**Fort Cady Borate Project, Lava Bed Mountains, San Bernardino County, California**

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**Acknowledgement and Disclaimer**

The information in this paper is taken largely from published and public sources. I have reproduced this material and present it pretty much as we found it, not trying to harmonize discrepancies in mine or geologic descriptions. I have changed verb tenses for readability and have used some paraphrase. I have expanded abbreviations or special characters with full text (e.g. feet instead of ft., inches instead of ") Italics indicate quotations. Authors of the original information are indicated at the end of each paragraph. Paragraphs without a citation are our own materials. The maps in this report have been compiled and rectified from digital and paper copies of original sources that were made at different scales and in different geographic projections. Therefore, many of the maps had to be adjusted or stretched. They do not fit perfectly. Most are accurate to within 100 feet, but reproduction and projection errors can be as much as 300 feet for some maps. PLSS means Public Land Survey System. That survey data was obtained from the U.S. Bureau of Land Management website.

MRDS, 2011, Mineral Resources Data System, U.S. Geological Survey, https://mrdata.usgs.gov/mrds/. This database relies on records that, in many cases, are inaccurate or imprecise. For example, if a report describes a mine as being in "Section 9", with no other information, MRDS plots the mine location in the center of the section. If a mine is reported in "SW ¼" of a section, MRDS plots the mine in the center of that SW quarter-section. Where I could confidently adjust an MRDS location of a mineral deposit tofeatures identifiable in aerial photographs or topographic maps, I did so.

Help me make this report better. If you have any photographs, memories or reports for this mine that you can share, please send them to yosoygeologo@gmail.com so we can incorporate into this paper.

**GEORECTIFIED MAPS FOR AVENZA AND ARCGIS**

Digital georectified .pdf files and map packages available by request to yosoygeologo@gmail.com

**LOCATION** (MRDS, 2011)

| | | | |
|---|---|---|---|
| 8N 5E Sec. 23 SBM | 34.76668 | -116.41753 | deposit |
| 8N 6E Sec. 19 SBM | 34.76441 | -116.38395 | plant |
| 8N 5E Sec. 25 SBM | 34.75422 | -116.40276 | solution mine |

*The site of the proposed FCMC Solution Mining Project is located in San Bernardino County near Pisgah Crater, approximately 40 miles east of Barstow and 17 miles east of Newberry Springs, California. The site is about two and one-half miles south of Interstate 40 (I-40) and the Atchison Topeka and Santa Fe Railway Pisgah siding in the Mohave Desert (Figure 1-1). The project area consists of approximately 6,500 acres, of which 342.5 acres would be disturbed (Figure 1-2).(San Bernardino County, 1994, Section 1.1.1, p. 1)*

**OWNERSHIP**

1990: Avalon Corporation, management by Kilbourne International Construction (https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10023265; https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10023265 both accessed June 15, 2020

1994: Fort Cady Mining Company (San Bernardino County, 1994).

**HISTORY**

*"Exploration and mining of hectorite clay in the project area has continued without interruption since the early 1930s. Rhoex, Inc. currently operates a large open-pit mine to recover high-grade hectorite clay approximately one-half mile southwest of the proposed Fort Cady ore body and well field. Less than two miles to the southeast of the project area, Kiewit Mining Group, Inc. (Pisgah Mining Operations, also called the Twin Mountain Mine) once mined a basaltic lava aggregate within Pisgah Crater; however, this mine is currently inactive."*(San Bernardino County, 1995, Section 1.1.1, p. 2).

*"Initial discovery of the FCMC borate deposit occurred in 1964 when the Congdon Exploration Company found several zones of colemanite, a calcium borate mineral, between the depths of 1,330 and 1,570 feet below the surface in Section 26, TSN, RSE. In September 1977, Duval Corporation initiated land acquisition and exploration activities near Hector, California, and by March 1981 had completed 33 exploration holes in· an approximately 800-foot drilling grid configuration on the project site. As a result of that drilling program, it was estimated that a borate ore body of sufficient size and grade existed to warrant further investigation."* (San Bernardino County, 1995, Section 1.1.1, p. 2).

*"In 1981, Duval Corporation began conventional underground mine planning. Because of the depth of the ore body, it appeared that underground mining methods would not be technically or economically feasible for use in its recovery. However, subsequent studies and tests indicated that in-situ technology could be a feasible method to employ in mining the F C M C colemanite ore body, and a pilot mining and processing operation was initiated in order to explore this possibility."* (San Bernardino County, 1995, Section 1.1.1, p. 2).

**GEOLOGY**

The borate deposit and borate solution mine sites are both located on faults in Quaternary sediments (Phelps and others, 2012). This suggests that the colemanite deposit is related to hot springs that invaded and altered pre-existing sediments along those faults.

**Regional Geology**

The following is found in the San Bernardino County Mine permit of 1994. It quotes information supplied to San Bernardino County as part of their mining permit application by Fort Cady Minerals Incorporated:

*"Regional geologic information in this report was compiled, unless otherwise indicated, from Dibblee (1980a, 1980b). The project area is located in the Barstow Trough of the central Mojave. The Mojave comprises a structural entity commonly referred to as the Mojave block, and is bounded on the southwest by the San Andreas fault zone and the Transverse Ranges, on the north by the Garlock fault zone, and on the east by the Death Valley and Granite Mountain faults. The central Mojave region is made. up of a number of relatively low mountain ranges separated by intervening basins which ·are floored primarily by alluvium. The central Mojave area is cut by numerous faults of various orientations but which predominantly trend to the northwest."* (San Bernardino County, 1994, p. 1).

*"'The oldest rocks exposed in the central Mojave .area are Precambrian in age, and consist primarily of gneissic metamorphic and granitic igneous rocks. The Precambrian rocks are severely deformed and are presumed to underlie younger rock units throughout the central Mojave. Paleozoic and younger*

*sedimentary and volcanic rocks were subsequently deposited above the Precambrian units. During the Mesozoic, older crustal rocks were intruded by predominantly granitic igneous plutons which underlie much of the central Mojave area. Subsequent uplift and erosion have removed much of the rock units overlying the plutonic rocks, leaving isolated granitic remnants exposed in the area. The batholithic and older rocks were subsequently uplifted, eroded, and overlain by later Cenozoic and recent alluvial sediments*." (San Bernardino County, 1994, p. 1).

*A dominant feature of the region is the Barstow Trough, which is a structural depression extending northwesterly from Barstow toward Randsburg and east-southeasterly toward Bristol. The Barstow Trough is characterized by thick successions of Cenozoic sediments, including borate-bearing lacustrine deposits, with abundant volcanism along the trough flanks (Gardner, 1980). The northwest-southeast trending trough initially formed during Oligocene through Miocene times. As the basin was filled with sediments and the adjacent highland areas were reduced by erosion, the areas receiving sediments expanded, and playa lakes, characterized by tine-grained elastic and evaporitic chemical deposition, formed in the low areas at the center of the basins. The Barstow Formation, which is found at the surface in the Mud Hills area north of Barstow, comprises the bulk of the Miocene (roughly 13 to 19 million years old) sediments in that area, where its measured thickness is about 1,000 feet (Woodbume, et a., 1990). The Barstow Formation in the Mud Hills area is made up of conglomeratic basal and marginal units, interfingering with marginal and lacustrine sands, muds, and limestones (algal in some cases). Interbedded volcanic ash units,.often water-laid and/or zeolitized, occur throughout the unit. Depositional relationships indicate that at least local tectonic activity continued through at least the end of Barstow Formation deposition*." (San Bernardino County, 1994, p. 1).

*"Volcanism periodically accompanied faulting in the region, and was generally more extensive at the beginning of the Cenozoic. Aerially, volcanism was more intense in the Barstow Trough area, where it accompanied development of the structural basin. Volcanics are frequently found intercalated with sediments in the Barstow Trough area (Subsurface Surveys, Inc., 1990).11 "Subsequent tectonic disruption of the area during Pleistocene times resulted in elevation of the present topographically high areas and resulted in filling in of former basin areas with coarser grained elastic sediments. Accumulation of alluvium has continued in low areas to the present. Cenozoic sediments in the central Mojave area are relatively undeformed, although there is local deformation in the vicinity of the northwest-trending faults."* (San Bernardino County, 1994, p. 1-2).

*"The project area is located in the south-central portion of the wedge•shaped Mojave block, a structural block bounded by the San Andreas fault zone to the southwest and the Garlock fault zone to the northwest. The eastern tectonic boundary of the Mojave block is vague and poorly defined; however, it is generally represented by an alignment of valleys extending southeastward from Death Valley. Along this alignment, the Death Valley fault zone, evident north of the Garlock fault zone, may extend as a concealed fault southeastward an unknown distance (Dibblee, 1980)."* (San Bernardino County, 1994, p. 2).

*"Recent and historical seismicity and the presence of numerous active and potentially active northwest-trending right-lateral, strike-slip faults provides evidence that the Mojave block is tectonically active. The primary driving force for this activity is believed to be associated with transform motion between two major crustal plates, the Pacific and North American plates. The plate motion is thought to be accommodated across a broad zone of California, both east and west of the northwest-trending, right-lateral, strike-slip San Andreas fault system which represents the principal surface manifestation of the zone of plate interaction and is the dominant seismotectonic element of California. Major faults within the Mojave block generally parallel the San Andreas. The northeast to east-west trending generally left-*

*lateral Garlock fault zone is considered active despite the apparent lack of historic seismic activity clearly attributable to this fault."* (San Bernardino County, 1994, p. 2).

*"Major northwest-trending fault zones of the Mojave block include the Helendale, Lockhart• Lenwood, Camprock-Emerson-Homestead Valley-Johnson Valley, Blackwater-Calico-West Calico- Hidalgo, Pisgah-Bullion, and Ludlow Faults. Although the dominant displacement on fault zones appears to be right-slip, some faults, such as the Pisgah, have significant vertical displacements (Dibblee, 1980a). A regional gravity survey was performed by Subsurface Surveys, Inc. (1990) for the Mojave Water Agency in the west and central Mojave area, ending just west of the project area. The results of that survey indicated that, to a rough approximation, the gravity contours may be viewed qualitatively as structural contours on the bedrock in the area. Evidence for normal, reverse, and strike-slip faulting was found, although upthrown and downthrown relationships across strike-slip faults were commonly observed to change along the fault trends. Offsets of up to 3 to 4 miles (on the Harper Lake-Waterman Fault) were observed, although offsets of roughly 2 to 2.5 miles, as inferred for the Calico-Newberry Fault, were typical. The majority of these faults, evaluated by the California Department of Conservation Division of Mines and Geology (CDMG) under the Alquist-Priolo Special Studies Zones Act as part of the Mojave Desert study region (except for the Ludlow Fault, which was outside the study area), are considered to be Holocene active (Hart, et al., 1987). The 1992 Landers earthquake indicates that these faults are capable of generating large earthquakes."* (San Bernardino County, 1994, p. 2).

*"Several east-west trending faults are present in the northeastern and southern portions of the Mojave block. These active or potentially active faults are generally considered to be high-angle left-slip faults associated with the Garlock fault zone. Several small north-south trending faults are also located within the Mojave block, generally adjacent to, and probably associated with, the large northwest-trending fault zones. most of these faults do not show evidence of Quaternary displacement (Bortugno, 1986); however, a few have demonstrated historic seismicity, including the Manix and Galway Lake Faults (1947 and 1975, respectively). The 1947 Manix earthquake reportedly had a magnitude of 6.2 (Wesnousky, 1986)."* (San Bernardino County, 1994, p. 2).

**Local Geology**

*"Strata ranging in age from probable Pliocene through Recent in age are exposed at the surface within the project area. Exposures of fine-grained lacustrine sediments and tuffs, possibly Pliocene in age, are found throughout the project area. Younger alluvium occurs in washes and overlying the older lacustrine sediments. Recent olivine basalt flows occur in the central and eastern portions of the project area, and along the northern boundary of the western portion of the project area."* (San Bernardino County, 1994, p. 3).

*"Two major geologic features in the project area are the Pisgah Fault, which transects the southwest portion of the project area, trending in a northwesterly direction, and the lava flows from Pisgah Crater. The Pisgah Fault is believed to be one of the many throughgoing northwest-trending strikeslip faults which are found in the region and exhibits substantial vertical separation in the project area, with the eastern side of the fault upthrown at least 700 feet relative to the western side of the fault. A second fault, designated Fault B, is a north-south trending fault in the northeastern portion of the project area which also exhibits at least 700 feet of vertical separation. A block of fine grained lacustrine sediments between the twofaults has been raised relative to the coarser-grained alluvial sediments to the cast and west. The central portion of the project area is covered by Recent olivine basalt flows from Pisgah Crater, which is located approximately two miles east of the site. The basalt flows roughly parallel to the fault*

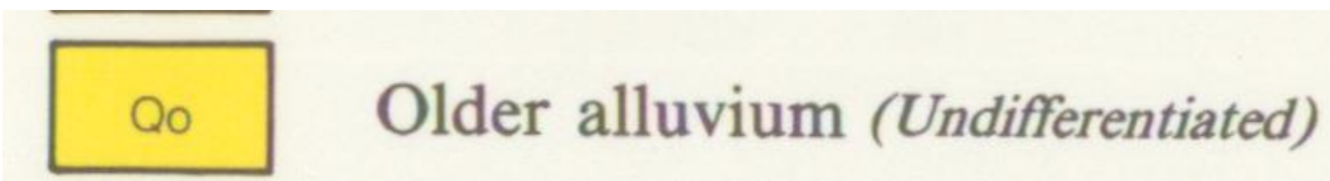
*immediately north of the west part of the project area. The project area east of the Pisgah Fault and west of Fault B lies within an area of thick fine-grained, predominantly lacustrine mudstones which appear to have ben uplifted a minimum of 700 feet along both faults, forming an uplifted block of lacustrine sediments that appear to be floored by an andesitic lava flow."* ( San Bernardino County, 1994, p. 3).

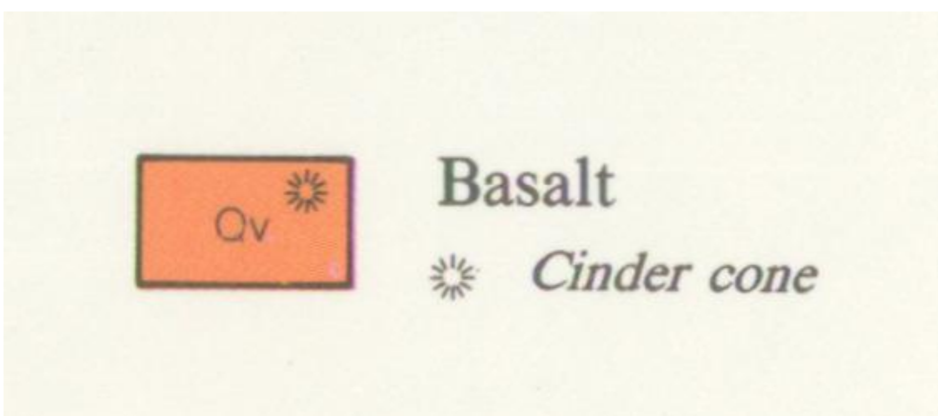
*"Boring logs have consistently demonstrated the presence of a clay layer beneath the evaporite/ mudstone body that surrounds and encloses the ore body. The lower clay layer appears to be underlain by volcanic sand and andesitic volcanic rock. The lower clay layer appears to be underlain by volcanic sand and andesitic volcanic rock. Exploratory drilling in the project area indicates that the ore body lies between approximately 1,000 and 1,000 feet bgs."* (San Bernardino County, 1994, p. 3).

*"Based on exploratory drilling logs provided by F C M C , the ore body is elongate in shape and trends northwesterly. The eastern margin of the ore body appears to be roughly linear, paralleling the Pisgah Fault which lies approximately one miles to the west. Based on the similarity of the trend, it appears possible that lacustrine sedimentation in the ore body area was controlled by a structural element paralleling the Pisgah Fault."* San Bernardino County, 1994, p. 3).
*"'The ore body consists of variable amounts of calcium borate (colemanite) within the mudstone. matrix. X-ray diffraction analysis of the ore body mineralogy indicated the presence of the evaporite minerals anhydrite, colemanite, celestite, and calcite. The mineralogy of the detrital sediments included quartz, illite, feldspars, and clinoptilolite, a zeolite mineral (Rooke, 1982)."* San Bernardino County, 1994, p. 3).

**GEOLOGIC MAPPING**
**1:250,000**

Bortugno and Spittler (1986) mapped the area of the Fort Cady Borate Project as undifferentiated Quaternary older alluvium (Qo). The solution mine site is near a contact with Quaternary basalt.



**1:100,000**

Phelps and others (2012) mapped the area of the Fort Cady Borate Project as Older intermediate alluvial fan deposits (Qiao) at processing plant site, Older young alluvial fan deposits (Qyao) at the solution mine site, and Older intermediate alluvial fan deposits  with partly covered substrate (Qiao/pc) at the ore deposit site).

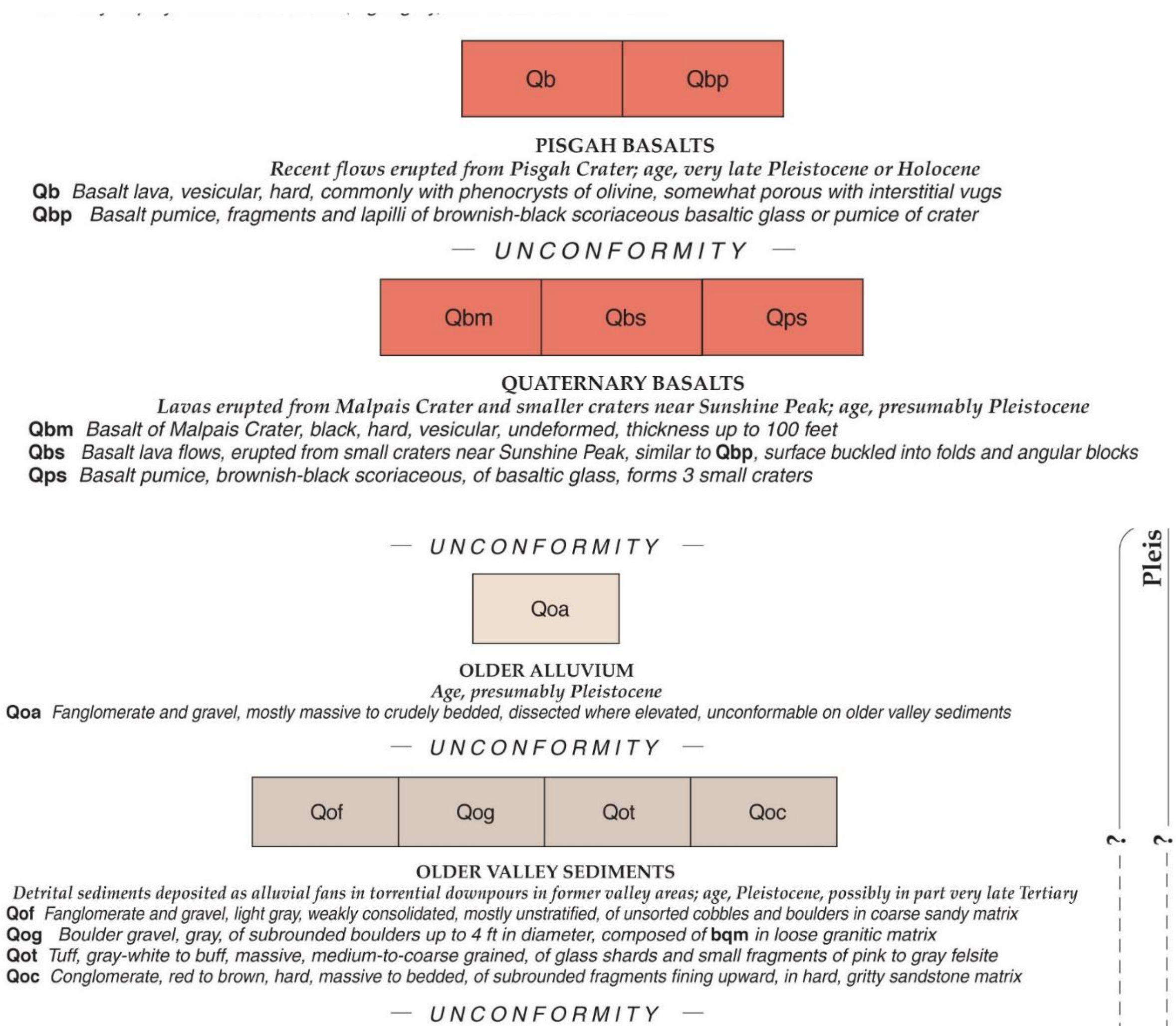
| | |
|---|---|
| Qiao | **Older intermediate alluvial fan deposits (late and middle Pleistocene)** |
| Qyao | **Older young alluvial fan deposits (early Holocene and latest Pleistocene)** |

**SUBSTRATE MATERIALS (PRE-QUATERNARY)**

| | |
|---|---|
| pc | **Partly consolidated sediments** |
| mv | **Intermediate to mafic volcanic rocks** |
| fv | **Felsic volcanic rocks** |
| mp | **Intermediate to mafic plutonic rocks** |
| fp | **Felsic plutonic rocks** |
| fpg | **Felsic plutonic rocks that weather to grus** |
| sl | **Siliciclastic rocks** |
| mr | **Metamorphic rocks** |
| ca | **Carbonate rocks** |

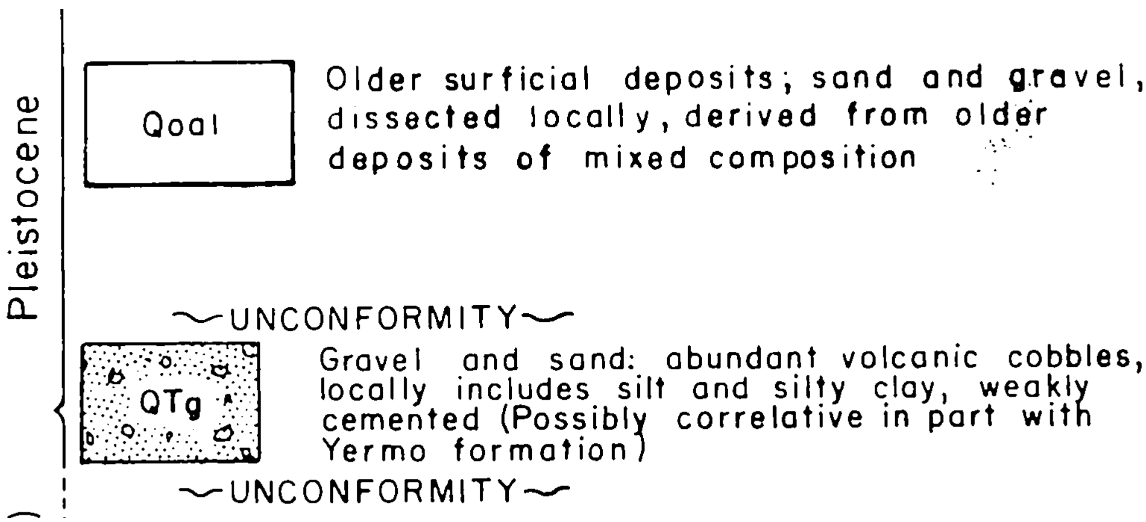
**1:62,500**

Dibblee and Minch (2008d, 2008e) mapped the area of the Fort Cady Borate Plant site as Older Alluvium (Qoa), the Solution Mine site at the contact of Older fan deposits (Qof) and Pisgah Basalt (Qb), and the Ore Deposit area as Quaternary Older Alluvium (Qoa).



**1:10,000**

Conrad (1957, 1958) mapped the Fort Cady Borate Plant site, the Solution Mine site and the Ore Deposit area as Quaternary-Tertiary gravel (QTg)




**DEVELOPMENT**

Duval Corporation  nitiated this project in the Early 1980'S. Duval developed, tested and patented a unique insitu solution mining and solar evaporation process for Colemanite. In this process, colemanite is converted to boric acid and calcium chloride while still (Information Service 1 PUB LIT https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10023265 accessed June 15, 2020)

Mountain States Mineral Enterprises of Tucson, Arizona, purchased property in 1986 (https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10023265 accessed June 15, 2020 ).

In May, 1990, Corona Corporation was in the process of transferring ownership of Fort Cady Minerals to Avalon Corporation, a NYSE-listed oil and gas company. As of May, 1990, 35% of detailed construction engineering work was completed and mining and reclamation plans were about to be submitted for permitting (https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10023265 accessed June 15, 2020)..

Project management was awarded to Kilbourne International Construction for a 82,000 Ton/Year Plant that would cover an area of 155 ha. This is the largest known colemanite deposit in the United States. It was scheduled for opening in 1990 (https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10023265; https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10023265 both accessed June 15, 2020).

The deposit has the following ore reserve data:

| | |
|---|---|
| Ore Tons | 147,435,000 |
| Grade: | 6.4% $B_20_3$ |
| $B_2O_3$ Tons | 9,393,000 |

(San Bernardino County, 1994, Section 1.1.5 Land Holding Status, p. 4

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**MAPS**

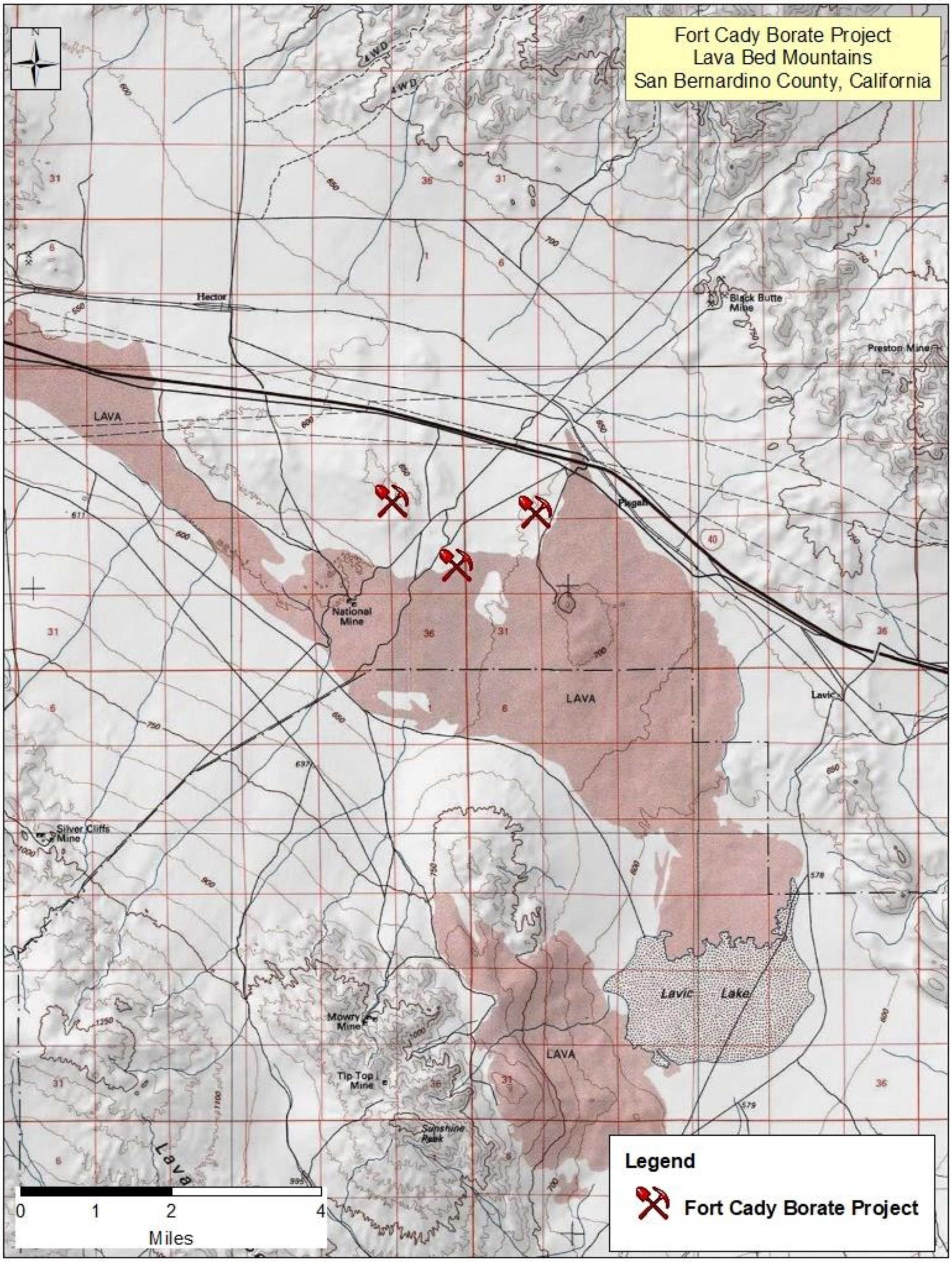


*Figure 1. Regional topographic map of the Fort Cady Borate Project and surrounding area.*

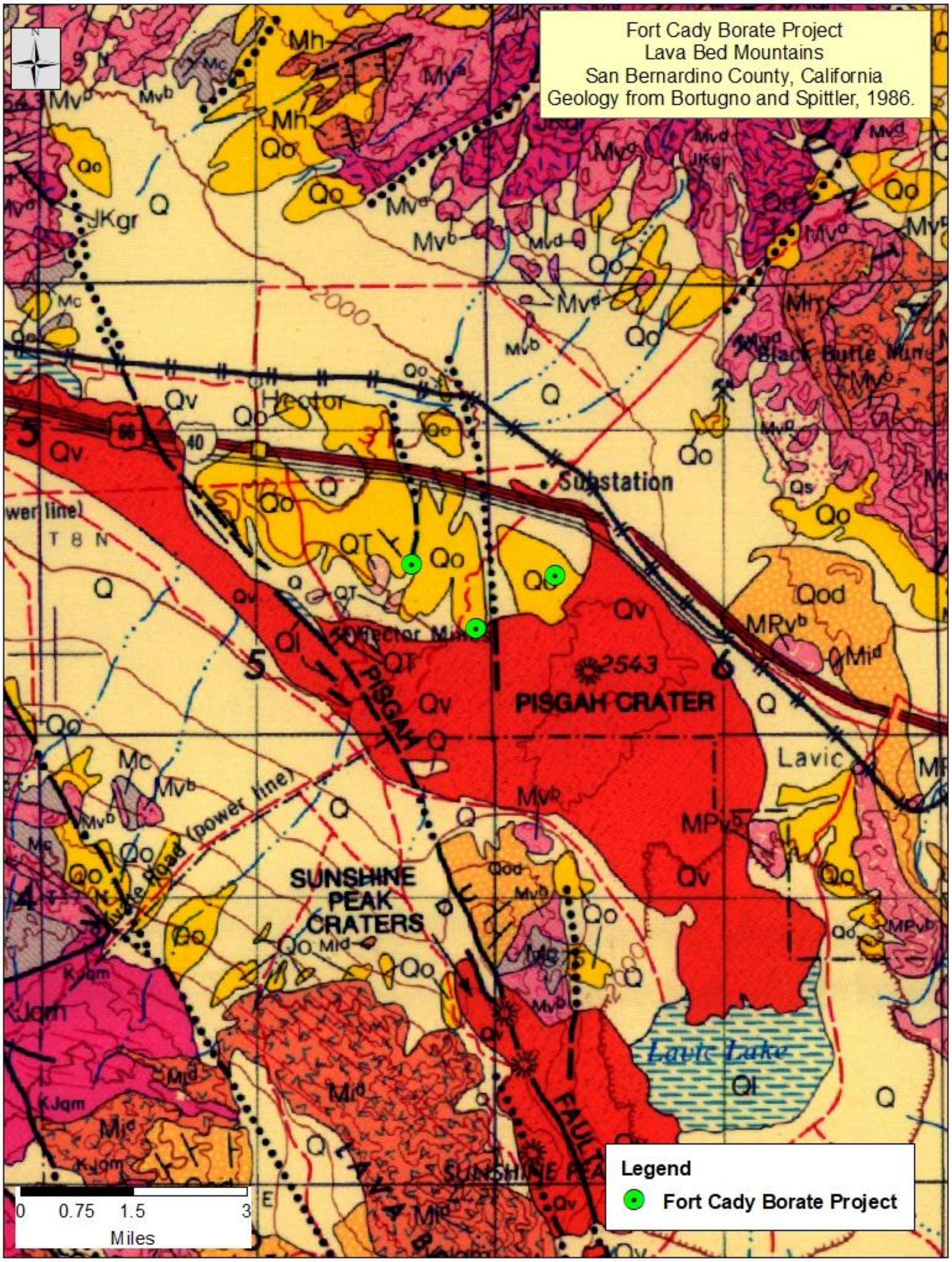


*Figure 2. Regional geological map of the Fort Cady Borate Project and surrounding area. From Bortungno and Spittler, 1986.*

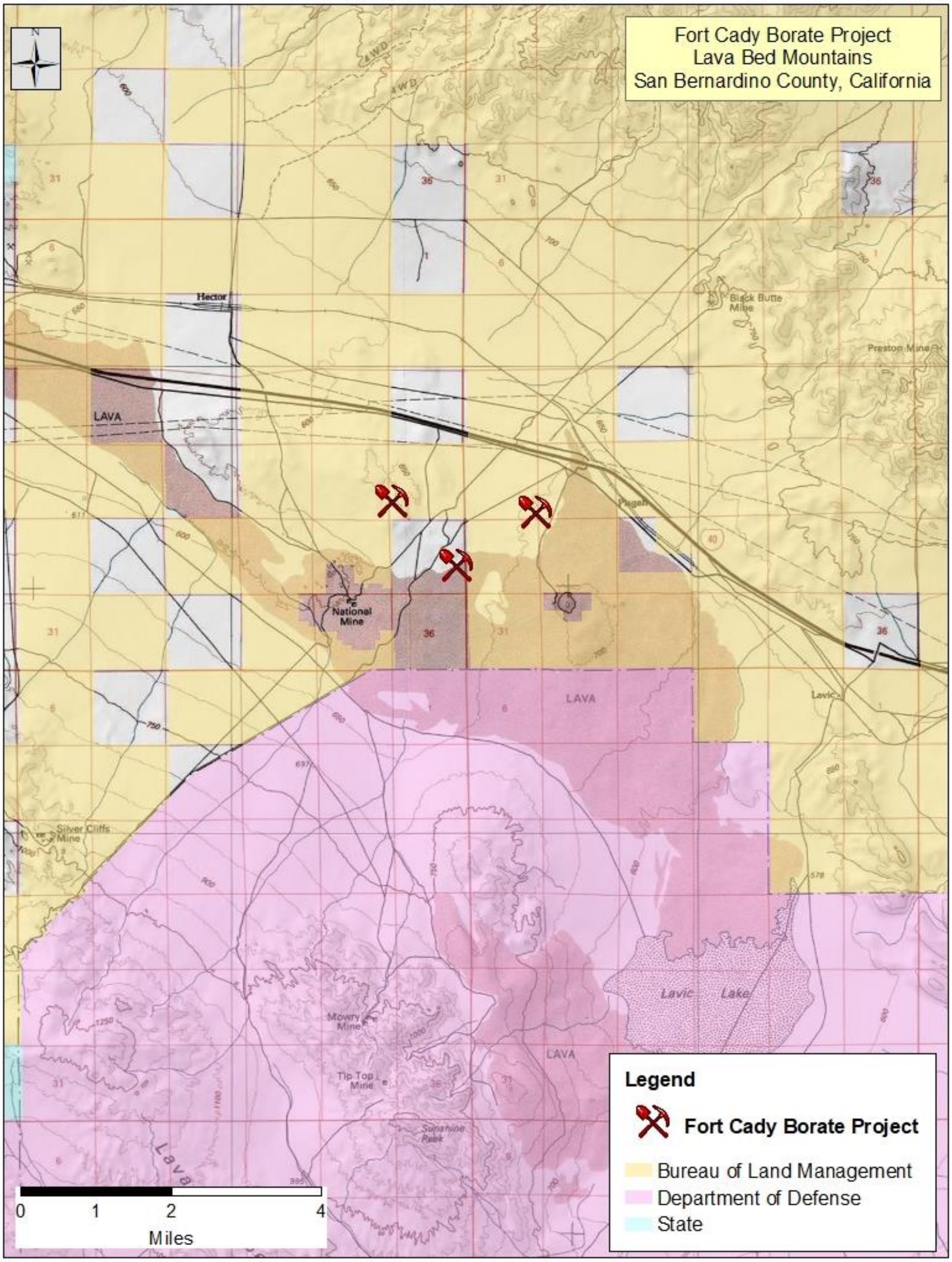


*Figure 3. Land status map for the Fort Cady Borate Project and surrounding areas.*

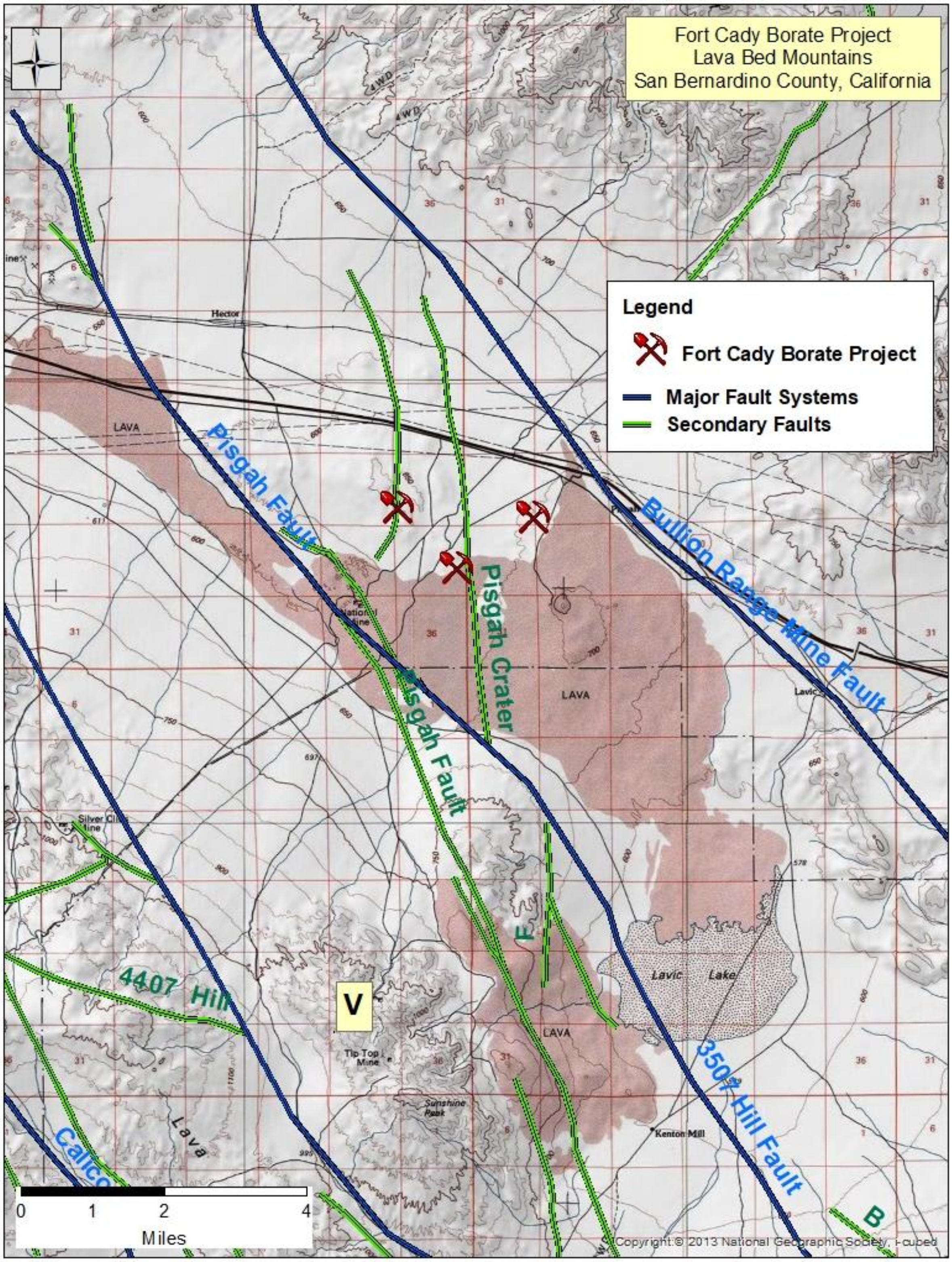


*Figure 4. Faults of the Fort Cady Borate Project and surrounding areas.*

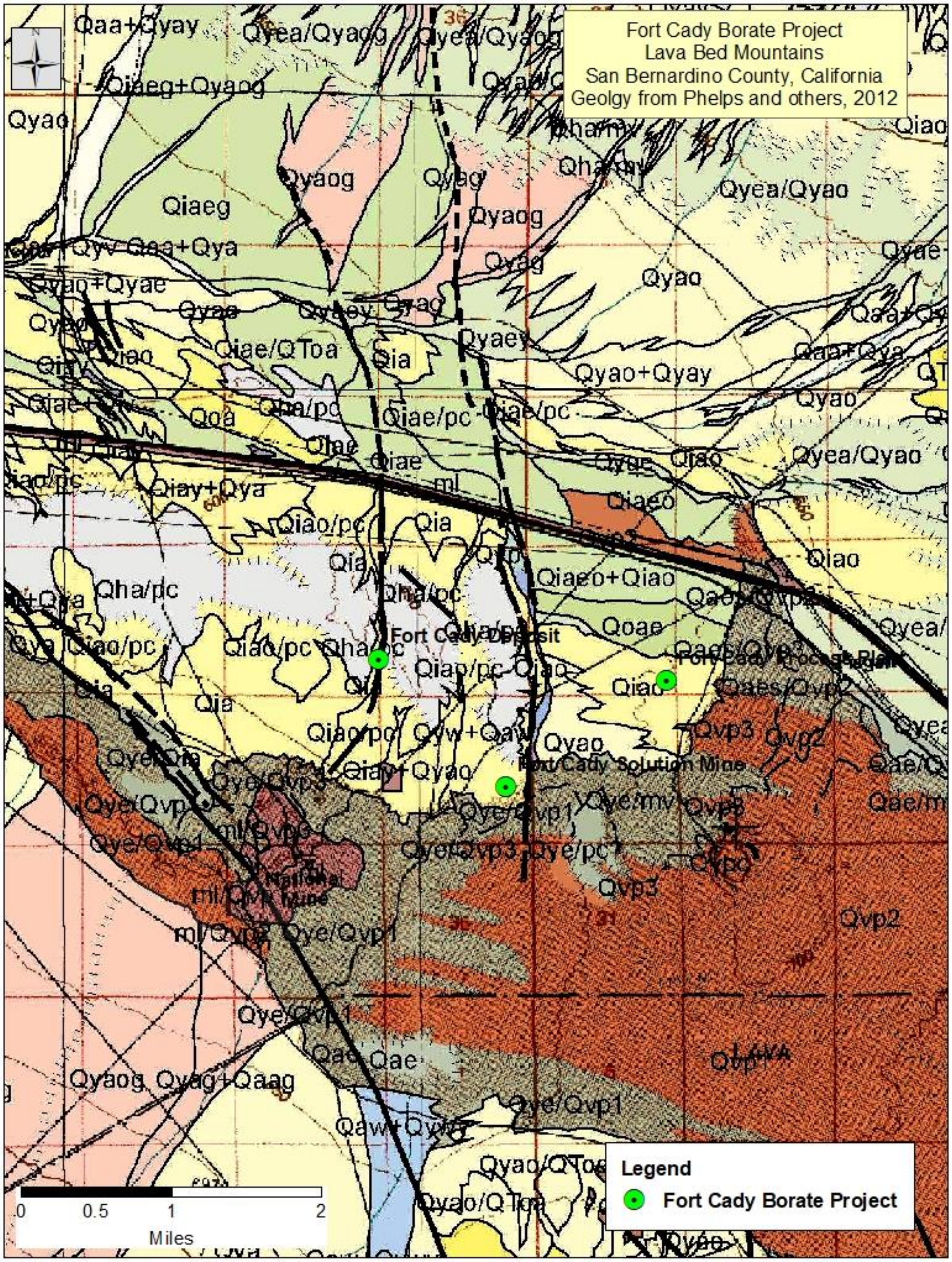


*Figure 5. Regional geological map of the Fort Cady Borate Project and surrounding area. From Phelps and others, 2012.*

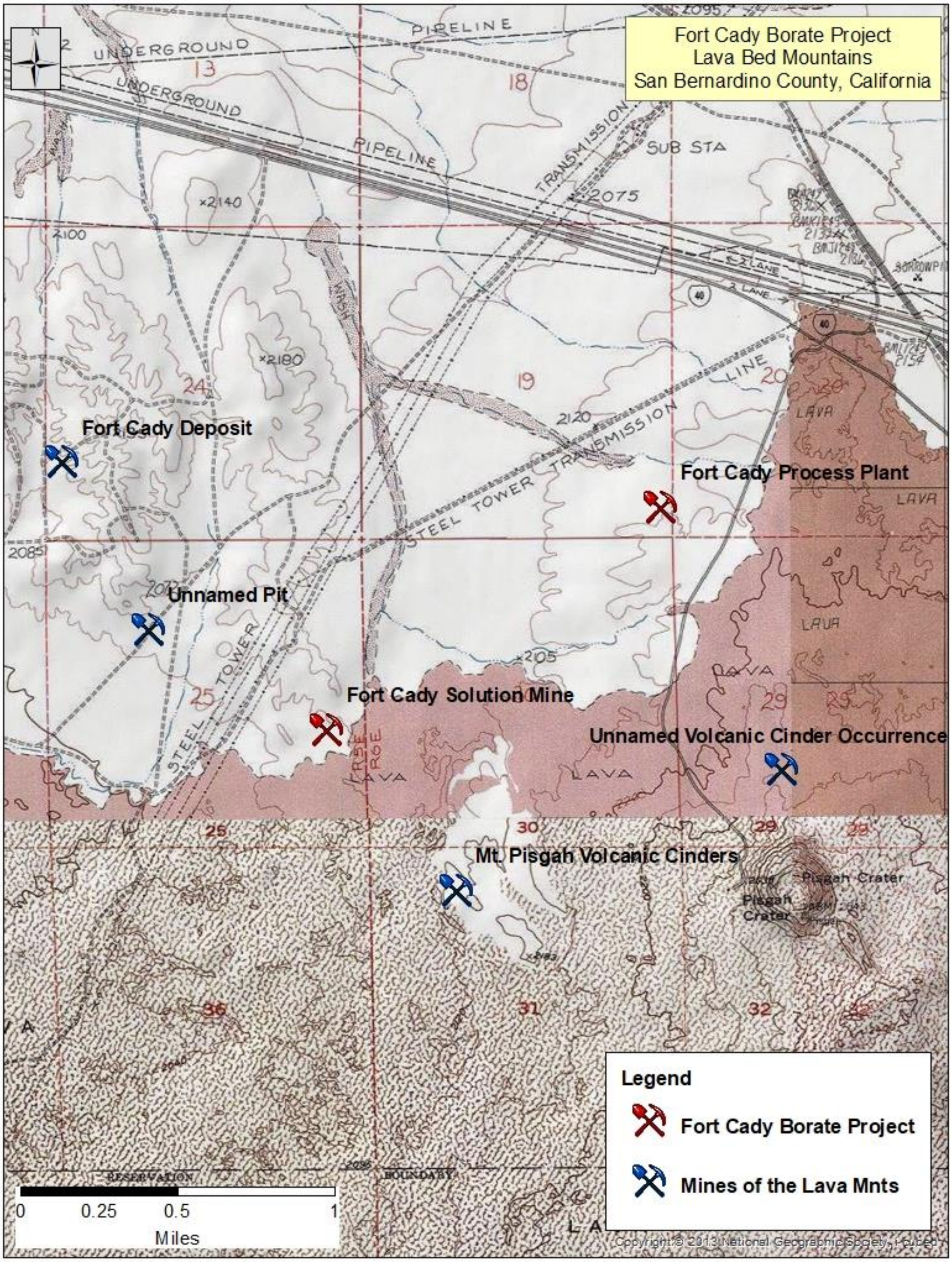


*Figure 6. Topographic map of the Fort Cady Borate Project and other mines in the Lava Bed Mountains. Scald 1:24,000.*

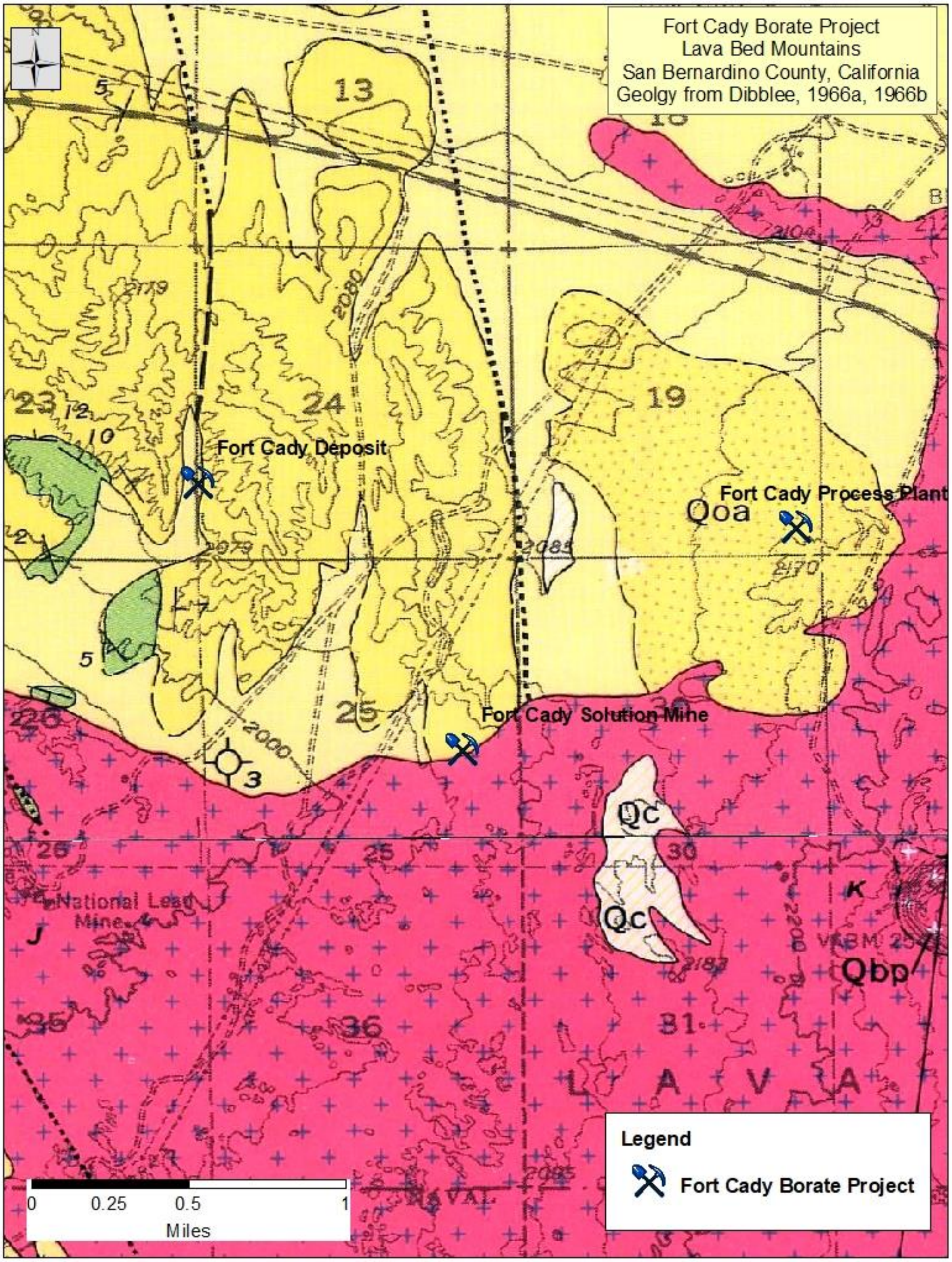


*Figure 7. Area geological map of the Fort Cady Borate Project and surrounding area. From Dibblee, 1994a, 1966a.*

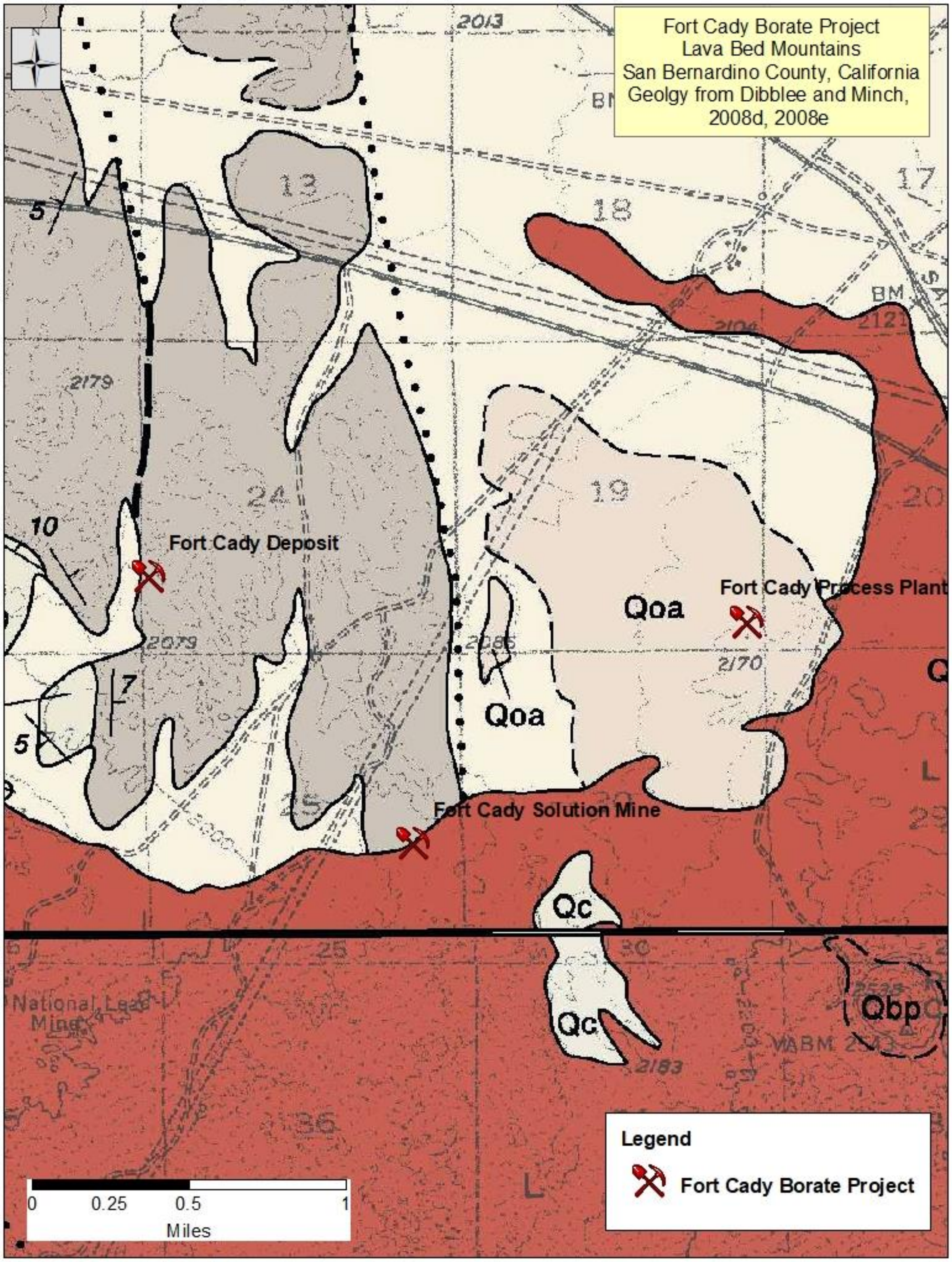


*Figure 8. Area geologic map of the Fort Cady Borate Project. From Dibblee and Minch, 2008d.*

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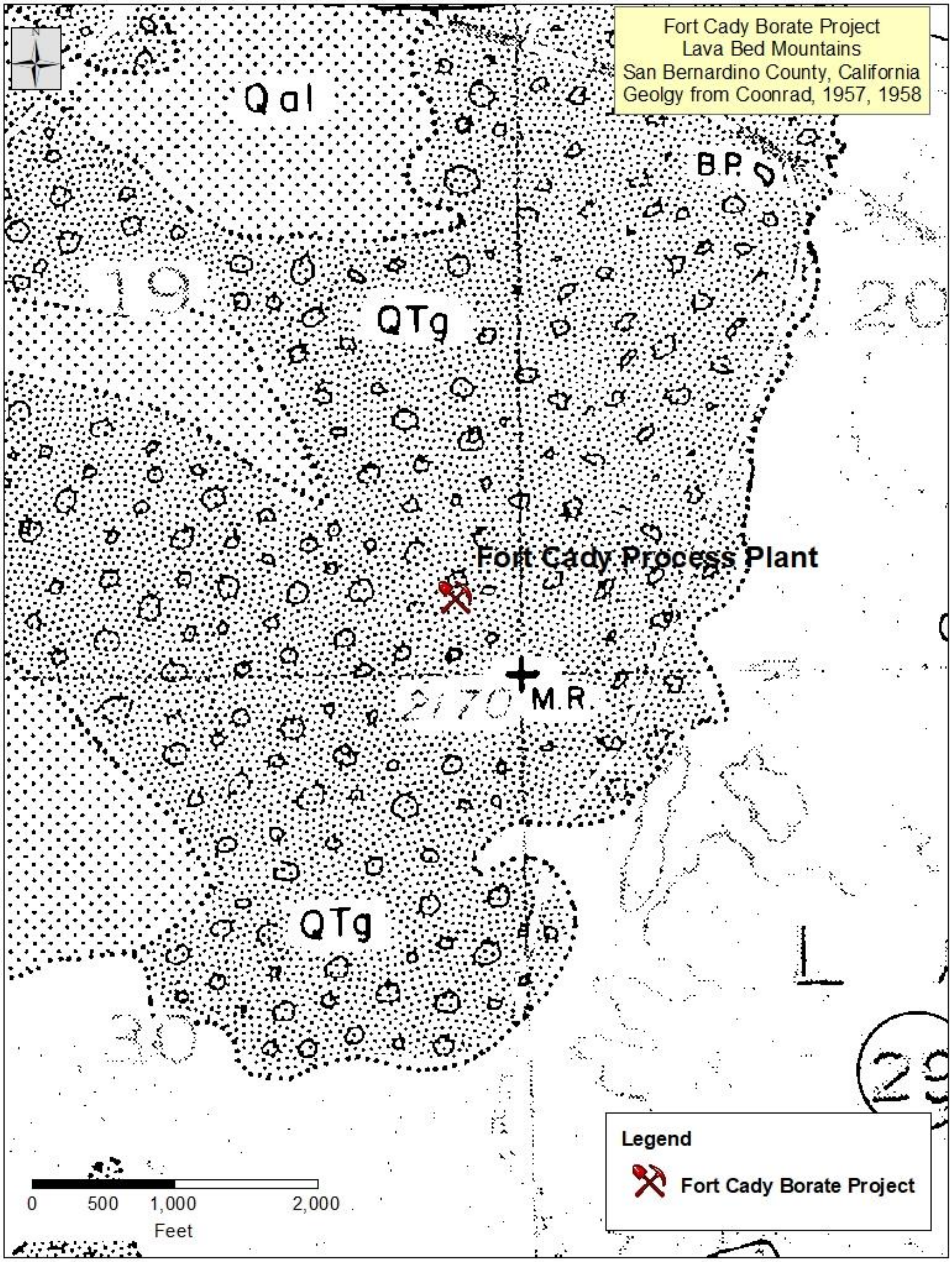


*Figure 9. Geologic map of the Fort Cady Borate Processing Plant Site. Scale 1:10,000. From Coonrad 1957-1958*

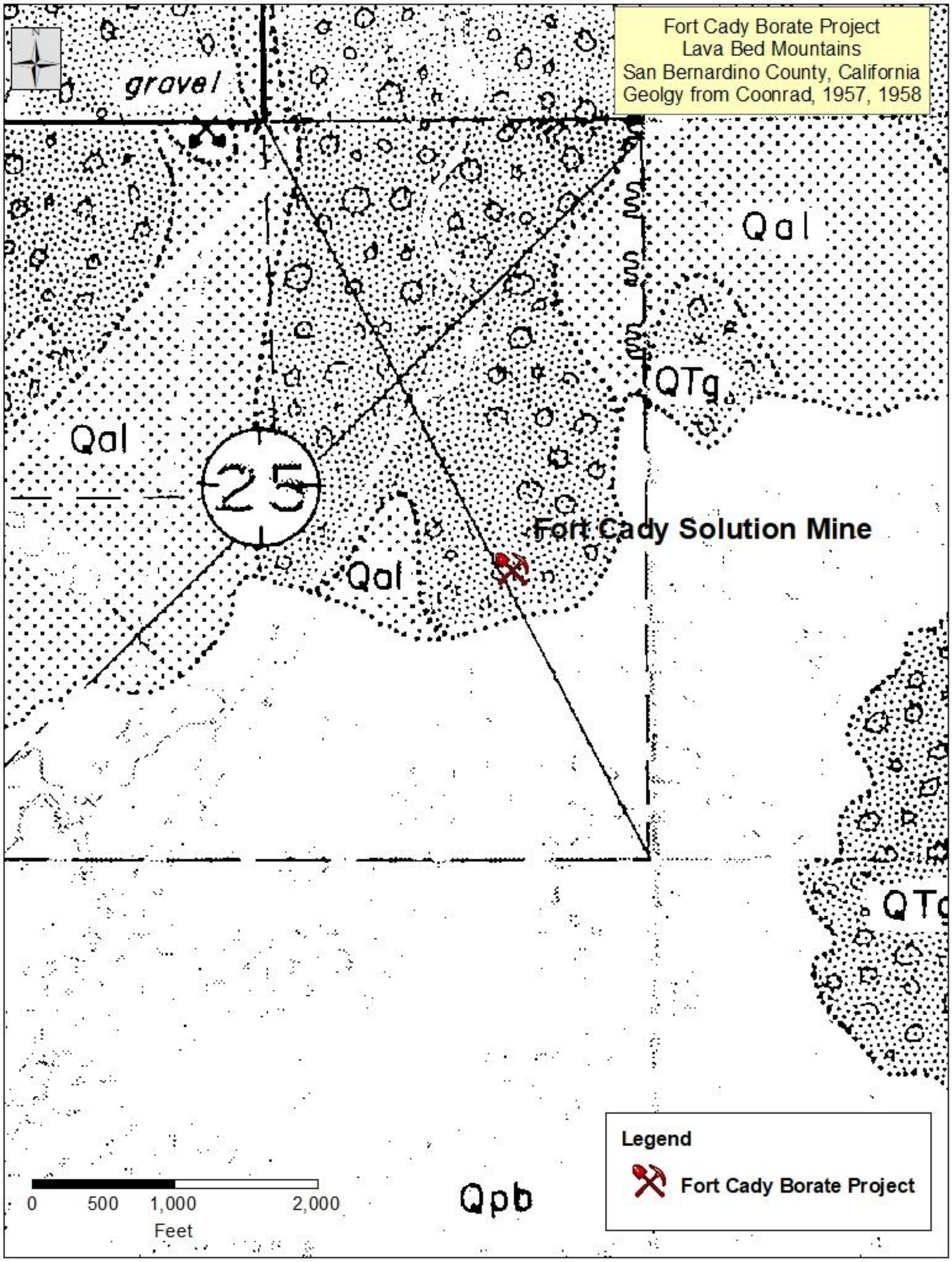


*Figure 10. Geologic map of the Fort Cady Borate Solution Minet Site. Scale 1:10,000, From Coonrad, 1957-1958*

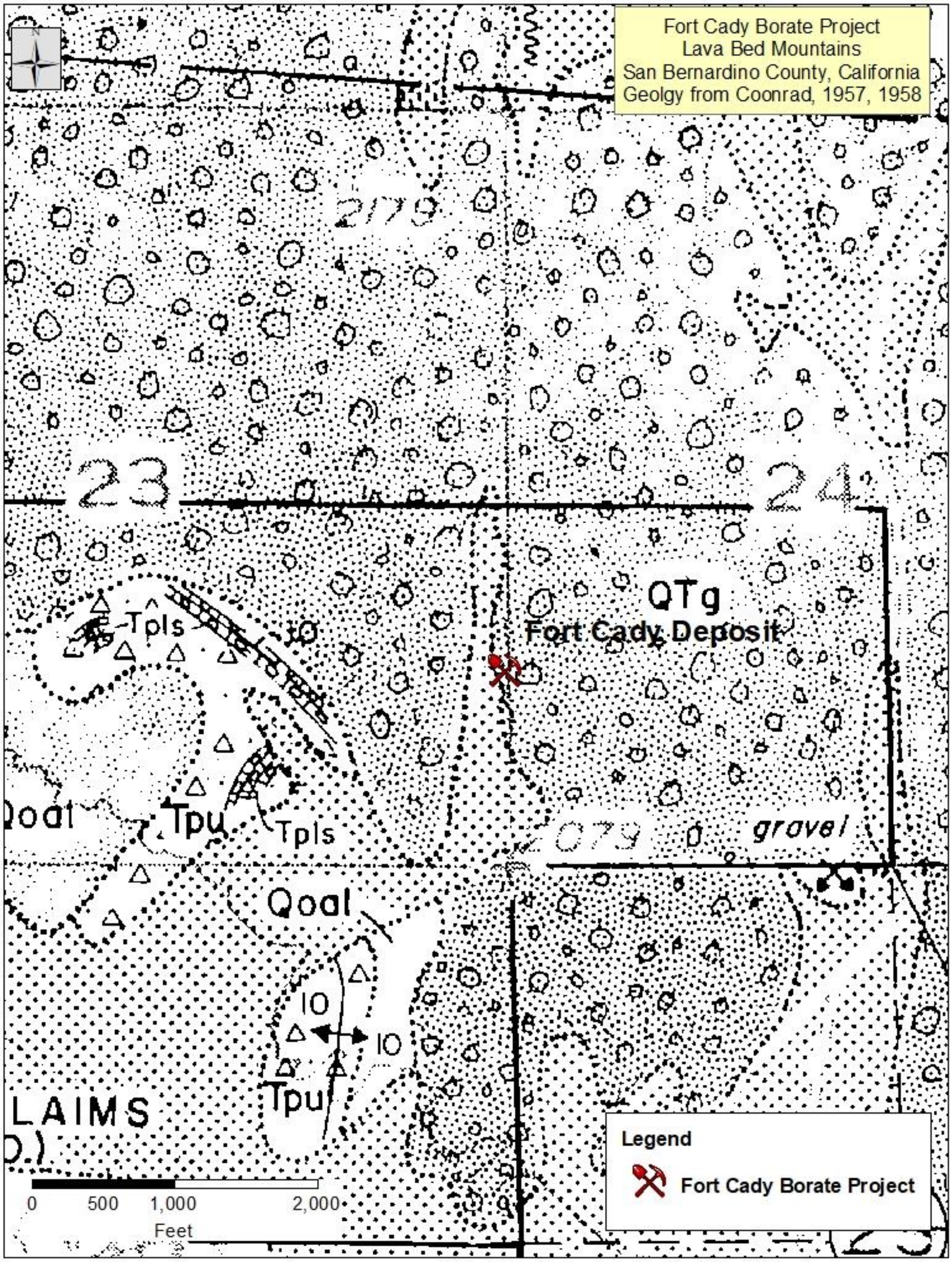


*Figure 11 Geologic map of the Fort Cady Borate Deposit Site. Scale 1:10,000. From Coonrad 1957-1958*

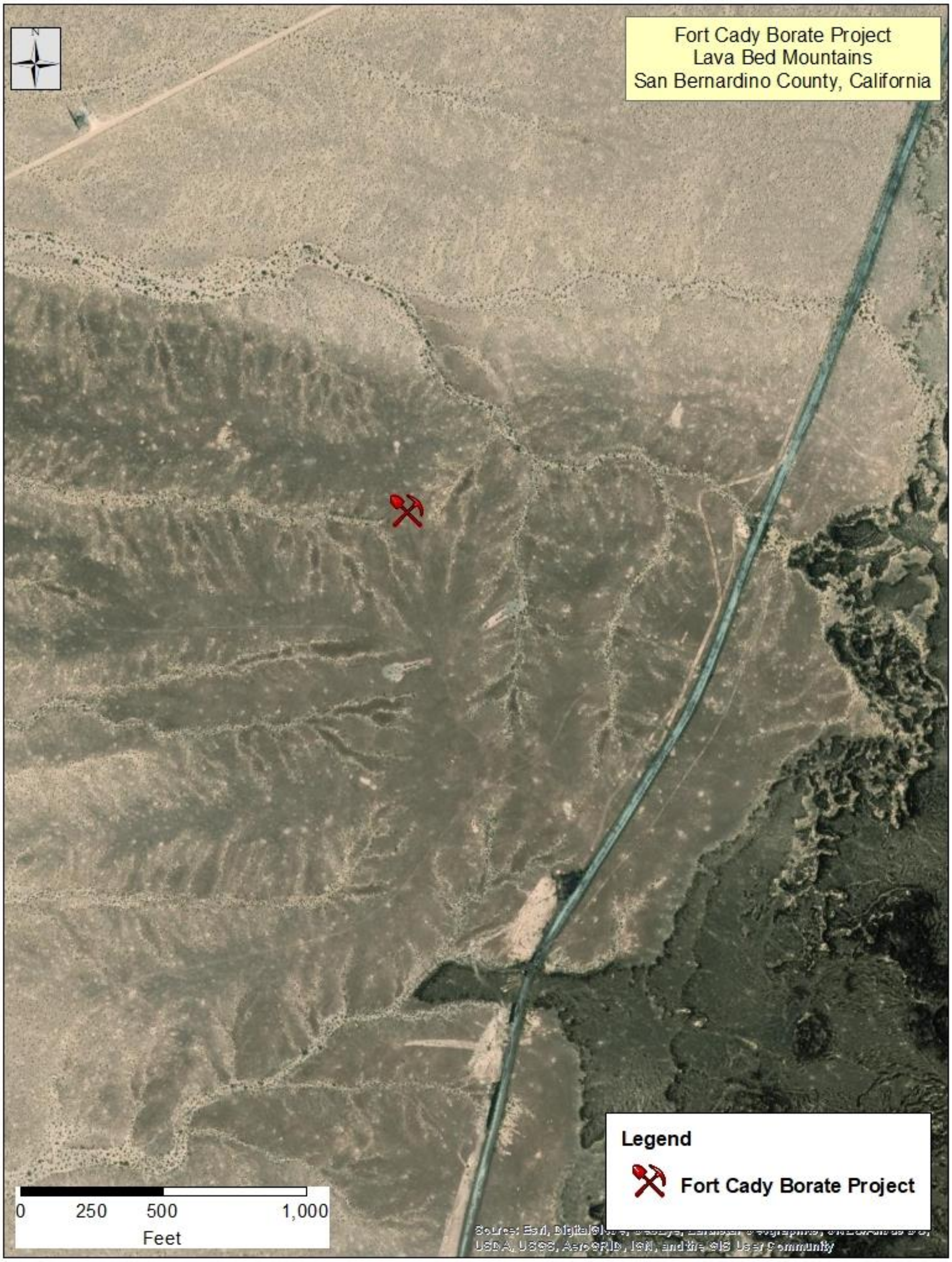


*Figure 12. Aerial photograph of the Fort Cady Borate Processing Plant site. From ESRI*

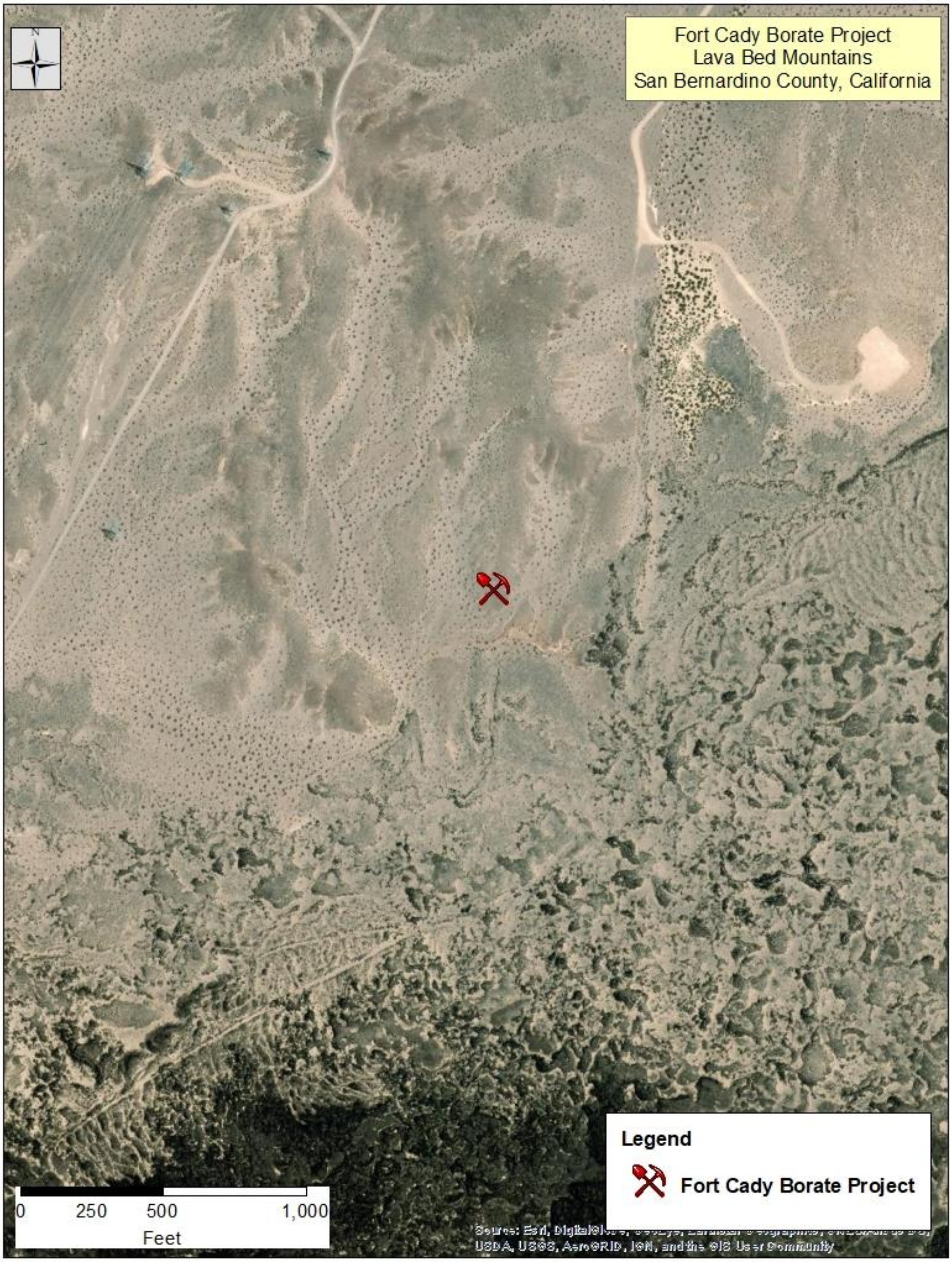


*Figure 13. Aerial photograph of the Fort Cady Borate Solution Mine site. From ESRI*


*Figure 14. Aerial photograph of the Fort Cady Borate Deposit site. From ESRI*

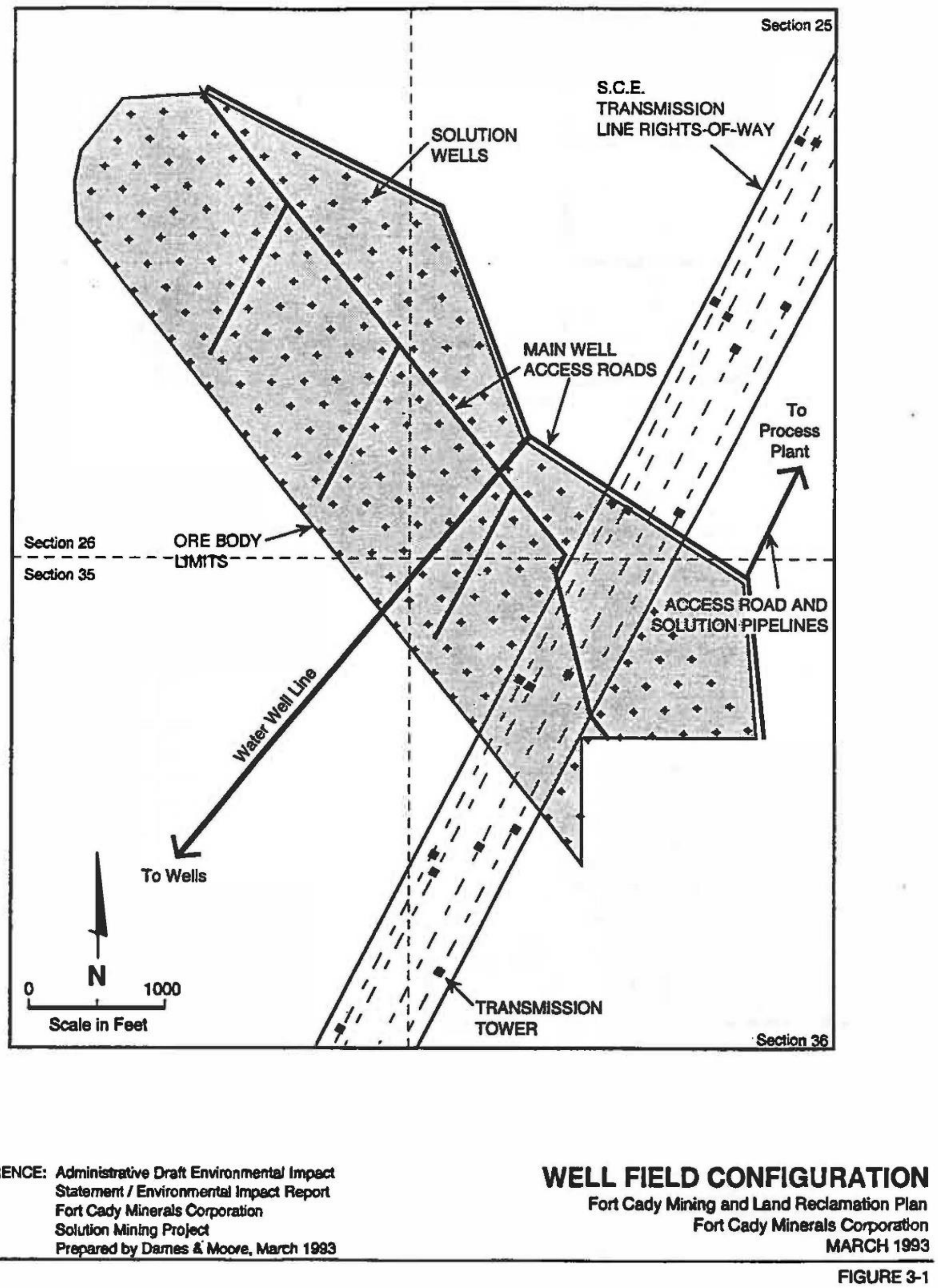


*Figure 15. Proposed well field for Fort Cady Minerals Corporation Borate project. From San Bernardino County, 1994.*