STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES AND GEOLOGY

# HOLDEN TAILINGS

By

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By Gerald W. Thorsen

## INTRODUCTION

### Purpose and Scope

The Division of Mines and Geology of the Department of Natural Resources has long supported the concept of "multiple use." Basic to this concept is the need to minimize the long-term detrimental effects of mining so as to not unnecessarily hinder subsequent uses of the land. The purpose of this study was to investigate the basis for public concern regarding the mill tailings piles left at Holden, Washington after the closing of the copper mine there. This concern has ranged from casual comments by hikers about the appearance of the tailings to published statements such as:

> ".... at the Holden mine where the tailings dump has killed the surrounding vegetation and all the fish in the creek and is now starting to pollute Lake Chelan." (THE MOUNTAINEER, April 1967, p. 12).
>
> "Hopefully, toxic chemicals will be slowly leached out and the piles of loose debris overgrown before floods send masses of orange mud down to Lake Chelan." (Routes and Rocks, Crowder, D. F. and Tabor, R. W., 1965, p. 188).

I spent two days in June 1967 examining the tailings area. This examination consisted of inspection by walking around and across the piles, taking photographs of various locations of interest, digging shallow exploratory holes with a shovel, and taking samples for further study. A limited amount of soil testing was done on these samples by the Washington State Department of Highways.

A brief summary of the milling process as well as a description of the waste tailings themselves and their method of disposal are included in this report with the hope that these details may help the engineer, forester, or biologist not familiar with ore milling to deal with his particular aspect of the problem.

## History of Holden

In 1887 the Great Northern Railway was exploring possible routes across the Cascade Mountains. A route location engineer, Major A. B. Rogers, noticed abundant iron staining on the rocks about 14 miles up a stream, now known as Railroad Creek. On his return to Seattle, he mentioned this to the Denny family, who grubstaked a prospector to examine the area. The prospector, J. H. Holden, staked the first group of claims in 1892.

Numerous unsuccessful attempts to develop a producing mine were made over a period of many years, both by stock groups and major mining companies. In 1938, the Chelan Division of the Howe Sound Company began production from the property. From that time until the closing of the mine in 1957, a total of $66.5 million worth of copper, gold, zinc, and silver was produced from approximately 10.6 million tons of ore. At times, close to 500 employees worked to produce and concentrate as much as 2,000 tons of ore a day.

In April 1961 the 15 patented claims were given to the Lutheran Bible Institute of Seattle and were later transferred to Holden Village Incorporated. The latter organization maintains the Holden townsite and runs it as a camp for religious groups of all denominations. The area used for tailings disposal, under "special use permit," reverted back to the U.S. Forest Service after abandonment of the operation.

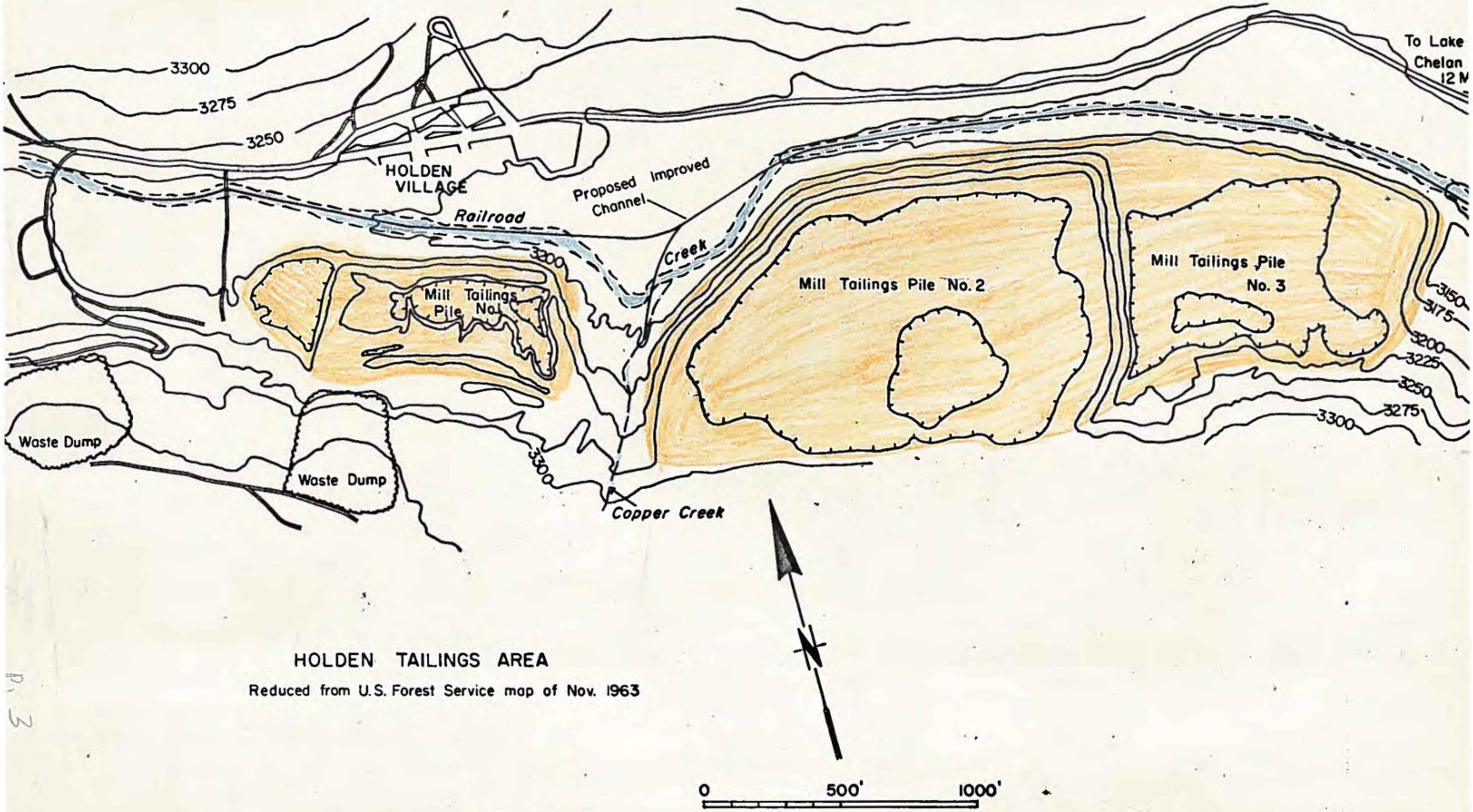
## Setting

The mine, tailings, and townsite of Holden lie about seven miles east of the Cascade Crest on the floor of the steep-sided valley of Railroad Creek. The elevation is 3,200 feet, with peaks of more than 8,000 feet common within a 5-mile radius. Precipitation at Holden ranges from 19 to 45 inches, with a mean of 35 inches, and includes a mean snowfall of approximately 25 feet.

The area is reached by boat from Chelan, to the settlement of Lucerne, a distance of about 40 miles. It is another 11 miles by narrow gravel road from Lucerne to Holden.

The tailings disposal site is located on Federal land, along the south bank of Railroad Creek downstream from the mine area (see map, Fig. 1, and photo No. 1). Over an area of 80 acres, approximately 8 million tons of mill tailings are spread to a maximum depth of about 130 feet.

Setting



HOLDEN TAILINGS AREA

Reduced from U.S. Forest Service map of Nov. 1963

p. 3

Figure 1

Photo No. 1.—Mill tailings pile number 1 with mine dumps in background, looking west, up valley of Railroad Creek. This pile was partially hydrauliced (1947), remilled, and pumped underground as sand fill. This operation was apparently responsible for presence of tailings in the creek bank as no such condition exists along the other tailings piles.

Oxidation of iron sulfide minerals has cemented the particles at the surface of the tailings piles to a depth of at least 10 inches and stained them an orangish-brown color (see photo No. 1). While this cemented material is quite erosion resistant, accumulation of windblown material has built up over the years on the lee sides of the piles (see photos 1, 2, and 4).

A small pond is present on tailings area 2 and more than one-fourth the surface of area 3 is covered by a pond. These ponds, accumulating on the gently dished surfaces of the tailings, occupy sites similar to the original settling ponds. They appear to be fed largely by small streams from the hillsides above and drain through the central drainage system around which the tailings were built (see "Construction of tailings").

Photo No. 2.—East face of tailings pile number 2 viewed from surface of pile number 3. Bank is about 75 feet high. Note wind deposited material at angle of repose on this lee slope. Note also the willows and unidentified brush rooted in talus material used as diking near upper level of the dike. Thimble berry and a few conifers are present at this same level on the other side of the pile.

## Froth Flotation Milling Process

The following description of the froth flotation treatment of ores to produce concentrates for shipment to a smelter briefly outlines the procedure used at Holden.

To free the metallic sulfide minerals from the enclosing silicate mineral wall rocks, the ore is crushed and ground until 65 percent of it is small enough to pass through a 200-mesh screen (openings of 0.003 inch, or about the size limit between very fine sand and silt). The finely ground rock, now largely a mixture of mineral fragments, comes out of the grinding stage in the form of a very thin mud. This mud is treated with various chemicals and is agitated in tanks with beaters as compressed air raises through the mixture in the form of fine bubbles. Some of the chemicals added are attracted to the metallic minerals but not to the worthless non-metallic minerals. The metallic minerals, coated with this chemically induced water-repellant film, are attracted to the rising air bubbles which carry them to the surface of the tank. Here, they collect in a muddy-looking froth that is skimmed off.

Further chemical treatment and repetition of the "froth flotation" operation is used to separate the various metallic minerals from each other by floating one while depressing the other. The froth is filtered of excess water and the metallic sulfide mineral concentrate at this stage looks like a heavy damp silt. This concentrate is shipped to the smelter for treatment to separate the valuable metals from the sulfur and other waste materials. The bulk of crushed rock in the flotation operation does not float but remains in suspension and is pumped out of the bottom of the tanks, through a long pipeline and into large outdoor settling ponds.

The handling of this waste material or tailings from the mill at Holden is discussed under "Construction of the tailing piles."

## Construction of the Tailings Piles *

The disposal of flotation mill tailings resolves basically into a problem of moving (in a slurry form) the finely ground waste rock to a site large enough to permanently store it and there separating the solids from the waste water by settling and decantation. To maintain the settling pond on top of the ever-heightening tailings disposal site it is necessary to continuously build up both the peripheral confining dike and the central drainage system.

Initial preparation of the tailing storage areas at Holden consisted of building an earthern-toe dam around the site about 8 feet high and 10 feet wide at the top, clearing any marketable timber, and constructing central vertical concrete overflow weirs connected by 12-inch steel essentially horizontal drainage pipes to a point outside the tailings storage site. These drainage pipes were covered with 3 to 4 feet of loose earth to prevent their floating during initial tailings deposition.

The concrete weirs or risers are 2 feet by 2 feet 9 inches in cross section and from 10 to 20 feet high. They were initially open on one side for their full height, with this side being "boarded up" with 6 X 6's to regulate the depth of pond water as the tailings built up. The weirs are connected with each other by 10-inch spiral-weld pipe with Victaulic couplings. Before a lower weir was buried by tailings, it was capped by a 3/8-inch steel plate upon which 4 inches of concrete was poured. Thus, tailings pile number 2, the highest, probably has at least 7 concrete risers connected by as many horizontal steel pipes conducting water from the pond on its surface.

* Most details are from Zanadvoroff, 1946.

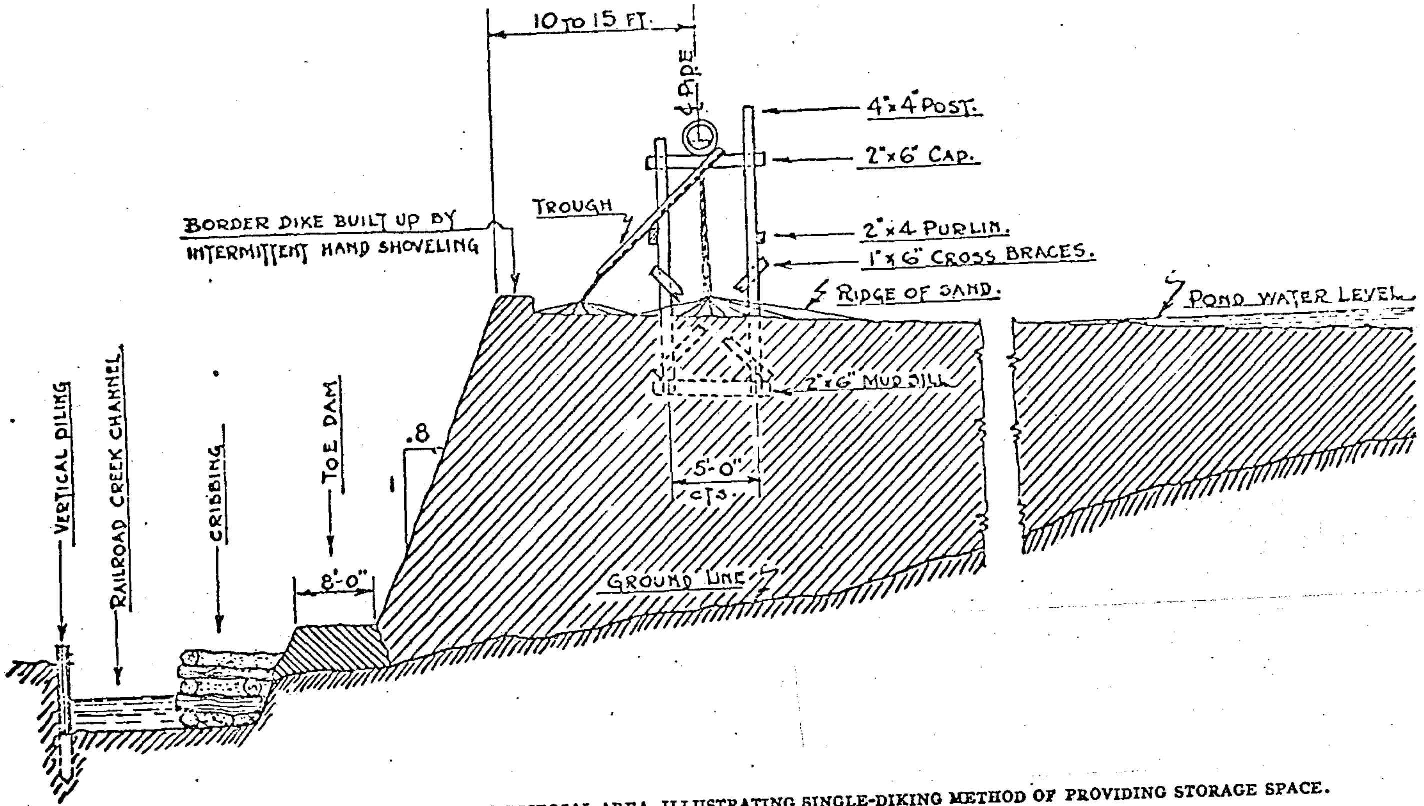


FIG. 2.—IDEALIZED SECTION OF TAILING-DISPOSAL AREA, ILLUSTRATING SINGLE-DIKING METHOD OF PROVIDING STORAGE SPACE.

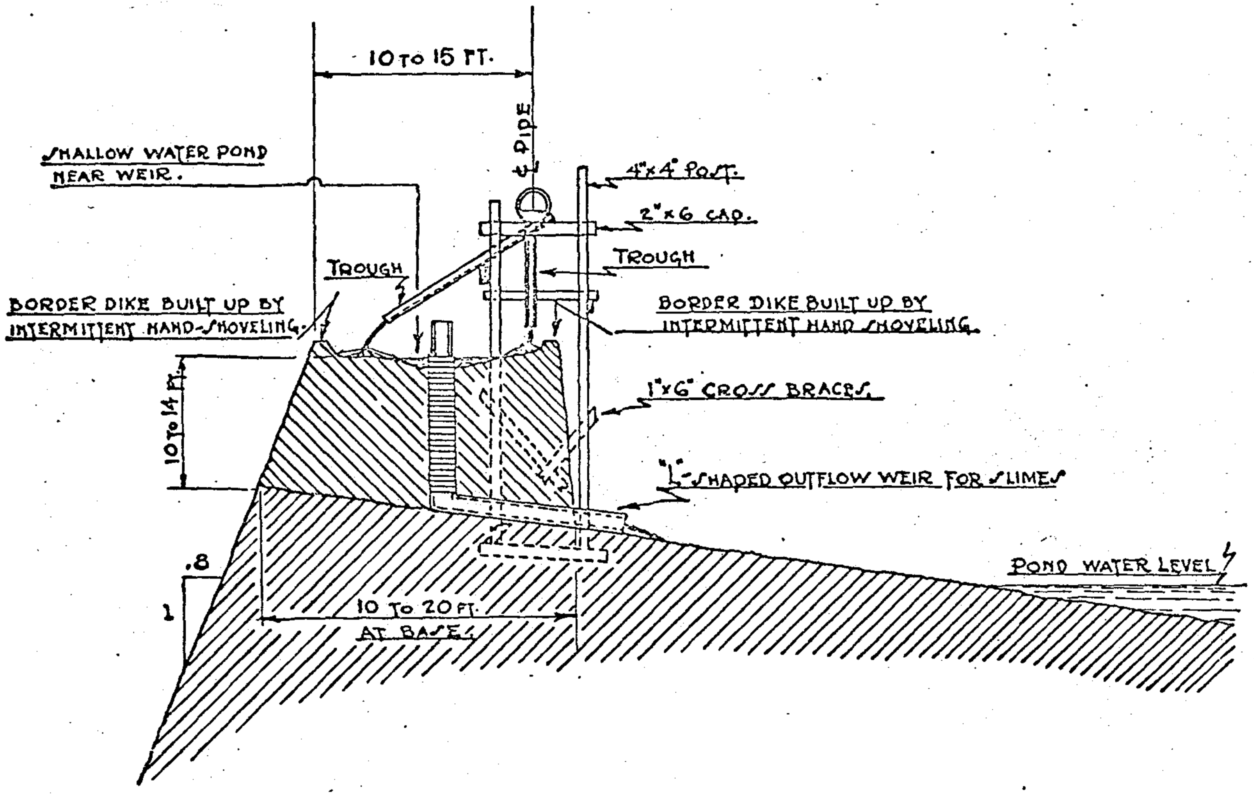


FIG. 3.—IDEALIZED SECTION OF TAILING-DISPOSAL AREA, ILLUSTRATING DOUBLE-DIKING METHOD OF PROVIDING STORAGE SPACE.

Reproduced from: Disposal of Mill Tailings at the Holden Concentrator, by V. A. Zanadvoroff, A.I.M.E. Transactions, v. 169, 1946, 686-693.

The dikes that maintained the central settling pond, drained by these risers, were built as shown in Figures 2 and 3. The double dike method (Fig. 2) was used to provide extra storage capacity over the winter when it was impossible to build dikes due to the heavy snowfall. Most of the diking was done with "thickened" tailings from which the bulk of the extreme fine mud-size particles were removed (see Physical Characteristics). This enabled construction of a stable dike at slopes averaging 0.8 to 1 or about 52 degrees (Zanadvoroff, p. 690).

During the later stages of use of tailings pile number 2 a dike of bouldery soil (apparently about 10 feet high) was used (see Photo 2). Above this level tailings were again used, but this latter dike appears to have been built by dozing the tailings into a peripheral ridge rather than by the conventional construction previously described.

## NATURE OF THE TAILINGS

### Physical Characteristics

A report on the disposal of mill tailings at the Holden concentrator was made by Zanadvoroff (1946) during the time the mill was in operation.

Zanadvoroff (1946, p. 690) shows the size distribution of Holden tailings particles to be as follows:

| | Percent |
|---|---|
| +100 mesh (> 0.0058 inch) ........ | 8.0 |
| +200 mesh (>0.0029 inch) ........ | 26.9 |
| +325 mesh (> 0.0017 inch) ........ | 13.5 |
| -325 mesh (< .0017 inch) ........ | 51.6 |
| | 100.0 |

The Holden mill tailings were treated to remove most of the extreme fines (or "slimes" to the extractive metallurgist). The remaining coarser material, which was used for most of the dike construction, was of the following size distribution:

| | Percent |
|---|---|
| +100 mesh ...................... | 11.8 |
| +200 mesh ...................... | 47.6 |
| +325 mesh ...................... | 17.3 |
| -325 mesh ...................... | 23.3 |
| | 60.0 |

The other 40 percent of the tailings were 93.6 percent minus 325 mesh (smaller than 0.0017 inch in diameter).*

The iron sulfide minerals pyrite and pyrrhotite, being hard and brittle, break readily into fine particles. It is these minerals in a finely ground state that make up much of the black pigmentation in the finest grained layers of the unoxidized tailings (see Photo 3). The thicker (as much as 2 inches) layers are light gray and are made up largely of coarser silicate particles.

Photo No. 3.—Test pit dug 4 feet into tailings pile number 2 approximately 20 feet from a small central pond. The finer grained dark layers showed the glisten of surface moisture characteristic of "fat" clays but no water accumulated in the hole after 18 hours. The oxidized layer is about 10 inches thick. Note that there are no loose fines on the tailings surface but a "desert pavement" of iron oxide cemented chips.

* The bulk of this material settled out in the central ponds.

Photo No. 4. — East edge of tailings pile number 1 (photo is "off-color"). This picture shows the relative resistance to erosion of undisturbed oxidized tailings compared to wind deposited tailings. Culvert discharging stream of about 3 square inches in cross section falling 4 feet onto sloping surface of stratified tailings. Note the relatively minor erosion considering that this stream has apparently flowed, at least intermittently, for at least 20 years. No turbidity noticeable in the runoff.

When oxidized the sulfides present cement adjacent particles together with iron oxide. Fragments of this cemented material require considerable pressure to crush with the fingers and thus could be considered to have medium "dry strength" (Earth Manual, 1963, p. 391). The oxidized dike material is practically impossible to penetrate with a shovel and must be first picked to loosen. In climbing the faces of the tailings piles, it was impossible to "kick" steps but instead they had to be hacked with a pick. The effectiveness of this cementation is shown in Photo 4. Walking on "oxidized in place" material, even where underwater, had little effect on it. Wind-deposited oxidized tailings, however, were found to have practically no strength where saturated. Apparently once disturbed the oxidized grains will not bond again and are easily eroded by the wind. This wind-blown material was present only as a veneer on the lee sides of the tailings piles (Photos 1, 2, and 4) and as collars as much as a foot or so thick around the central settling ponds where moisture has stabilized the wind-blown material.

A test hole dug near the center of tailings pile number 2, about 20 feet west of a pond, was started in oxidized material but encountered unoxidized tailings within 10 inches of the surface (Photo 1). The damp unoxidized material in this hole stood up well in a 4-foot vertical face. Despite the nearness of the pond, there was no seepage into the test pit after 18 hours. This may have been due to partial sealing of the pond by wind-blown fines rather than being a true indication of lateral permeability. The tailings in the lower foot or so of the pit were noticeably darker, and the gray-black clay-size layers at this level showed a distinctly wet surface when disturbed; as though they were saturated. Both bulk and undisturbed samples taken from the unoxidized portion of the pit were tested by the Materials Laboratory of the Washington Department of Highways. The following data are representative of the samples, with the moisture content and moisture-dependent properties based on an undisturbed sample taken at the 42 to 46 inch depth interval:

| | |
|---|---|
| Moisture content ............. | 37.6 percent |
| Liquid limit ................. | 25.6 |
| Angle of internal friction ..... | 20° |
| Dry density .................. | 78 lb/ft$^3$ |

The material as a whole was found to be nonplastic although there are muddy partings, generally less than $\frac{1}{4}$ inch thick, that, by themselves, are plastic. It should be kept in mind that material from this test hole is not representative of the dikes (see Construction of the Tailings Piles); the dikes being practically unstratified and considerably coarser grained.

Four small streams discharged onto tailings pile number 2 at the time of my visit. One of these, about a foot wide and 1 inch deep where it reaches the tailings, meandered across the surface for about 200 feet before it completely disappeared into the oxidized tailings. This seems to indicate very poor permeability, at least vertically, across the stratification. Another pit dug 1 foot from the edge of the pond, in tailings area number 3, began collecting seepage water almost immediately. This suggests fair permeability along the silt layers even within the oxidized zone. A critical factor on tailings pile stability would be the relative permeability of the peripheral dikes and the enclosed tailings. The fact that the coarseness of tailings particles increase outward and the dikes themselves represent the coarsest fraction (see Construction of tailings piles) indicates that, excluding oxidation, permeability should increase outward and there would be no "damming effect" of pore water in the zone of saturation. Oxidation does not seem to adversely effect permeability in the coarser fractions, or at least not enough to compensate for grain size factors.

It would require considerable more lab testing as well as field measurements such as piezometer readings to arrive at quantitative information on the overall stability of the tailings piles. Even then, such factors as the inhomogeneity of the original tailings and the influence of later oxidation on the strength and permeability of the dikes would probably require the making of various assumptions. It appears however that natural settlement of the tailings plus this cementation by oxidation of the dike material would make the tailings more stable now than when originally emplaced.

## Chemical Characteristics

The great bulk of material (about 85 percent) in the tailings consists of practically insoluble silicate minerals. The relatively soluble fraction consists largely of sulfide minerals, with only minor and variable amounts of marble ($CaCO_3$). Chemicals added during the flotation process were copper sulfate, hydrated lime, pine oil, Barrett No. 4 oil, either Minerec "B" or Pentasol zanthate, and sodium cyanide. The quantity of sodium cyanide used in the flotation process, at least during the early operations, was about 0.04 pounds per ton of ore (Pearse and Zanadvoroff, p. 34). In addition to this use as a depressant of pyrite, pyrrhotite, and sphalerite during the floation process; cyanide was used on the coarse tailings during the early 1940's and again in the late 1940's in attempts to increase the gold recovery.

The addition of hydrated lime in the amount of 1.2 pounds per ton of ore (Pearse and Zanadvoroff, 1939, p. 34) made the pulp in the flotation process quite alkaline. Probably a good part of this original alkalinity was lost to Railroad Creek by decantation from the tailings ponds. Nevertheless, the tailings were undoubtedly somewhat alkaline when deposited. Once oxidation of the iron sulfides commenced, however, the oxidized zone became acid. A test of the oxidized surficial material showed a high soluble-salt content and a pH of 2.8 (W. R. Rines, Jr., written communication, 1967).

The presence of 4 to 5 percent sulfur, largely in the form of $FeS_2$ and FeS, indicates a potentially large volume of sulfuric acid to be eventually formed. The slow rate of oxidation means that this large potential of acid will be released over a period of many years, however. An illustration of this is the fact that a test hole dug on the surface of tailings pile number 2 encountered unoxidized tailings within 10 inches of the surface. This indicates an average oxidation rate of on the order of $\frac{1}{2}$ inch per year, although this rate undoubtedly varies with the texture and degree of stratification in the tailings. Oxidation on the banks of the tailings piles has progressed considerably deeper than this however, and may extend the full thickness of the dikes. In one place a 3-foot hole failed to penetrate the oxidized layer.

## DISCUSSION OF PROBLEMS

### Stability

As suggested under "Physical Characteristics," there seems to be little danger, at the present time, of any mass movement of tailings. Overall stability would be even further ensured however, if surface drainage were guaranteed. (Complete drainage would however aggravate somewhat the summer dust problems.

The central drainage systems (see "Construction of the Tailings Piles") are subject to failure by clogging with floating debris, vandalism, or eventual collapse due to corrosion by acidic water. The drainage system of pond number 2 was functioning normally at the time of my visit in spite of wood jammed in the vertical riser. The pond on tailings area 3 was much larger and it would require a boat to see if the drainage riser was clogged. The scour resistance of the oxidation cemented dike material (see Photo 4) suggests that even if the dikes were to be overtopped due to outlet clogging and an unusually rapid snow melt, that erosion and downcutting probably would not be serious.

Even though the in-place tailings are quite resistant to scour by running water, they should, of course, be protected from undercutting by Railroad Creek. The diversion of the creek, as suggested by the Forest Service engineering consultants (see map), would offer a permanent and, in the long run, probably cheaper solution to this potential hazard than the repair of the existing log cribbing.

### Biological Effects

While it was beyond the scope of this investigation to directly study the biological effects, a review of available information may help to evaluate the statements quoted in "Purpose and Scope" and repeated below.

> ". . . . the tailings dump has killed the surrounding vegetation. . . ."

This was found to be true in one place, along the south edge of tailings pile 2, where several dozen small fir trees were dead. The fact that trees a few feet away looked healthy suggests that the dead trees had been "drowned," as by an encroaching beaver pond, rather than poisoned. In other places, trees and brush of various species were seen growing through several inches of wind-deposited tailings. Nowhere, however was anything seen rooted in tailings, so it appears that they form an effective barrier to the seeding of annual vegetation wherever the tailings completely cover the ground.

". . . . tailings dump has killed. . . all the fish in the (Railroad) creek."

I made no attempt to catch fish during my visit, although former residents of Holden report good fishing downstream from the tailings area during their stays at the mining camp when it was operating (H. A. Pearse, M. E. Defoe, J. S. Mitchell, J. J. Curzon, V. A. Zandon, written communications). Tank tests with trout were conducted by Pearse while milling operations were going but failed to show any difference in fish mortality between "clean" creek water and a creek water-tailings effluent blend (H. A. Pearse, J. J. Curzon, written communications). Although all the details are not known, it would appear that such a test would prove only that the chemical quality of the water used was not toxic to mature trout. Such a test would, of course, yield little or no information on the long-term effects of effluent or tailings particles on the food chain or reproductive cycle of the trout. Apparently the influence of the chemical quality of water on fish can be both subtle and complex. McKee and Wolf (1963, p. 176) state that the "toxicity of cyanides toward fish is effected by the pH, temperature, dissolved oxygen, and concentration of minerals." They cite test results where cyanides in a concentration of 0.005 mg/l were found to be "lethal" to trout and where another study showed a higher concentration (of 0.084 mg/l) to be "not toxic." It is not clear whether this apparent contradiction is due to differences in exposure time, one of the factors mentioned, or some other condition. These authors state further (p. 176), that "toward lower organisms cyanide does not appear to be as toxic as toward fish."

A field study of aquatic insects in the bed of Railroad Creek was made by Roland Pine, a Washington Water Pollution Control Commission Biologist, in September 1967. He found a substantial decrease in creekbed insect fauna at the tailings site and for several miles downstream. He concludes that the "mine tailings at Holden are significantly affecting the already limited productivity of the creek. This is due principally to the deposition of tailing material upon the stream bottom effectively suffocating the aquatic insect fauna" (W.W.P.C.C. Tech. Paper 67091). Assuming that both the testimony of former Holden residents and Pine's findings are true and the fish population has decreased since the closing of the mine, a contributing factor might be that the failure to maintain a year-around settling pond on the tailings surfaces has allowed drying during the summer months resulting in more severe dust conditions and silting than took place while the mine was active. An increase in post-1957 wind erosion plus the normal long-term buildup of dust might result in a cumulative effect that had not yet made itself felt during the years the mine was in operation and the fishing was reportedly good.

". . . the tailings dump . . . is now starting (1967?) to pollute Lake Chelan.."

If pollution is defined as the introduction of a foreign substance, careful analysis of creek water at Lucerne in 1940 probably would have shown more than normal amounts of metals as well as some entirely foreign chemicals from the flotation process. Thus, pollution here is not some new threat nor, as far as Lake Chelan is concerned, does it appear to be a threat at all. The dilution factor is such that pollution would probably not be detectable much beyond the zone of turbidity at the creek mouth.

Sampling of Railroad Creek water on June 15, 1967 by Federal Water Pollution Control Administration personnel yielded the following data (D. B. Krawczyk, written communication, Nov. 20, 1967):

| | At Wilderness Boundary | Downstream from tailings pipe | At Lucerne |
|---|---|---|---|
| Copper | 0.0036 | 0.029 | 0.021 |
| Zinc | 0.008 | 0.016 | 0.011 |
| Iron | 0.2 | 0.9 | 0.8 |
| Arsenic | < 0.001 | < 0.001 | < 0.001 |
| Cyanide | < 0.010 | 0.056 | 0.045 |

All concentrations reported in milligrams per liter

Examination of these data show that the "pollution level" at Lucerne is, for most of the constituents, on the order of 4 times that found at the Wilderness area boundary. For comparison purposes the U.S. Public Health Service Drinking Water Standards (1962) are reproduced below:

| | Recommended limit* |
|---|---|
| Copper | 1.0 |
| Zinc | 5.0 |
| Iron | 0.3 |
| Arsenic | 0.01 |
| Cyanide | 0.01** |

* All values reported as milligrams per liter.

** Mandatory limit for cyanide is set at 0.2 milligrams per liter.

The metal content of the Railroad Creek water, even below the tailings pipe, (with the exception of iron) can be seen to be well within the recommended standards for drinking water. While the iron content at this point is about twice that for municiple wells in the cities of Omak and Okanogan for example (high-iron wells reported by Van Denburgh and Santos, 1965, p. 66). No evidence was found suggesting that such concentrations are any more than a nuisance due to staining effects.

The recommended limit (stated above) for cyanide is apparently a practical one in that it is "easy to attain" and is based more on toxicity to fish than to man. The mandatory limit of 0.2 milligrams per liter gives a "factor of safety of about 100" for drinking water. Thus, even though the recommended limit for cyanide is exceeded at Lucerne, it is still less than one fourth the mandatory limit.

In summary, it appears that while the iron and cyanide levels of Railroad Creek would make it a domestic water source of marginal quality, the water presents no dangers for human consumption such as by campers and hikers.

## Dust Problems and Possible Solutions

Wind erosion seems to be the most immediate problem but is more in the category of a nuisance than a danger. I saw 35 mm slides taken by the Holden Village management in which portions of the opposite valley wall were obscured by clouds of orangish dust. While riding to Holden from Lucerne on the bus, it was possible to smell and "taste" the tailings at lease a half mile downvalley from the tailings area. This was probably due largely to tailings previously deposited by wind along the road.

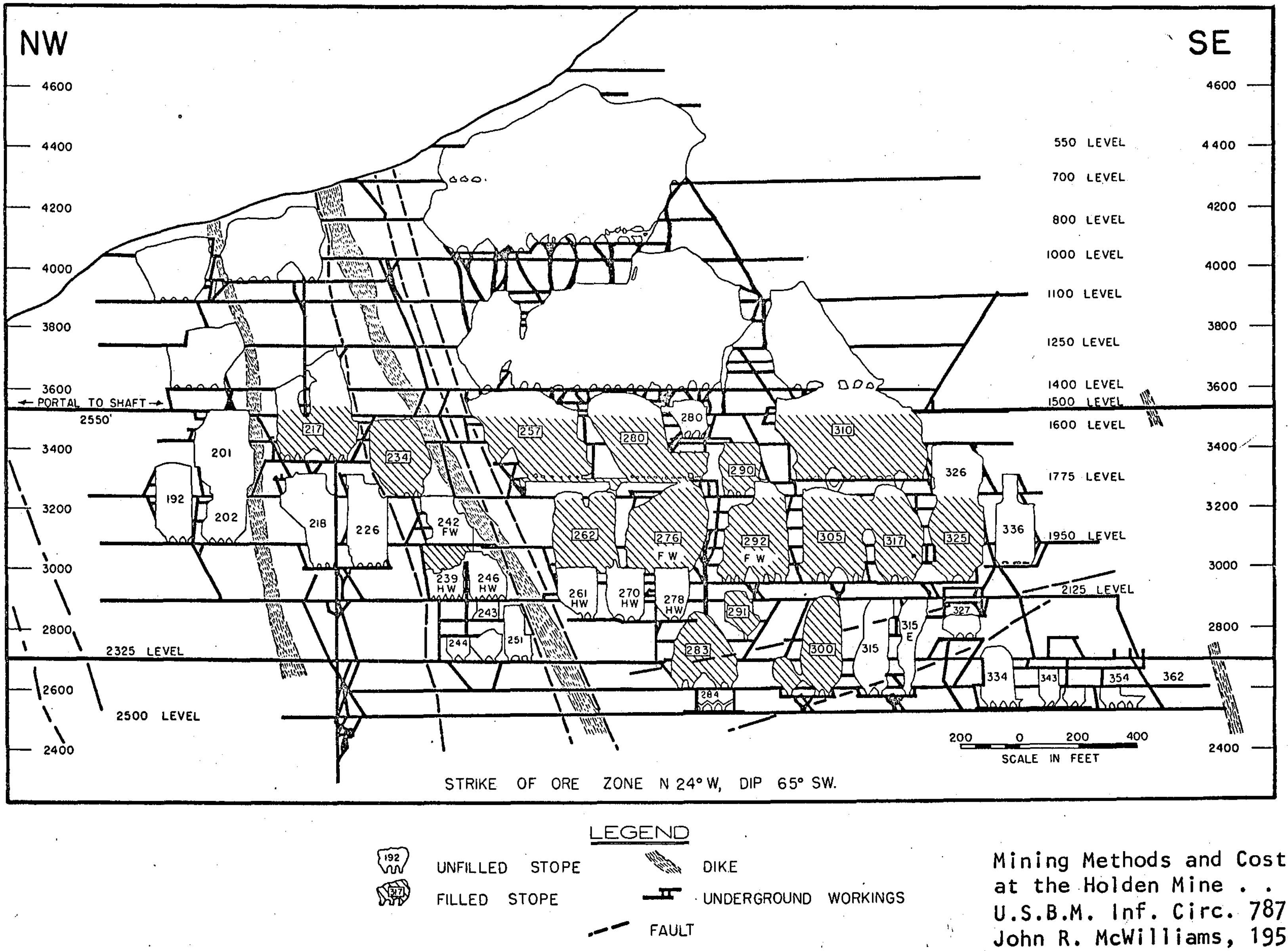
Simply wetting the tailings surface will stop wind erosion and this fact suggests one remedy during the 4 or 5 months when this a problem. The availability of high pressure water from the existing power plant diversion point on Copper Creek might make it feasible, at least on a short term basis, to sprinkle or "fog" the tailings during the summer months. Such an installation could be laid on the surface and drained each winter to avoid freezing. The major shortcoming of such a system is that it would have to be maintained year after year, offering no permanent solution.

Studies have been made of agricultural applications in which a thin layer of asphaltic material is sprayed on the surface of a soil to prevent evaporation of soil moisture. A similar material on the surface of the tailings ponds might not only prevent drying, but act as a binder to further ensure against wind erosion. In tailings stabilization experiments conducted by the U.S. Bureau of Mines, a resinous adhesive, "Coherex", was found to be effective in amounts as low as 0.18 gallons per acre at a dilution of 1 part by volume to 4 parts water (Dean and others, 1969, p. 14). This treatment, at a chemical cost of $34.80 per acre, was combined with seeding of grasses and brush, but it is unlikely that it would be a permanent solution alone. Surface films would be susceptible to puncture and subsequent "blowouts" by wind erosion. The numerous deer tracks on the tailings indicates that this could be a serious problem.

A soil cement might be made by harrowing in a suitable binder. Careful testing would need to be done to select a binder that would be chemically compatible with the oxidized tailings. While this technique might be a permanent solution to erosion, much of the irregular surface of the westernmost pond would need regrading. Also, the technique probably would not be feasible on the steep dike slopes of the tailings piles. Wind scour however appears to be most severe on the top surfaces, probably due to the generally finer grain size of this material. The fact that the tailings cover 80 acres means that a soil cement approach would require a considerable volume of material, all of which would have to be hauled in at great cost.

Probably the most esthetically pleasing approach to the wind erosion problem would be revegetation. The tailings alone, however, would probably not support native vegetation even if planted. Thus, such a method would require either correcting the excessively high soluble salt content and low pH (2.8) (W. R. Rines, Jr., written communication, 1967) or, veneering the tailings with a suitable soil. Both of these approaches would be very expensive. If the veneer approach is considered, it would seem worthwhile to consider the mine waste dumps as a source of "topsoil," thus avoiding the cost and esthetic effects of a large new excavation. It would require on the order of 150,000 cubic yards of material to cover the tailings to a one-foot depth. While metal mine dumps, in the short term, appear to be very sterile, some old mine dumps have tree stands that match or surpass the surrounding natural terrain. The development of a brush and tree cover on such a veneer could, of course, be greatly accelerated by actual planting and by fertilizing.

Revegetation would be relatively simple if the acid-forming iron sulfides were removed from the tailings. While a remilling of the tailings might produce on the order of 3.5 million dollars (gross) worth of gold-bearing pyrite concentrate (assuming a nominal $10/ton for pyrite), the remoteness of the area would almost certainly make it uneconomical at present. Should a form of gold subsidy be introduced, as suggested by some, this otherwise farfetched idea might warrant investigation. Should it prove feasible, not only would the remaining tailings be easier to revegetate but their bulk might be substantially reduced by pumping much of the remaining tailings into mined out areas of the mine above the 1500 level (see Fig. 4).



Mining Methods and Costs
at the Holden Mine . . .
U.S.B.M. Inf. Circ. 7870
John R. McWilliams, 1958

FIGURE 4.—Longitudinal section in plane of ore zone.

## SUMMARY

Cementation through oxidation of iron sulfides and settlement appear to have made the tailings piles at least as stable, or possibly even more stable, as when originally implaced. The proposed Railroad Creek diversion should permanently remove any dangers of undermining.

Dust and dust blankets result from wind erosion during the summer. The dust is esthetically displeasing and contributes to stream siltation. The dust blankets do not seem to effect established "woody" vegetation but appear to be a barrier to reproduction by seeding.

Leachates from the tailings are present in Railroad Creek, possibly in concentrations sufficient to adversely effect aquatic life. Stream siltation by tailings particles appears to be responsible for a decreased aquatic insect population downstream from the tailings.

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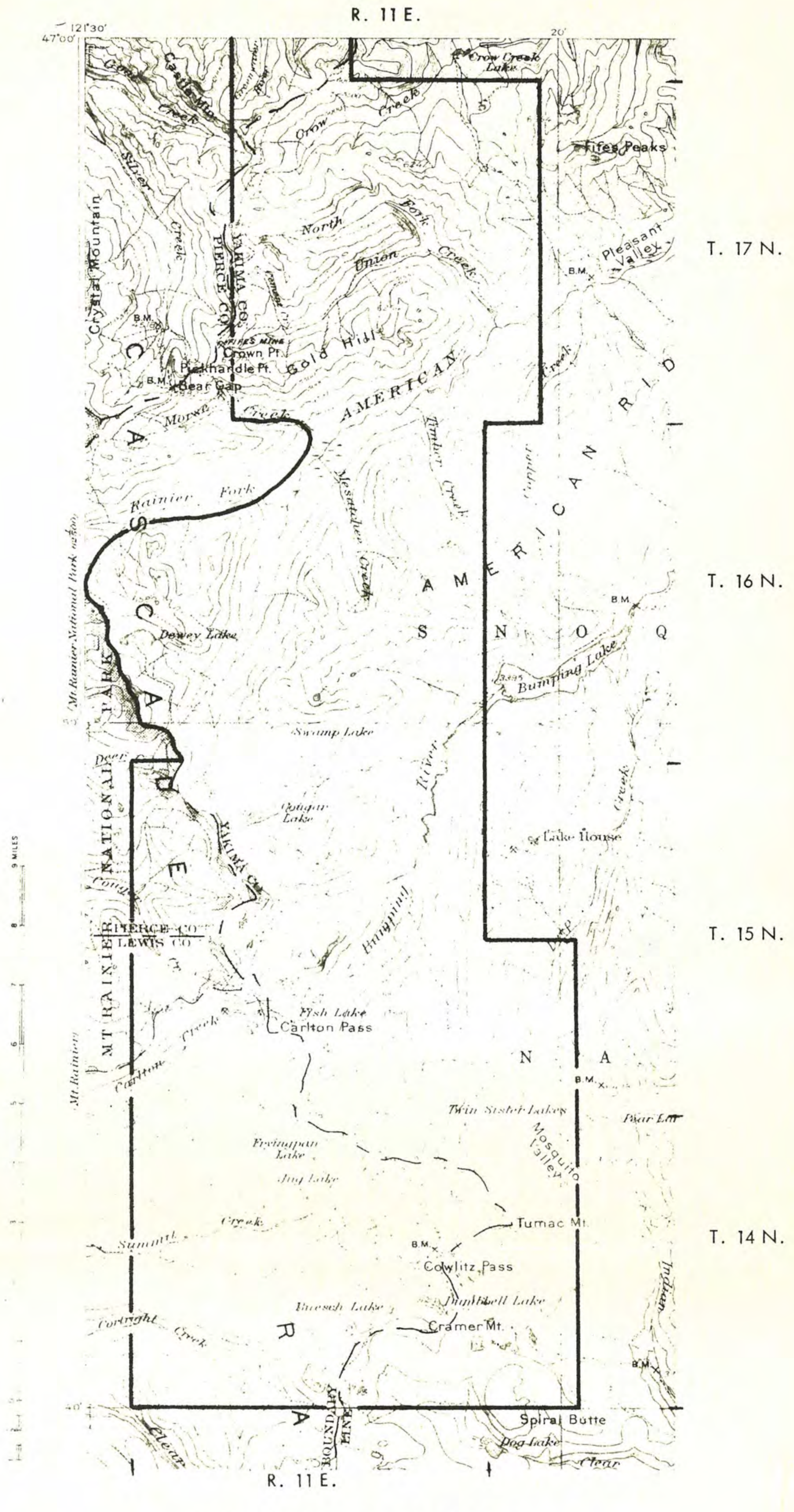

FIGURE 1.—Cougar Lake Limited Area.

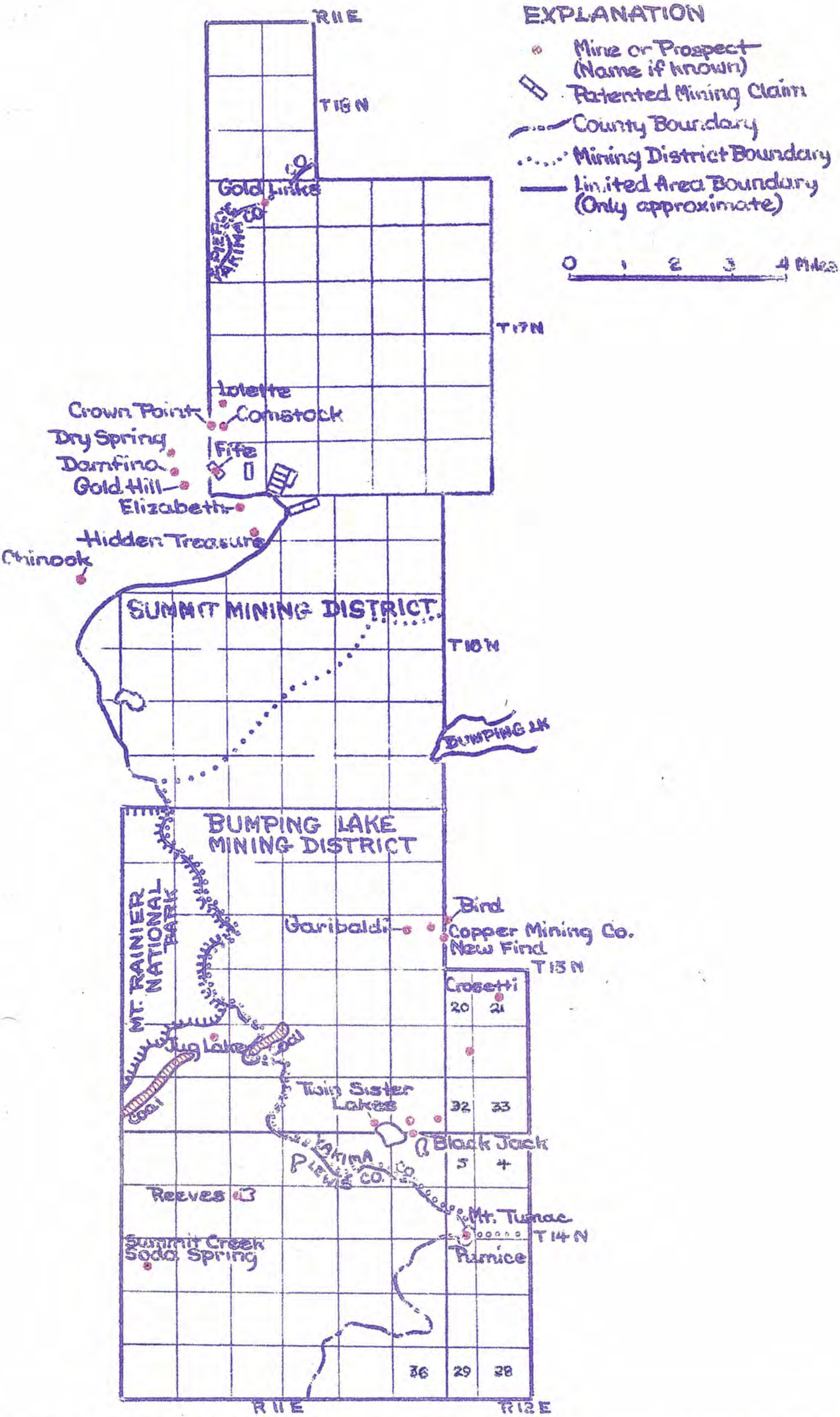

FIGURE 3 - MINES AND PROSPECTS OF THE COUGAR LAKE LIMITED AREA

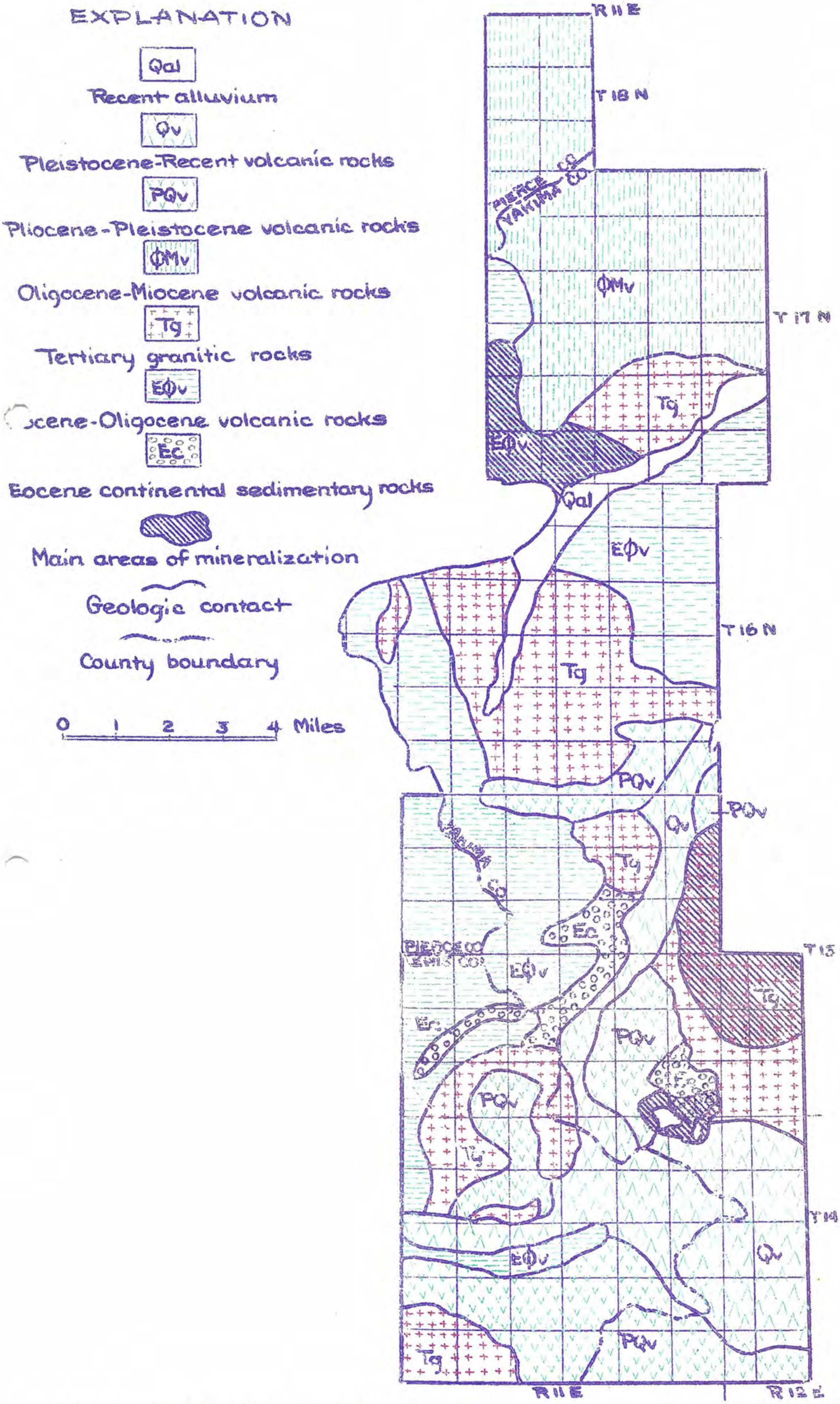

FIGURE 2 - GEOLOGIC MAP OF THE COUGAR LAKE LIMITED AREA