sulfur ore body, but also in small quantities throughout the body.

Mineralized tuff contained as much as 70% sulfur, but averaged about 35%. Mineralized andesite (?) had a wide variability in sulfur content, but averaged about 25%. Thick masses or veins of pure sulfur occurred in both rocks but only rarely. Contacts between mineralized tuff and nonmineralized tuff are quite sharp, whereas contacts in the andesite (?) were gradational over 10 to 15 feet.

Several veins of pure sulfur roughly 1' to 2' thick were noted in the lower underground workings by Anaconda Company geologists. The veins cut tuff. All underground workings have been excavated during development work.

An agglomerate unit about 120 feet in maximum thickness overlies the tuff. Clasts are rounded to angular fragments of brown, gray, and black, and largely porphyritic volcanic rocks. The clasts are poorly sorted and range in size from roughly 1 foot to a fraction of an inch in longest dimension. They are set in a gray tuffaceous sandstone matrix. This unit greatly resembles typical rocks of the Mehrten Formation. Overlying the agglomerate is an unmineralized white tuff about 100 feet in maximum thickness. It thins rapidly and pinches out in the plane of section A-A' (Figure 2). Prior to pit development a silicified "cap rock" rested on the tuff. It was as much as 160 feet thick, but thinned markedly away from the center of the ore body (Figures 1, and 2).



Meager chemical data is available and comes courtesy of the Anaconda Company. A typical analysis of a sample from a truck load lot of mineralized tuff is: insoluble (mostly  $\text{SiO}_2$ ), 49%; Fe, 6%; S, 33%; soluble salts, 12%, and traces of  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ , and  $\text{CaO}$ .

Available geologic information, in large part obtained through James R. Wilson, geologist, Anaconda Company, Reno, Nevada suggests to me the following possible origin for the sulfur mineralization.

1. Tuff was altered by ascending  $\text{SiO}_2$ -rich solutions in part derived from an unknown source, presumably an unexposed magma. The part, if any, which heated ground water may have played in mineralization is not known.
2. Contemporaneously, and closely following silicification iron-rich and  $\text{H}_2\text{S}$  charged solutions were channeled through vents such as those once exposed in the underground workings.
3.  $\text{H}_2\text{S}$  gas was oxidized with precipitation of sulfur and formation of water.
4. Tuff served as a sponge for solutions and they spread laterally through the porous material.
5. Precipitation of sulfur in the pores eventually caused the tuff to seal, and resulted in more lateral and downward spreading of gas charged solutions. There is no known widespread mineralization below the zone shown in Figures 2, and 3. Deep drilling could prove otherwise. The last phase of sulfur deposition consisted of fracture filling in the andesite (?) and filling of the vents with sulfur.
6. Time, mode of origin, and significance of "cap rock" silicification is not known. It has been removed during pit development, and future study is impossible. There are many other silicified areas which do not have sulfur below them (Figure A). However, "cap rock" silicification could have been an integral part of the rock alteration leading to mineralization.
7. Oxidation of sulfur bearing rock produced at the least the following sulfate minerals: chalcantite,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ; iron - chalcantite,  $\text{FeO} \cdot \text{CuO} \cdot 2\text{SO}_3 \cdot 10\text{H}_2\text{O}$ ; halotrichite,  $\text{FeSO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 22\text{H}_2\text{O}$ ; melanterite,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ; romerite,  $\text{FeSO}_4 \cdot \text{Fe}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ . Gary (1939, pp. 488-489) identified all these minerals in the underground workings. Some, or perhaps all of these minerals are forming on the pit floor where ground or surface water is impounded.

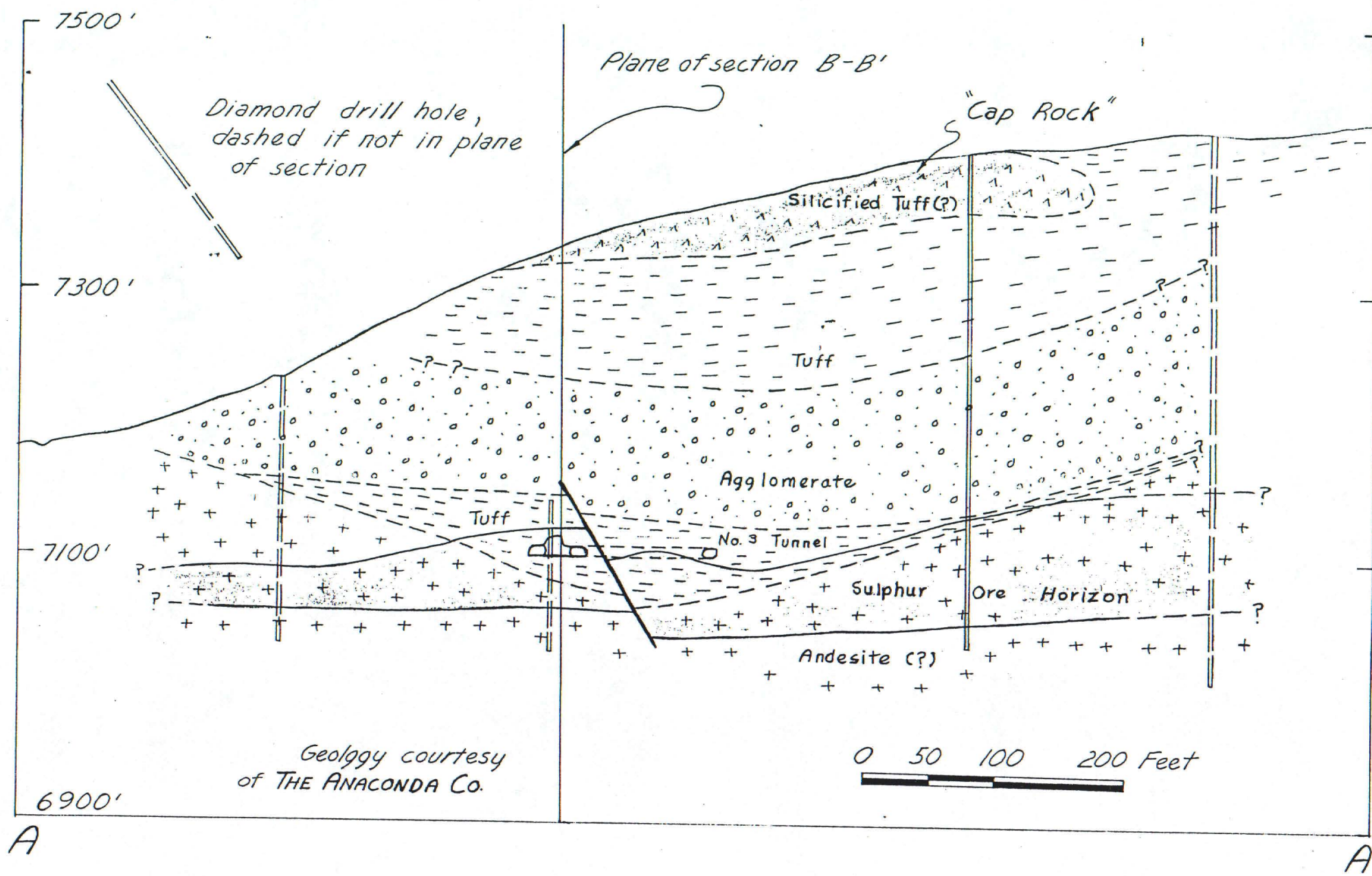


Figure 1. Structure section A-A', Leviathan Mine.



## Mining Operations

A maximum of 350 feet of overburden was stripped from the orebody by the Isabel Construction Co. Thirtyfive-foot benches were maintained, in contrast to the 15-foot benches used for mining the ore body. At present the pit is roughly 2000 feet long, 1000 feet wide and 400 feet in maximum depth. The waste to ore ratio was generally about 11 to 1, although locally it was only 4 to 1. Primary blasting of the orebody was done in the 1960's with Dupont gelatin. Prior to this time, a special blasting compound was used. It was composed of 80 pounds of ammonium nitrate, 1 gallon of molasses and 1 gallon of water. This seemingly odd mixture served well as it did not ignite the highly inflammable sulfur.

Blasted ore<sup>was</sup> loaded by a power shovel into Euclid trucks for a  $\frac{1}{2}$  mile haul to the crushing plant west of the pit area. Ore was dumped over a 21-inch grizzly with automatic oversize reject. Oversize was broken by a 2300 pound drop ball for return to grizzly. Material from the grizzly went to the 5-inch jaw crusher (300 tons/hr) and then to 4, 100 cu. yd. storage bins by conveyor belts. Overflow from the bins was stockpiled in the yard. From the storage bins ore was trucked to Weed Heights by the Wells Cargo Co. belly dump trucks, where it was crushed to -3" by jaw crusher, -1" by a Nordberg short-head crusher and pulverized in 4 rod mills. Fines were roasted at 1100-1250°F to produce SO<sub>2</sub> which was cooled in a water-spray chamber and then passed through a series of cyclone precipitators to remove dust. The gas was then scrubbed in a Peabody scrubber, passed through Cotrell mist precipitators, and sent to a contact sulfuric acid plant. A minor amount of selenium is recovered during treatment of the sulfur. Sulfuric acid was piped from the plant to copper ore treatment vats.

Several problems plagued the mining operations, one of which could not be solved. The unsolvable problem was that of heavy snowfall, and other rigorous winter conditions to be expected at the over 7,000 feet elevation in this area. The mine could be operated only 6 months out of the year, roughly May through October.

Leviathan Creek drains northward across waste dumps and in the process becomes very acidic (ph<sub>3</sub>) and rich in iron sulfate, particularly in the summer months when the water volume is low. A settling pond was made to impound water north of the dump. Lime from Diamond Springs, El Dorado County, was moistened and sprayed over the pond to neutralize the acid water. Iron precipitated out as a red sludge which was dredged and stockpiled. Water was then released down Leviathan Creek to Carson Valley. Evidently not all the iron or acid was removed, as stock ranchers and the Nevada Fish and Game Bureau filed a 1 million dollar damage suit against Anaconda Company in the early 1960's.

To combat the problem an earth dam was built upstream from the waste dump. A one-quarter mile pipeline connected the dam and the area downstream from the dumps. Dam overflow going through the dumps during the winter months supposedly did not cause any problem because the large volume of water diluted the contaminating agents.

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## CONTENTS

|  | Page |
|--|------|
| Geological road guide, junction U. S. 50 and<br>California State 80 highways near Lake Tahoe<br>to Junction U. S. 50 and U. S. 395 in Carson<br>Valley, D. B. Slemmons, J. Lintz, and A. E.<br>Jones ..... | 1    |
| Geology and structure of the Mono Basin, Mono<br>County, California, Charles W. Chesterman,<br>and C. H. Gray .....  | 11   |
| Mono Lake tufa pinnacles, David W. Scholl .....  | 19   |
| Geology of Mono Lake, David W. Scholl, Roland<br>von Huene, and Pierre St.-Amand .....   | 22   |
| Islands of Mono Lake, Mark Twain .....   | 37   |
| Mammoth-Minaret Summit-Convict Lake-Rock<br>Creek-Owens Gorge area, Inqua Guide<br>Book .....  | 45   |
| Geomorphology of the Reversed Creek Recreation<br>area, N. E. A. Hinds .....   | 62   |
| Leviathan mine, J. R. Evans .....  | 63   |
| Zaca mine, J. R. Evans .....   | 69   |

## Plates

|  |           |
|--|-----------|
| Geologic map of the Carson Valley area, California<br>and Nevada .....                                 | In pocket |
| Bathymetric chart of Mono Lake .....   | In pocket |
| Geologic map of Mono Basin, Mono County, California .....  | In pocket |
| Plan distribution of sulphur mineralization Leviathan<br>sulphur mine, Alpine County, California ..... | In pocket |
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6. Time, mode of origin, and significance of "cap rock" silicification is not known. It has been removed during pit development, and future study is impossible. There are many other silicified areas which do not have sulfur below them (Figure A). However, "cap rock" silicification could have been an integral part of the rock alteration leading to mineralization.
7. Oxidation of sulfur bearing rock produced at the least the following sulfate minerals: chalcantite,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ; iron - chalcantite,  $\text{FeO} \cdot \text{CuO} \cdot 2\text{SO}_3 \cdot 10\text{H}_2\text{O}$ ; halotrichite,  $\text{FeSO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 22\text{H}_2\text{O}$ ; melanterite,  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ; romerite,  $\text{FeSO}_4 \cdot \text{Fe}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$ . Gary (1939, pp. 488-489) identified all these minerals in the underground workings. Some, or perhaps all of these minerals are forming on the pit floor where ground or surface water is impounded.

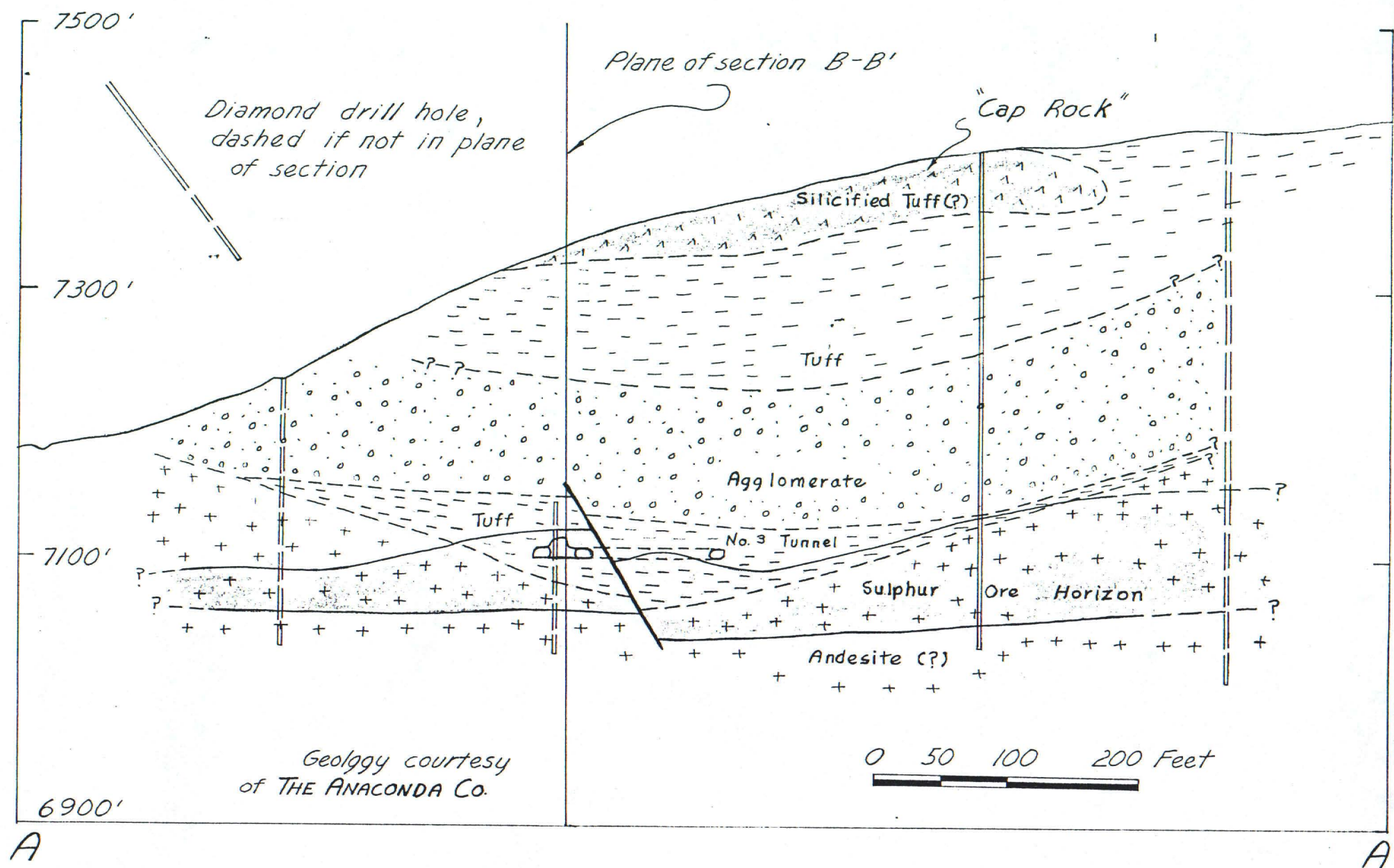


Figure 1. Structure section A-A', Leviathan Mine.



## Mining Operations

A maximum of 350 feet of overburden was stripped from the orebody by the Isabel Construction Co. Thirtyfive-foot benches were maintained, in contrast to the 15-foot benches used for mining the ore body. At present the pit is roughly 2000 feet long, 1000 feet wide and 400 feet in maximum depth. The waste to ore ratio was generally about 11 to 1, although locally it was only 4 to 1. Primary blasting of the orebody was done in the 1960's with Dupont gelatin. Prior to this time, a special blasting compound was used. It was composed of 80 pounds of ammonium nitrate, 1 gallon of molasses and 1 gallon of water. This seemingly odd mixture served well as it did not ignite the highly inflammable sulfur.

Blasted ore<sup>was</sup> loaded by a power shovel into Euclid trucks for a  $\frac{1}{2}$  mile haul to the crushing plant west of the pit area. Ore was dumped over a 21-inch grizzly with automatic oversize reject. Oversize was broken by a 2300 pound drop ball for return to grizzly. Material from the grizzly went to the 5-inch jaw crusher (300 tons/hr) and then to 4, 100 cu. yd. storage bins by conveyor belts. Overflow from the bins was stockpiled in the yard. From the storage bins ore was trucked to Weed Heights by the Wells Cargo Co. belly dump trucks, where it was crushed to -3" by jaw crusher, -1" by a Nordberg short-head crusher and pulverized in 4 rod mills. Fines were roasted at 1100-1250°F to produce SO<sub>2</sub> which was cooled in a water-spray chamber and then passed through a series of cyclone precipitators to remove dust. The gas was then scrubbed in a Peabody scrubber, passed through Cotrell mist precipitators, and sent to a contact sulfuric acid plant. A minor amount of selenium is recovered during treatment of the sulfur. Sulfuric acid was piped from the plant to copper ore treatment vats.

Several problems plagued the mining operations, one of which could not be solved. The unsolvable problem was that of heavy snowfall, and other rigorous winter conditions to be expected at the over 7,000 feet elevation in this area. The mine could be operated only 6 months out of the year, roughly May through October.

Leviathan Creek drains northward across waste dumps and in the process becomes very acidic (ph<sub>3</sub>) and rich in iron sulfate, particularly in the summer months when the water volume is low. A settling pond was made to impound water north of the dump. Lime from Diamond Springs, El Dorado County, was moistened and sprayed over the pond to neutralize the acid water. Iron precipitated out as a red sludge which was dredged and stockpiled. Water was then released down Leviathan Creek to Carson Valley. Evidently not all the iron or acid was removed, as stock ranchers and the Nevada Fish and Game Bureau filed a 1 million dollar damage suit against Anaconda Company in the early 1960's.

To combat the problem an earth dam was built upstream from the waste dump. A one-quarter mile pipeline connected the dam and the area downstream from the dumps. Dam overflow going through the dumps during the winter months supposedly did not cause any problem because the large volume of water diluted the contaminating agents.

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Gary, George L., 1939, Sulfate minerals at the Leviathan sulfur mine, Alpine County, California, 35th Report of the State Mineralogist, Calif. Div. Mines, pp. 488-489.



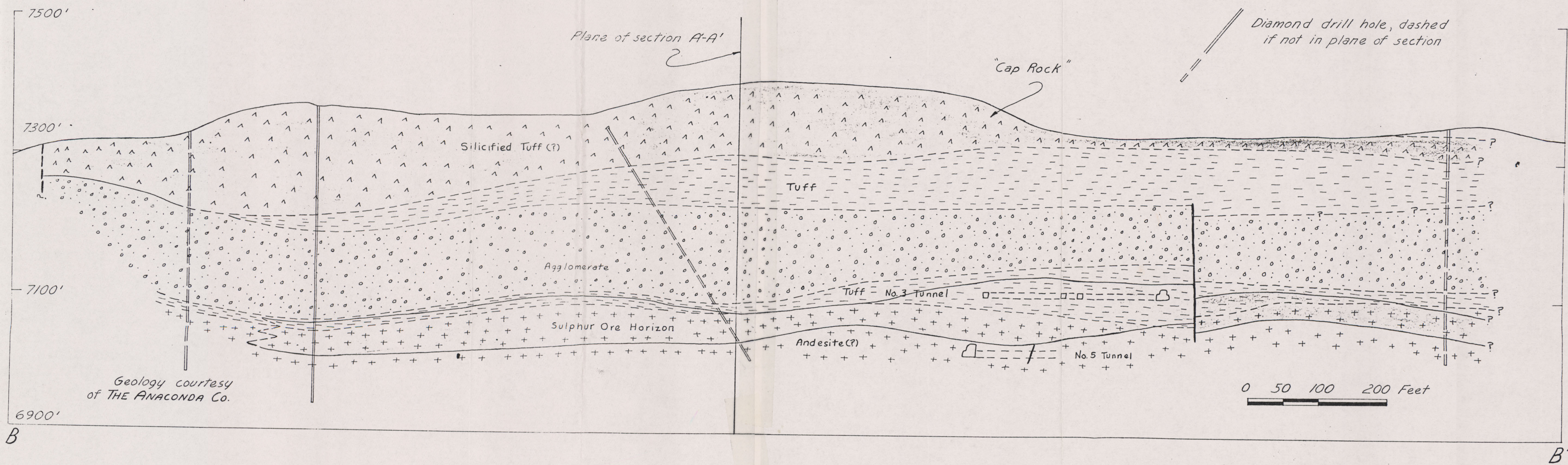
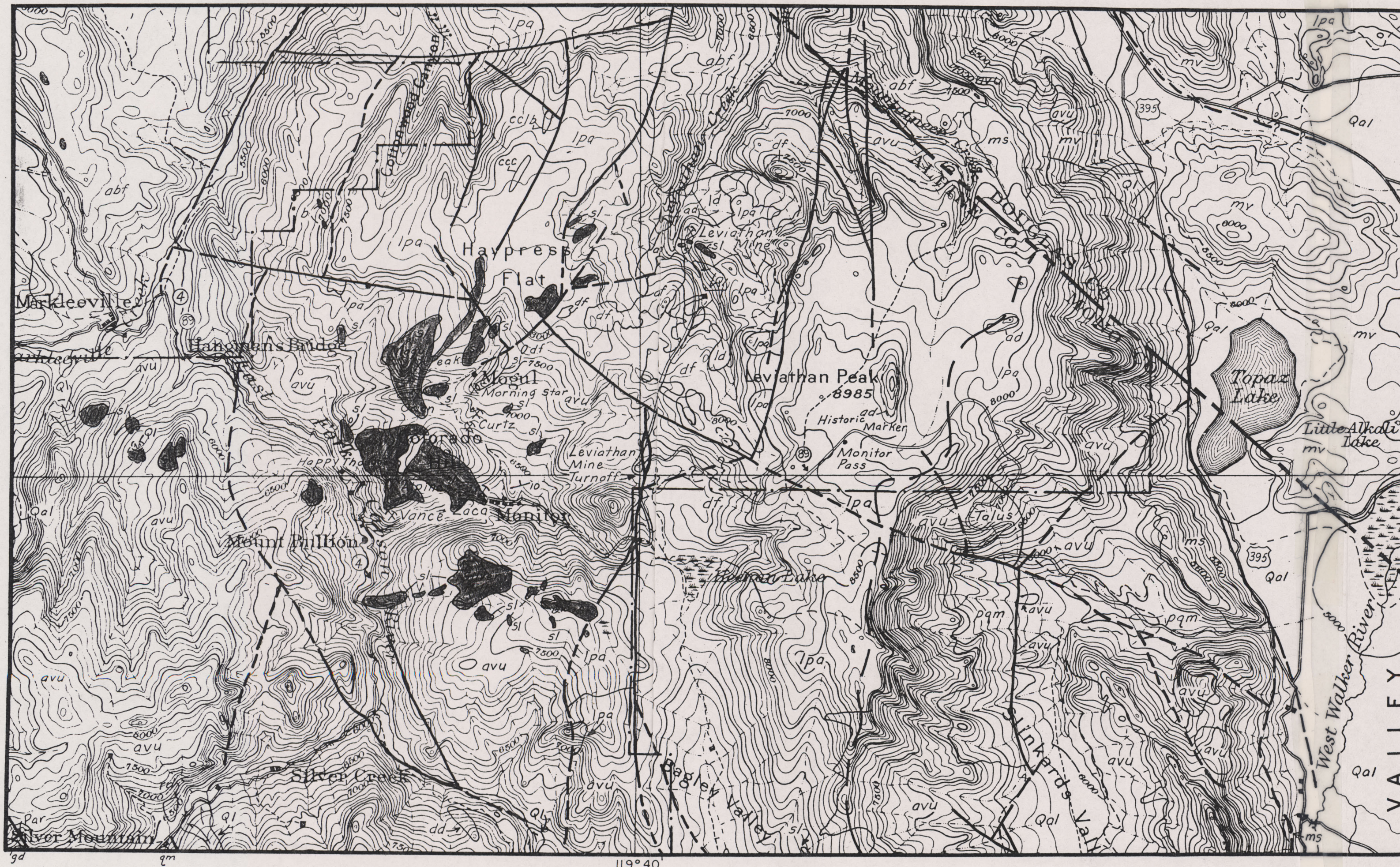


Figure 2. Structure section B-B', Leviathan Mine.





# GEOLOGIC MAP OF THE MONITOR PASS AREA, CALIFORNIA AND NEVADA

## EXPLANATION

Quaternary

|     |           |
|-----|-----------|
| Qal | Alluvium  |
| Ql  | Landslide |
| Qt  | Talus     |

Geologic contact,  
dashed where  
approximate

Fault, dashed where  
probable or concealed,  
question marked  
where inferred.

Mine

|    |                  |
|----|------------------|
| b  | Basalt intrusion |
| ad | Andesite dome    |
| dd | Dacite dome      |
| rd | Rhyolite dome    |

df Dacite flow

abf Autobrecciated flows

Silicified & mineralized  
rocks

lpa Andesite of Leviathan  
peak area

ld Lake deposits in  
Leviathan Peak area;  
conglomerate & lake beds  
at Cottonwood Creek

avu Andesitic rock  
undifferentiated

par Pre-avu Rhyolite

gd Granodiorite,  
porphyritic quartz  
monzonite, quartz  
monzonite

ms Metasedimentary  
and metavolcanic  
rocks

Jurassic to  
Triassic? Cretaceous

Pliocene

Tertiary

Miocene

0 1 2  
Scale in Miles  
Contour Interval: 100'

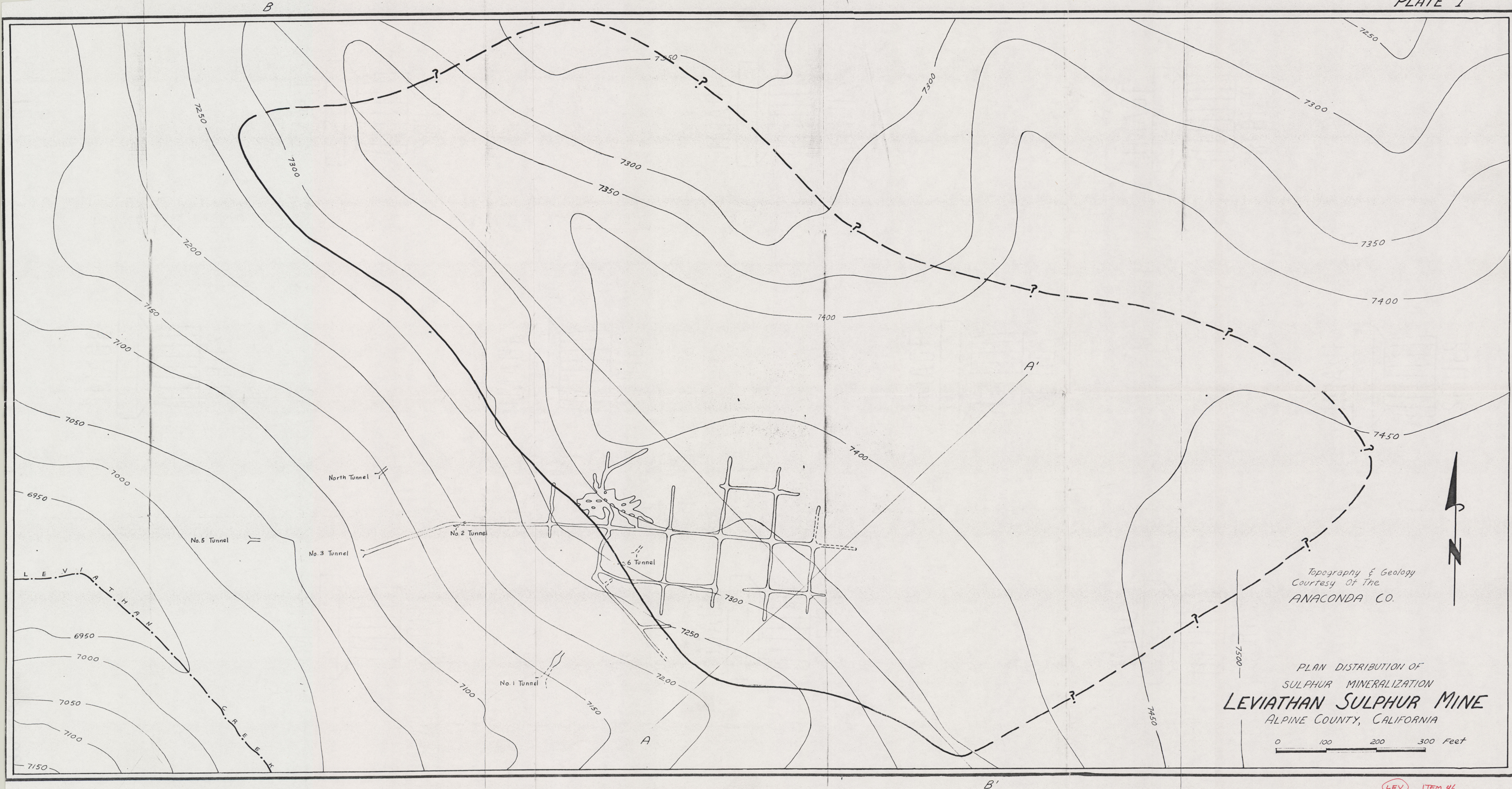
Base map from U.S.G.S.  
Calif.-Nev. Markleville  
Quad. N3830-  
W11930130, 1893

Geology taken from  
unpublished map by  
Garniss Curtis, 1951,  
slightly modified by  
J. R. Evans, 1966

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LEV  
ITEM 46





Topography & Geology  
Courtesy Of The  
ANACONDA CO.

PLAN DISTRIBUTION OF  
SULPHUR MINERALIZATION  
**LEVIATHAN SULPHUR MINE**  
ALPINE COUNTY, CALIFORNIA

0 100 200 300 Feet