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UNITED STATES
DEPARTMENT OF THE INTERIOR
Geological Survey

PINE CREEK AND ADAMSON TUNGSTEN MINES
INYO COUNTY, CALIFORNIA

By

Paul C. Bateman
May 1945

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Introduction

The Pine Creek mine, operated by the U. S. Vanadium Corporation, was one of the principal domestic sources of tungsten from 1938 to October 1944. It also supplied important amounts of molybdenum and lesser amounts of copper. The adjacent Adamson mine made a much smaller production of the same metals in 1942 and 1943, when it was operated by Panaminas, Inc.

The mines are situated in rugged, glaciated country near the crest of the Sierra Nevada in Inyo County, California (Mt. Goddard quadrangle). They are on a branch of Morgan Creek, a tributary to Pine Creek, an eastward-flowing stream that empties into the Owens River near the town of Bishop. The Pine Creek mine is at elevations between 10,750 and 11,700 feet; workings on the Adamson property range from 11,500 to 12,800 feet in elevation. A surfaced road extends from Bishop to the U. S. Vanadium Corporation's 1500-ton mill at the junction of Pine and Morgan Creeks (only the old mill, now dismantled, is shown on plate 1). From the mill, at an elevation of 7,700 feet, a dirt road leads 7 miles to the Pine Creek mine and 9 miles to the Adamson mine. Ore is moved from the Pine Creek mine to the mill by an aerial tramway with a capacity of about 100 tons per hour.

The Pine Creek deposit was discovered in 1916. It was operated by the Pine Creek Tungsten Company from 1917 to 1919, by the Tungsten Products Company from 1922 to 1926, and by the U. S. Vanadium Corporation since 1936. Total production to the end of 1944 (Table 1) amounted to 586,834 units of WO_3 (tungsten trioxide) and 2,655,281 pounds of molybdenum.

The amount of ore mined during 1942 and 1943 averaged about 1,200 tons daily, nearly a third of which was from 3 open cuts. After exhaustion of these cuts in the latter part of 1943, all production came from underground workings. Mining operations were suspended on October 1, 1944 because of shortage of manpower with a resultant lag in mine development.

The Pine Creek mine is developed by means of 4 main levels, known as levels 250, A, C, and E, at elevations of 10,540, 10,790, 11,070, and 11,370 feet, and by numerous sublevels, raises, and stopes. In August 1944 the main levels amounted to 14,400 feet of drifts and crosscuts, the sublevels to 8,000 feet. Work on a low level adit (Zero level), designed to intersect the ore bodies 1,500 feet beneath the present workings, was begun in August 1944. The portal of this adit, at an elevation of 9,251 feet, is 6,000 feet south of the southernmost known ore body, the South ore body.

The Adamson mine adjoins the Pine Creek mine on the north and is on the same geologic structure. Operations were discontinued in 1944 because of high costs, an inadequate supply of labor, and termination by the Metals Reserve Co. of its contracts to purchase tungsten concentrates. The total production of 38,609 tons of ore was sold to the Metals Reserve Co. and treated in the U. S. Vanadium mill where 18,109 units of WO_3 were recovered.

Workings in the Adamson mine are much less extensive than those in the Pine Creek mine. Level workings total 2,000 feet and are limited to the Northwest ore body and to the contacts between granite and marble 600 to 1,000 feet southeast of that ore body (pl. 25). The Ridge ore body, 1,000 feet higher at an elevation of 12,800 feet, is developed only by means of open cuts. In 1943, a jig-back aerial tramway connected the Ridge ore body with a bin near the Northwest ore body.

The data for this report were assembled from several sources. A topographic and geologic map of the surface (pl. 1) prepared by D. M. Lemmon of the Survey in 1939 and 1940 was revised slightly. Detailed maps of the Pine Creek mine made in August and September 1942 by Lemmon and the writer were brought up to date by the writer and M. P. Erickson during 2 weeks in August 1944. The writer and Erickson also prepared maps of the Adamson mine in August 1943, and revised them in September 1944.

The U. S. Vanadium Corporation supplied surveys of the mine levels and stopes in the Pine Creek mine, geological information on inaccessible parts of the mine (in particular,-level 250, which was under water), and comprehensive assay data. Plate 2, the surface map showing the Pine Creek ore bodies on a scale of 100 feet to 1 inch, is a reduction from maps on a scale of 40 feet to 1 inch prepared by the mine staff of the U. S. Vanadium Corporation. Panaminas, Inc., supplied surveys of the underground workings on the Adamson property and considerable assay data.

Most of the geological data for the general part of this report are based on observations made in the Pine Creek mine. The Adamson mine is much smaller and less well developed and does not offer comparable opportunities for geologic study.

Geology

The mines are near the north end and on the west side of the Pine Creek pendant, an elongate block of metamorphic rocks bounded on all sides by intrusive granite and diorite. The pendant is about 5½ miles long and 1 mile wide, extending from Mt. Tom on the south across Pine Creek to Wheeler Ridge on the north. It is composed principally of hornfels, schist, and quartzite, but also contains marble for 3½ miles on the west side. All of the ore bodies except the Ridge ore body are in the contact zone between this marble and granite. The depth to which the pendant extends is unknown, but there is no indication of granite encroaching even in the deepest workings.

In Pine Creek Canyon, the beds are folded into a southward-plunging syncline. This structure probably continues northward into the mine area, but there the folding is tighter and the beds dip vertically or steeply to the east or west, and strike parallel to the north trend of the pendant.

The granite is later in age and more extensive than the quartz diorite, with which it is genetically related. It is a light-colored, even-grained rock containing biotite as the only dark mineral. A typical specimen examined by Lemmon[1] contained 58 percent of orthoclase and microcline, 18 percent of oligoclase, 5 percent of biotite, and 1 percent of accessories (including zircon, sphene, apatite, and pyrite). The quartz diorite is darker and is composed of 67 percent of oligoclase, 11 percent of quartz, 11 percent of hornblende, 10 percent of biotite, and 1 percent of accessories (zircon, sphene, pyrite, and apatite). Aplite dikes are abundant in the granite and diorite where they lie along flat joints, but few occur in the metamorphic rocks.

Elongate bodies of quartz diorite crop out between granite and the pendant southward from the South ore body, but both the surface exposures and those in underground workings at the south end of Level A in the Pine Creek mine (pl. 5A) indicate that the quartz diorite bodies are cut out at depth by granite. No ore bodies have been found along this part of the contact.

In much of the mine area, the contact between granite and the pendant probably follows a pre-intrusive fault that guided the emplacement of the granite. For a distance of 3,000 feet north from the prominent granite re-entrant between the North and South ore bodies (pl. 1), the contact is remarkably straight and cuts across bedding in the marble at a small angle. South of this re-entrant and on line with the straight part of the contact, the marble within the pendant is silicified and contains considerable pyrite.

To the south, the re-entrant becomes increasingly elongated at depth and on level A extends 1,200 feet farther south than at the surface (pl. 5A). At this level, both the re-entrant and the contact of the main body of granite with the pendant, where explored in the long cross cut, are on line with the postulated fault.

Faulting is further strongly suggested by the anamalous stratigraphic position of a sliver of hornfels, half a mile long and completely enclosed in marble. This body of hornfels is south of the limits of Plate 1 but still in line with the straight part of the contact at the surface north of the granite re-entrant. Because of steep slopes much of this hornfels is inaccessible, but where it can be reached the beds along its margins are considerably contorted. Pre-intrusive faulting might also explain the stratigraphic displacement of the hornfels contained in the elongate block of metamorphic rocks explored by the 1300-main adit on the Adamson property. It is not entirely certain that this block is connected with the main pendant at its south end, for intervening areas are covered by talus.

1/ Lemmon, Dwight M., Tungsten deposits in the Sierra Nevada near Bishop, California: U. S. Geol. Survey Bull. 931-E, pp. 83-84, 1941.

The trace of the contact north of the North ore body across extremely rugged topography is straight and indicates a vertical dip; in the workings of the Pine Creek mine the contact dips vertically or very steeply to the west. In the North ore body (pl. 20) the contact and the bedding are parallel and local irregularities are few. In the proximity of the Level E ore bodies, however, where the beds dip 75° E. and are truncated by the granite, granite sills penetrate along bedding planes downward and away from the main contact. (pls. 23 and 24). The local influence of bedding on the emplacement of the granite is also shown on the level maps of the North ore body.

The contact zone consists of garnet-diopside tactite, and quartz and quartz-feldspar rocks. The garnet-diopside tactite, which makes up the larger part of the contact zone, is a medium- to fine-grained rock consisting essentially of garnet and diopside with small amounts of scheelite, molybdenite and other sulfides, including chalcopyrite, bornite and pyrite. The quartz and quartz-feldspar rocks frequently contain molybdenite, but no scheelite.

The quartzose rocks mapped as a unit include, in addition to quartz and quartz-feldspar rock, the more quartzose portions of the tactite. Most of the quartz in the tactite occurs in veinlets, but some of it is an integral part of the tactite. Because the amount of quartz in the tactite is variable, the separation of a quartzose portion is somewhat arbitrary.

The age relations of the various contact rocks are not entirely clear, but it is thought that both the quartz and quartz-feldspar rocks are younger than the tactite. The quartz-in stringers was unquestionably the last to be formed.

Detritus-filled solution channels, locally called "sand streaks", are well developed in the marble adjacent to the North and South ore bodies and in horses of marble within the North ore body. Individual channels range from a few inches to several feet in width, extend as much as 200 feet along the strike, and, in the North ore body, can be traced from the surface down to 150 feet below Level A (pl. 20). A few large, unfilled cavities have been found (notably in the Pine Creek mine on Level A at 6380 N., 5600 E.), but most are filled with stratified granitic sand and with coarser fragments of granite, limestone and contact rock. The stratification is usually steep, and ranges from horizontal to vertical. The dips are presumably initial, and steep ones may have resulted from deposition in narrow crevices simultaneously with solution of the limestone. Within some of the detrital fillings there are slickensided surfaces caused by slight slippage along minor faults.

Numerous post-mineral faults that strike northeasterly and dip steeply occur between the main tactite masses and near their extremities. The gouge along these faults was thickened by alteration of the wall rock resulting from downward percolation of surface waters along the fault planes. In the underground workings of the Pine Creek mine the greatest displacements observed were only a few feet. The faults are obscured at the surface by talus, but to the east along the contact between marble and hornfels there are no noticeable offsets. The faults apparently represent minor adjustments between the rigid tactite masses.

Ore Bodies

General Features

Five ore bodies crop out in the area of the Pine Creek mine and two on the Adamson property (pls. 1, 2, 25). All of them contain tungsten in commercial amounts, but only the North and South ore bodies of the Pine Creek mine contain molybdenum in important quantities. Molybdenum is present in minor amounts in the other ore bodies and is recovered as a by-product. Copper also is a valuable by-product.

Scheelite, the only tungsten mineral, and molybdenite and secondary powellite, the molybdenum minerals, occur within the ore bodies in well defined ore shoots that are only partly co-extensive. The distribution of these shoots was determined by a study of assay data furnished by the U. S. Vanadium Corporation and by Panaminas, Inc. The general positions of the shoots are, for the most part, fixed by the assay data, but details of the boundaries can only be deduced from a study of the habits of the mineralization. The interpretations of the writer are shown on the accompanying illustrations. Ore shoots are not shown in the South ore body on the surface map, Plate 2, and on the upper part of the block diagram, Plate 18, where they are known to be present, because assay data is not available.

Tungsten Ore Shoots

The tungsten ore shoots are surprisingly continuous, especially in their vertical dimensions. This is particularly evident in the North ore body where individual shoots can be identified from level to level (pls. 5 to 15; pl. 20). The tungsten ore shoots are restricted to the tactite, of which they comprise less than half, on the average, and only about one-third in the North ore body. The shoots are sufficiently large and persistent, both laterally and in depth, to be stoped individually.

The grade of ore treated at the U. S. Vanadium Corporation mill during the three year period 1942-44 averaged about 0.45% WO_3, but this grade represents a mixture of ore from the tungsten shoots containing 0.7% WO_3 with barren or very low grade material, some of which, however, contained substantial quantities of molybdenite. Ore from the Adamson mine contained an average of 0.57% WO_3, but this also represents a mixture of higher grade ore and low grade material. The tungsten ore shoots shown on the illustration are areas in which few or no assays fall below 0.4% WO_3. The average of 959 assays from tungsten shoots in the Pine Creek mine, not including diamond drill samples, is 0.70% WO_3. Diamond drill samples from the tungsten shoots average somewhat higher, 0.79% WO_3 for 115 assays (see table 2 for statistical data). In contrast, the tactite in the ore bodies exclusive of the tungsten shoots and quartz and quartz-feldspar rock contains an average of 0.24% WO_3. The tungsten shoots outlined by assay values have reasonably sharp limits, and are not bordered by large tonnages of marginal grade ore.

Molybdenum Ore Shoots

The molybdenum shoots are more limited in their distribution than the tungsten ore shoots, are of substantially higher grade, have more erratic, and less sharply defined boundaries, and, although they occur in both tactite and the quartzose rocks, are more closely related to the latter. The largest known molybdenum shoot is in the North ore body. In the South ore body molybdenum is present in the outcrop, and on Level C, but little or no molybdenum occurs on Level A. Very little molybdenum is present in the Level E ore bodies. Flakes of molybdenite and powellite are scattered through the other ore bodies, but there are no concentrations comparable to those in the North ore body or the upper part of the South ore body.

Molybdenum assays are recorded in percentage of sulfide (MoS_2), but a substantial portion of the molybdenum is actually present in the ore either in powellite, the pure molybdate formed as an alteration product of molybdenite, or in scheelite, which frequently contains a small amount of molybdenum. No accurate information is available to the writer as to the relative abundance of the two minerals in the ores. Approximately ten percent of the molybdenum recovered in the mill is derived from molybdenum-bearing scheelite. Very little of the pure powellite is recovered. The ore treated in recent years has averaged about 0.45% MoS_2.

In the ore shoots plotted on the maps and sections, ore with a cut-off grade of 0.7% MoS_2 is distinguished from ore of lower grade with a cutoff of 0.4% MoS_2. Assays of 721 samples from shoots of both grades in the North ore body, excluding samples from diamond drill holes give an average of 0.95% MoS_2. As in the case of tungsten, the diamond drill assays average substantially higher, 1.14% for 59 assays (see table 3 for statistical data). The contact rock, including both tactite and quartzose rocks, exclusive of the molybdenum shoots, contains only about 0.20% MoS_2.

The tungsten and molybdenum shoots in the North ore body are only about 25 percent coextensive. Ore from the west stopes in the North ore body and from the small stope above Level A at 5850 N., although it contained tungsten, was mined primarily for its molybdenum content.

Copper Mineralization

The ore treated at the U. S. Vanadium Corporation mill contains from 0.20 to 0.25% copper. Chalcopyrite and bornite occur in the ore, but no information is available concerning the distribution of these minerals in the ore bodies. A substantial proportion of the copper is present as carbonate.

Ore Bodies in the Pine Creek Mine

South Ore Body

The South ore body is at the tip and west edge of a marble wedge separated from the North ore body by a granite re-entrant. On the surface the ore body is 300 feet long and 150 feet wide. In the underground workings the length is the same, but the maximum width diminishes downward to 75 feet on Level C and 50 feet on Level A. Two diamond drill holes that intersected the ore body 125 and 570 feet beneath Level A cored, respectively, 14 and 15 feet of ore (pl. 18). The ore body dips steeply east and rakes 60° south. Both dip and rake are controlled by the granite, the former by the attitude of the granite contact on the west, the latter by the pitch of the granite trough enclosing the north end of the ore body.

A single tungsten shoot extends through the south part of the ore body from the surface down to the deepest diamond drill hole. The north part of the ore body contains little or no tungsten. Twenty-eight samples from within the tungsten shoot on Level A contained 0.90% WO_3. Considerable molybdenite can be seen in the glory hole at the surface, but no assays are available. Only a single, small, low-grade molybdenum shoot occurs on Level C and none on Level A. Apparently a large molybdenum shoot occurred at the surface, but pinched out rapidly downward.

The ore body and the tungsten shoot will probably continue downward for some distance below Level A, perhaps to the level of the Zero adit; but decrease in the width of the marble downward suggests that the marble wedge, and consequently the ore body, will be cut off by granite at a moderate depth.

North Ore Body

The North ore body is the largest and most extensively explored in either the Pine Creek or Adamson mines. It averages 600 feet long and 100 feet thick, and extends from the surface downward at least 1,400 feet to the intersection with the deepest diamond drill hole below Level 250. The east side of the ore body is concordant with bedding in the marble. The ore body thickens southward as the marble beds diverge from the granite contact, and the south end fingers out into marble.

The ore body is thicker beneath two overhanging steps in the granite, one between Levels A 3 and A 5, and one between Level C 7 and the surface (pl. 20). Above Level C 7, both the width and length decrease and the area of the outcrop is little more than half the average area of the ore body in the underground workings.

The ore body dips steeply and rakes vertically with minor irregularities. It extends farther to the north between Levels A 5 and C 4 than it does above Level C 4 or below Level A 5 (pl. 22). The south end of the ore body on Level 250 is slightly north of its position on Level A, possibly because of a north rake, because of downward pinching, or because of local irregularity.

A wedge of quartzose rocks projects from the step in the granite between Levels A 3 and A 5 downward to the Grizzly level and splits the ore body longitudinally. The bulk of this mass is quartz-feldspar rock, but it is cut by numerous quartz veinlets, many of which continue into the surrounding tactite. Much quartz extends upward from this wedge, especially along the granite wall of the contact zone. On Level C 7 many quartz veins containing substantial amounts of molybdenite occur in the granite adjacent to the contact. The granite near the veins is silicified. A drill hole on Level A 5 cored similar molybdenum-bearing quartz veins.

A single tungsten ore shoot extends from the surface to Level C where it splits into a north and a south shoot, both of which continue downward east of the quartzose wedge. At Level A 1, with the downward termination of the quartzose wedge, these shoots begin to grow smaller and to merge with small irregular shoots in the west part of the ore body. Below Level A in the plane of section 6270 (pl. 20), a single tungsten shoot lies adjacent to the granite through the west portion of the ore body, but in section 6400 (pl. 21), there appear to be two shoots, separated by an intervening barren zone.

The average of 737 assays of muck samples from the tungsten shoots is 0.66% WO_3. Diamond drill samples average somewhat higher, 0.76% WO_3 for 82 assays. Between Levels C 4 and A, the average content of WO_3 in the ore shoots decreases downward proportionally as the shoots increase in size. This relation between size and grade is such that the total tungsten content is approximately the same at each level.

The largest shoot of molybdenum ore known in either the Pine Creek or Adamson mines is in the North ore body, extending from Level A to Level C 7 near the granite side of the ore body. The outcrop of the ore body was not sampled for molybdenum, so it is not known whether the ore shoot continues upward to the surface. Samples from a diamond drill hole bored upward from Level C 7, however, contained only small quantities of MoS_2. Shoots containing 0.7% MoS_2 and more decrease in size and those containing 0.4% MoS_2 and more increase in size on Level A and the Grizzly level. Beneath Level A, no extensions of the molybdenum shoots have been encountered in any of the workings or diamond drill holes and it is possible that none exist.

The great vertical extent of the North ore body compared to its horizontal dimensions suggests that it occupies a main channel along which ore-bearing solutions rose. Probably both the ore body and the enclosed tungsten ore shoots will continue downward, perhaps to the bottom of the marble. Thickening of the ore body beneath the overhanging steps in the granite contact probably indicates that the steps acted as traps for the mineralizing solutions.

Pinnacle Ore Body

The Pinnacle ore body extends along a pre-mineral fracture in marble. The ore-bearing solutions probably worked laterally from the North ore body along this fracture. On the surface the ore body contains a single tungsten shoot 160 feet long and averaging 25 feet in outcrop width. Twenty-six samples from this shoot contained an average of 0.62% WO_3. The ore body was explored underground from

Level C 7, several hundred feet beneath the outcrop, by means of 3 diamond drill holes, none of which encountered ore of commercial grade.

Level E Ore Bodies

The Level E ore bodies are situated along a discordant part of the contact zone where the beds dip 75° E. The contact is irregular in detail with granite in places following the bedding, in places cutting across it. Granite also penetrates downward along bedding planes from the discordant parts of the contact (pls. 23 and 24).

Ore bodies have been found from Level E to the surface, and from Level C for about 100 feet upward, in two distinct groups separated vertically by about 100 feet of barren contact. The upper group of ore bodies, above Level E, is larger and contains more tungsten. The ore bodies of the lower group lie beneath arches of granite and decrease in thickness downward.

Tungsten ore shoots occur in the upper parts of the ore bodies, but the amount of scheelite decreases downward and the ore shoots finger out. Assays of 85 samples from the outcrops of the ore shoots contained 1.02% WO_3, whereas 46 samples from Level E contained only 0.45% WO_3. The molybdenum content is low, amounting to 0.15% MoS_2 in an average of samples from the surface and Level E, and to 0.21% MoS_2 in the small stope above Level C at 7950 N.

Other similar ore bodies might be found along this part of the contact at greater depth, but it is unlikely that a large, continuous ore body will be found where the dip of the marble is discordant with the general dip of the contact.

Ore Bodies in the Adamson Mine

Northwest Ore Body

The Northwest ore body, shaped in plan like a distorted horseshoe, is at the north end of an elongate block of marble and hornfels that is split off from the main pendant. The ore body extends around and overlies the north end of the block, which is capped by granite. All the tactite is tungsten ore, and the thickest and richest portions are against the marble in the east limb of the ore body. Assays of 27 samples from different parts of the ore body gave an average of 0.59% WO_3. The ore body has not been explored beneath the 1300-north adit, and all the ore has been stoped above this level. The sides of the mass of metamorphic rocks converge gradually downward, and the pendant will probably be cut off by granite in depth. The Northwest ore body may extend as deep as the marble, but it probably pinches out at a shallower point similar to the Level E ore bodies, for the ore appears to have been accumulated beneath a granite cap.

The south end of the Northwest ore body is covered by talus and glacial till which obscure possible extensions. About 500 feet to the southeast, continuations of the metamorphic rocks are exposed estensively in the 1300-main adit where thin bands of scheelite-bearing tactite were followed for 400 feet without finding ore.

Ridge Ore Body

The Ridge ore body is a tactite bed several hundred feet long and from 15 to 20 feet thick with hornfels on both sides. The total length of the part of the bed that carries scheelite in commercial amounts is not known, but Lemmon estimated that scheelite mineralization is present for 350 feet. Where the best ore is exposed on the ridge, samples taken at 10-foot intervals for a distance of 120 feet contained an average of 1.1% WO_3. The only working is an open cut from which some ore was mined in 1943. There is no basis for estimating the depth to which ore may extend.

On the opposite slope and about 150 feet northeast of the Ridge ore body, a small mass of quartz-diopside rock, about 15 feet wide and 50 feet long, contains large, irregular pieces of scheelite as much as five inches across. The average grade of this rock is estimated to be from 2 to 5% of WO_3.

Genesis of the Ore Bodies

All the rocks and minerals of the contact zone are believed to have been deposited from solutions that worked upward along permeable zones developed by fracturing between marble and the solidified crust of cooling granite. The solutions deposited minerals successively, but with some overlap, in the following order: diopside and garnet, scheelite, quartz and feldspar, quartz and molybdenite, and quartz. Localization of the several stages of mineralization was controlled by fracturing. The position of the copper mineralization in this sequence is unknown because of scant information about the distribution of copper, but the primary copper minerals are believed to have accompanied molybdenite.

The relation of the irregularities in the granite contact to the shape and distribution of the ore bodies indicates that the adjacent granite was already solidified when the contact zone was formed and that the mineralizing solutions had an upward path. The granite trough that encloses the South ore body, for example, apparently guided the mineralizing solutions. The thick ore bodies beneath granite cappings seem to have been accumulated in traps effective only on rising solutions in the North ore body, in the Level E ore body, and perhaps in the Northwest ore body. The great vertical extent of the North ore body and of its enclosed pipe-like tungsten shoots strongly suggests a vertical path for the solutions.

The several constituents of the contact zone are believed to be of slightly different ages. Some scheelite is distributed throughout the tactite, but the larger part is concentrated in sharply defined ore shoots which seem to have been formed later than the enclosing low-tungsten tactite. The quartz-feldspar rock is believed to have been introduced after the tungsten in ore shoots because of its close relationship to the late quartz stringers, although its exact position in the sequence is not definitely known. The quartz stringers cut all of the rocks of the contact zone. These stringers contain most of the molybdenite, but quartz apparently continued to be introduced after the molybdenum, for the latest quartz stringers contain no molybdenite.

Permeability produced by fracturing probably controlled distribution of the minerals in the contact zone. Direct evidence of pre-mineral fracturing is scant, the Pinnacle ore body being the only convincing example of localization of ore along a fracture. The concordance between the east side of the North ore body and the bedding in the marble was probably caused by especial susceptibility of these beds to alteration; this susceptibility may have been chemical, textural, or the result of shearing along bedding.

Fracturing along the contacts of the granite with the pendant could have been caused by stresses arising from the emplacement or cooling of the granite. Such stresses would not have affected the contacts of the earlier quartz diorite with marble so strongly as those of the granite. This seems a reasonable explanation of the seeming preference of the ore bodies for parts of the contact zone adjacent to granite as contrasted with the absence of ore bodies from parts of the contact zone bordered by quartz diorite. Fracturing produced by regional stress would not account for this relationship.

A possible alternative explanation for the development of permeability along the contact is that solutions derived directly from the adjacent granite reacted with marble to produce minerals of greater density and less volume, thus making open spaces. Some such process may have developed initial porosity along the contact, but it does not account for the development of successive stages of permeability within the tactite necessary to explain the present distribution of the tungsten and molybdenum ore shoots.

Ore Reserves

Pine Creek Mine

The Pine Creek mine contains the largest reserve of tungsten ore known in the United States, estimated at 968,000 tons of measured ore containing 687,000 units of WO_3; 1,026,000 tons of indicated ore containing 733,000 units; and 568,000 tons of inferred ore containing 419,000 units -- a total of 2,562,000 tons containing 1,839,000 units. The molybdenum reserve in the North ore body amounts to 512,000 tons of measured ore and 342,000 tons of indicated ore, a total of 854,000 tons that contain an average of 20 pounds of MoS_2 per ton. Inasmuch as molybdenum is recovered mainly as a by-product from tungsten, these reserve figures have only limited significance as regards future production. Probably from 3 to 5 pounds of MoS_2 will be recovered per ton of ore mined during the life of the mine, but the amount may be increased by discovery of additional molybdenum ore shoots. The reserves of tungsten and molybdenum ore contained in ore shoots are listed in Tables 4 and 5. The estimates are based on measurements of the unstoped ore shoots at the surface and on mine levels (Tables 2 and 3).

Tungsten Reserves

In the North ore body the tonnage of tungsten ore between levels was computed by averaging the areas in square feet of the tungsten ore shoots on the levels, multiplying this average by the vertical distance, and dividing the product by 10 (assuming 10 cubic feet per ton). Between Level A and the Grizzly level, allowance was made for the absence of stopes on Level A, although several stopes extend almost to that level.

Much of the measured tungsten ore remaining in the North ore body cannot be mined by present practices. The main minable reserve is above Level C 7. Probably only about 200,000 tons of the 791,000 tons between Level A and the surface can be mined. The reserve between Level A and Level 250 is divided into indicated and inferred ore. In computing indicated ore, it was assumed that only ore already explored is present on Level 250. In computing inferred ore, it was assumed that twice as much ore exists on Level 250 as has been explored. The ore between Level 250 and the drill hole 500 feet below is divided equally between indicated and inferred ore. The indicated ore extends from the explored ore on Level 250 downward to a point at the drill hole intersection. The inferred ore flanks this ore on both sides assuming that the area of ore at the level of the drill hole intersection is equal to the area of the explored ore on Level 250.

The South ore body above Level A is exhausted, except for pillars around Level C at 5900 N. The reserve below Level A to the drill hole 580 feet lower is divided into indicated and inferred ore. The former extends from Level A downward to a point at the drill hole intersection. The latter is inferred from the probability that at least half as much ore exists at the level of the drill hole as on Level A.

In the Level E ore bodies, the block between Level E and the surface is classed as measured ore, the ore at Level C as indicated. From the surface, the measured ore decreases downward both in tonnage and in grade, and appears to be almost at its lower limits on Level E. The indicated ore is assumed, arbitrarily, to extend 70 feet above and 70 feet below Level C.

In the Pinnacle and Loop ore bodies, ore above the level of the lowest point of outcrop is classed as indicated, ore below this point as inferred. In the Pinnacle ore body the inferred ore extends half way to Level C 7, a distance of 106 feet; in the Loop ore body 130 feet, half way to Level E.

Molybdenum Reserves

A large part of the molybdenum recovered in the U. S. Vanadium Corporation mill is from tungsten ore that contains only small amounts of molybdenum. However, the calculated reserves include only ore contained in the molybdenum ore shoots. All of the reserves are in the North ore body, for the molybdenum ore shoots in the upper part of the South ore body are exhausted. The average grade of ore in the North ore body, including both plus 0.4% and plus 0.7% shoots, is about 1.0% MoS_2. Ore coextensive with tungsten ore shoots is tabulated separately from ore independent of tungsten ore shoots (table 3.).

The molybdenum reserves in the North ore body were computed by the same method as that used in calculating the tungsten reserves. It is doubtful if much of the measured ore between Levels A and C 4 can be mined by present practices. The main minable reserve is the indicated ore between Level C 4 and the surface and immediately beneath Level A. Recent exploration suggests that the ore shoots do not extend far beneath Level A.

Adamson Mine

The reserves in the Northwest ore body on the Adamson property lie beneath the 1300-north level, the ore above that level being exhausted. On the 1300-north level the ore covers an area of about 5,000 square feet and contains 0.59% WO_3 (average of 27 assays). If the grade and size of the ore body remain constant to a depth of 50 feet beneath the 1300-north level, there are 25,000 tons of indicated ore that contain 14,000 units of WO_3. Uncertainties as to factors that localized the ore body preclude calculation of reserves at greater depths.

The Ridge ore body has been shown by surface sampling to contain an average of 1.1% WO_3 for a length of 120 feet across an average width of 17 feet. Indicated ore, calculated to a depth of 60 feet beneath the outcrop, consists of 12,000 tons of ore that contain 13,000 units of WO_3. An equal amount of inferred ore of the same grade lies beneath this ore to a depth of 120 feet below the outcrop.

The small high-grade mass of quartz-diopside rock east of the Ridge ore body contains at least 2.0% WO_3. Indicated ore is estimated to a depth of 25 feet at 1,800 tons that contain 3,600 units of WO_3.

All the ore bodies contain molybdenum, but no data as to grade or distribution are available. No concentrations were observed camparable to the ore shoots in the North or South ore bodies in the Pine Creek mine.

* * *

TABLE 1. - PRODUCTION FROM THE PINE CREEK MINE, 1918 - 1944

Operator	Year	Units WO_3	Pounds Mo
Pine Creek Tungsten Co.	1918-19	1,736	
Tungsten Products Co.	1923	1,820	
	1925	8,000	
	1926	6,100	
	1927	532	
Herbert Sillinger	1933	67	
U. S. Vanadium Corp.	1937	975	
	1938	5,817	
	1939	20,526	
	1940	44,800	
	1941	86,907	168,170
	1942	172,864	836,768
	1943	150,832	943,999
	1944	85,867	706,344
		586,843	2,655,281

NGSTEN ORE SHOOTS IN THE PINE CREEK MINE;
DE OF SAMPLES IN ORE SHOOTS

0.4% WO_3 or more		Samples containing 0.4% WO_3 or more			
		Muck samples		Diamond drill samples	
toped	Remaining	Number	Percent WO_3	Number	Percent WO_3
ORE	BODY				
formation	No information ~~12,800~~	10	0.65	---	---
:,100	14,400	--	---	20	0.71
;,600	9,400	39	0.87	---	---
. . . .	. . . . .	7	0.51	---	---
),300	8,400	76	0.77	11	0.78
.,200	13,500	71	0.73	2	0.64
;,300	7,900	52	0.66	7	0.77
),500	7,400	24	0.79	7	0.90
3,400	8,600	71	0.65	5	0.69
5,600	9,100	114	0.66	11	0.74
2,500	16,100	148	0.62	2	0.50
0	24,200	116	0.59	13	0.81
. . . . .	. . . . .	9	0.70	4	0.77
		737	0.66	82	0.76
ORE	BODY				
All	0	--	---	--	---
All	0	--	---	1	0.99
0	4,000	28	0.75		
ORE	BODIES				
nformation	No information	85	1.02	--	---
0	5,000	46	0.45	4	0.94
0	13,900	--	---	28	0.83
RE BO	DY (8300 N)				
ll amount	No information ~~6,800~~	37	1.01	--	---
CLE O	RE BODY				
0	4,600	26	0.62	--	---
. . . . .	. . . . .	---	---	5	0.07
		959	0.70		

…E SHOOTS IN THE NORTH ORE BODY AND GRADE OF SAMPLES

…t	Coextensive with unstoped areas of 0.4% WO_3 or more		Samples containing 0.4% MoS_2 or more			
			Muck Samples		Diamond drill samples	
…MoS_2 …ore	0.4 % MoS_2 or more	0.7% MoS_2 or more	Number	Percent MoS_2	Number	Percent MoS_2
...	...	...	...	...	...	...
...	...	...	--	---	12	1.11
200	---	1,400	36	1.10	3	0.81
...	...	...	18	1.50	--	---
200	---	1,000	86	0.86	3	0.95
…00	2,700	2,550	57	0.75	2	0.98
…00	3,600	1,200	80	0.95	6	0.81
…00	200	1,700	63	1.30	7	1.52
…00	1,000	2,000	46	1.06	9	1.08
…00	1,800	1,300	102	0.80	5	0.78
…00	3,100	3,250	138	0.81	2	1.55
…00	4,900	4,500	93	1.10	9	1.59
...	...	...	2	0.76	1	0.49
			721	0.95	59	1.14

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TABLE 4. - RESERVES OF TUNGSTEN ORE IN THE PINE CREEK MINE

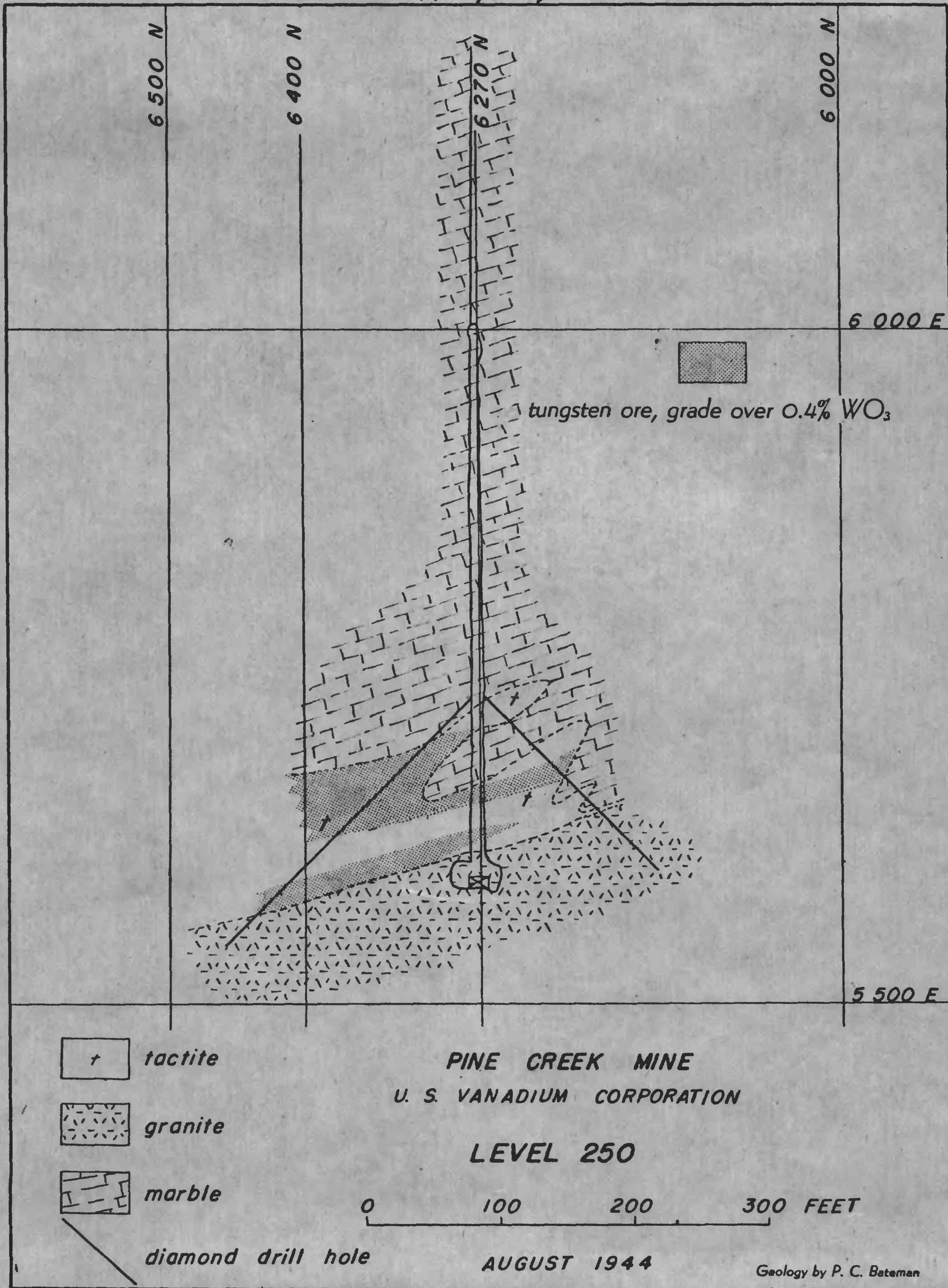
	Measured		Indicated		Inferred	
	Tons	Units WO_3	Tons	Units WO_3	Tons	Units WO_3
Loop ore body (8,300 N.)						
Above lowest outcrop			34,000	34,000		
Lowest outcrop to half the distance to Level E (130 feet vertically)					88,000	88,000
Level E ore body						
Surface to Level E	170,000	127,000				
Level C, 70 feet above to 70 feet below			195,000	136,000		
North ore body						
Surface to C 7	231,000	162,000				
C 7 to C 4	112,000	78,000				
C 4 to C	114,000	80,000				
C to A 5	39,000	28,000				
A 5 to A 4	40,000	28,000				
A 4 to A 3	30,000	21,000				
A 3 to A 2	26,000	18,000				
A 2 to A 1	27,000	19,000				
A 1 to Grizzly	44,000	31,000				
Grizzly to A	128,000	90,000				
A to 250			415,000	290,000	113,000	79,000
250 to drill hole 500 feet below			225,000	158,000	225,000	158,000
Pinnacle ore body						
Above lowest outcrop			18,000	11,000		
Lowest outcrop to half the distance to C 7 (106 feet vertically)					72,000	43,000
South ore body						
Pillars around level C	7,000	5,000				
Level A to drill hole 580 feet below			139,000	104,000	70,000	52,000
	968,000	687,000	1,026,000	733,000	568,000	420,000
Total 2,562,000 tons containing 1,840,000 units WO_3						

TABLE 5. - RESERVES OF MOLYBDENUM ORE IN THE NORTH ORE BODY.

	Independent of Tungsten Ore				Coextensive with Tungsten Ore			
	Measured		Indicated		Measured		Indicated	
	0.4% MoS_2 or more	0.7% MoS_2 or more	0.4% MoS_2 or more	0.7% MoS_2 or more	0.4% MoS_2 or more	0.7% MoS_2 or more	0.4% MoS_2 or more	0.7% MoS_2 or more
Surface to C 4	---	---	18,000	224,000	---	---	---	28,000
C 4 to C	7,000	109,000	---	---	---	15,000	---	---
C to A 5	5,000	18,000	---	---	5,000	13,000	---	---
A 5 to A 4	11,000	19,000	---	---	12,000	7,000	---	---
A 4 to A 3	10,000	28,000	---	---	6,000	6,000	---	---
A 3 to A 2	2,000	36,000	---	---	2,000	6,000	---	---
A 2 to A 1	8,000	19,000	---	---	4,000	5,000	---	---
A 1 to Grizzly	17,000	11,000	---	---	9,000	8,000	---	---
Grizzly to A	27,000	43,000	---	---	19,000	25,000	---	---
A to 30 feet below	---	---	18,000	26,000	---	---	15,000	13,000
	87,000	283,000	36,000	250,000	57,000	85,000	15,000	41,000

198,000 tons coextensive with tungsten ore.
656,000 tons independent of tungsten ore.

854,000 tons, average grade 1.0% MoS_2.



PINE CREEK MINE
U. S. VANADIUM CORPORATION

LEVEL 250

AUGUST 1944

Geology by P. C. Bateman

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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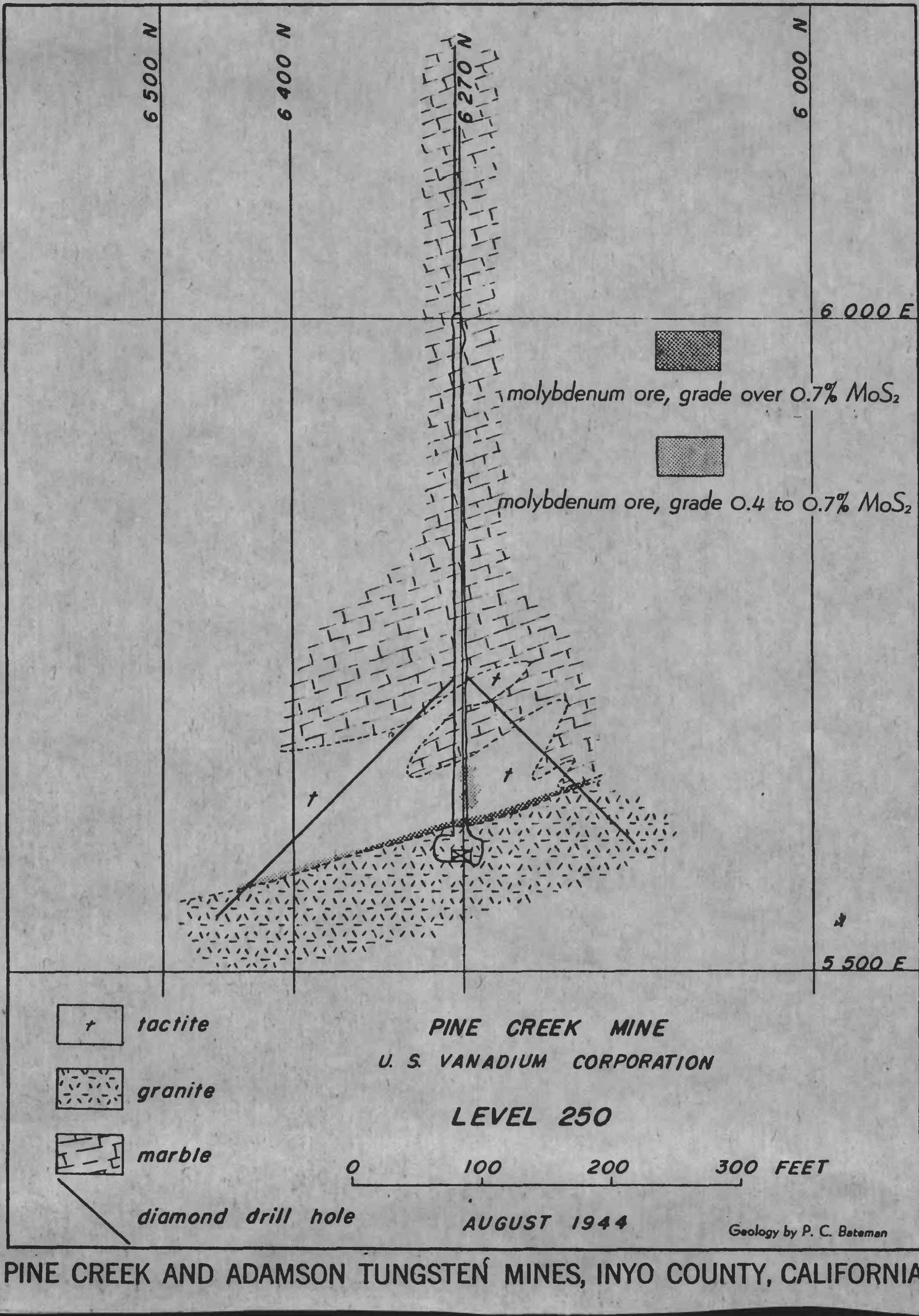
STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP
PLATE 4 A



PINE CREEK MINE

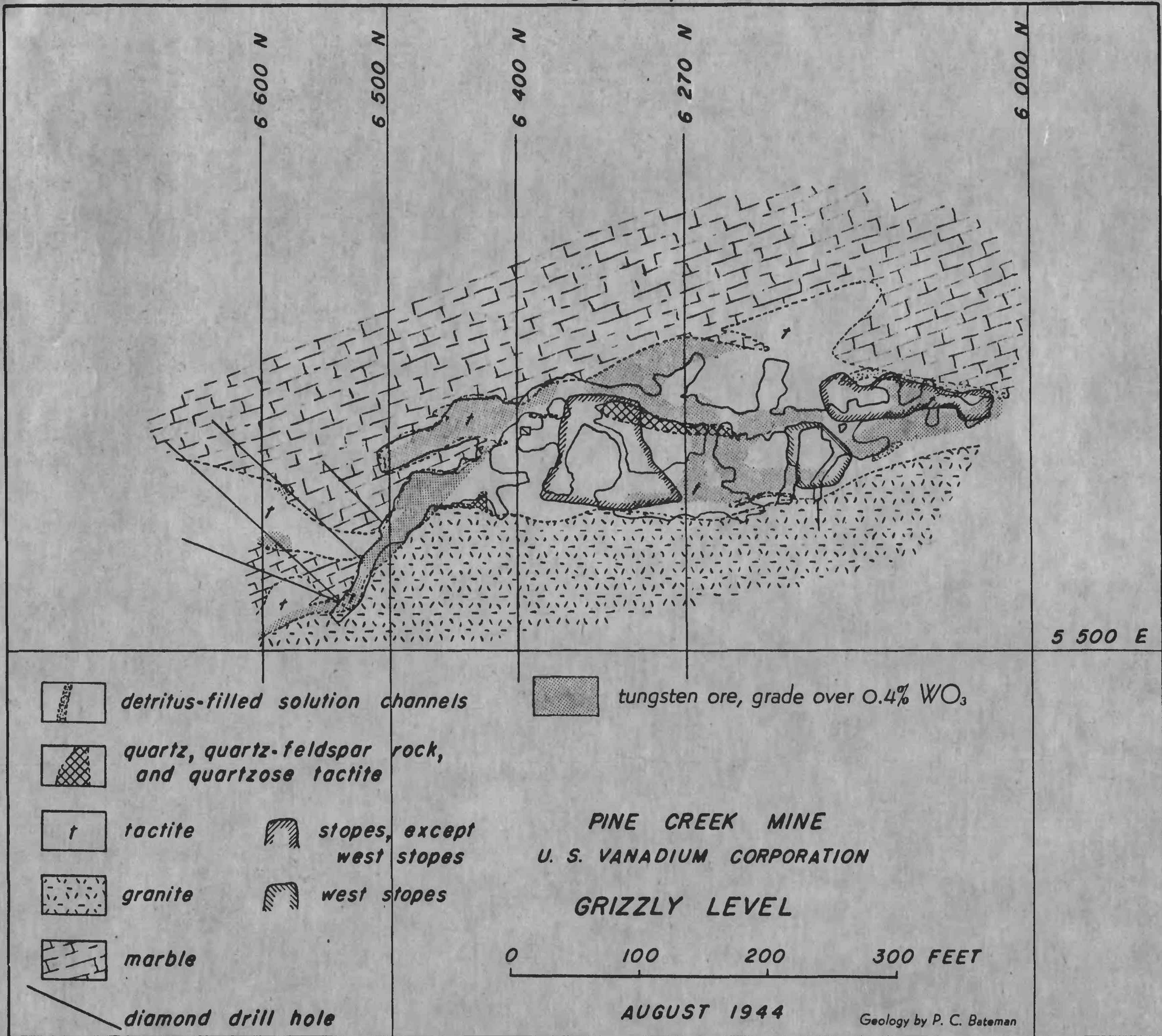
U. S. VANADIUM CORPORATION

LEVEL 250

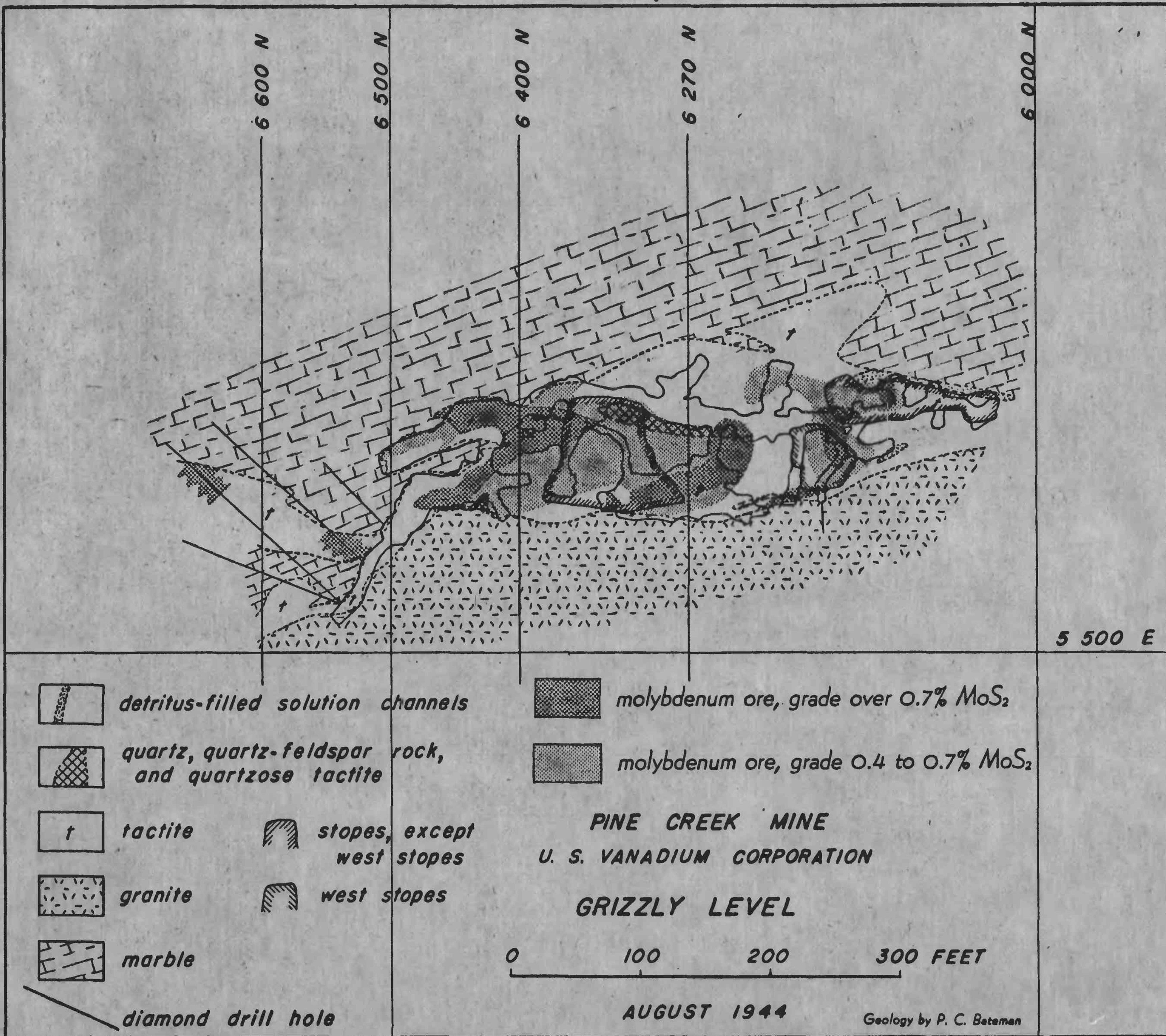
AUGUST 1944

Geology by P. C. Bateman

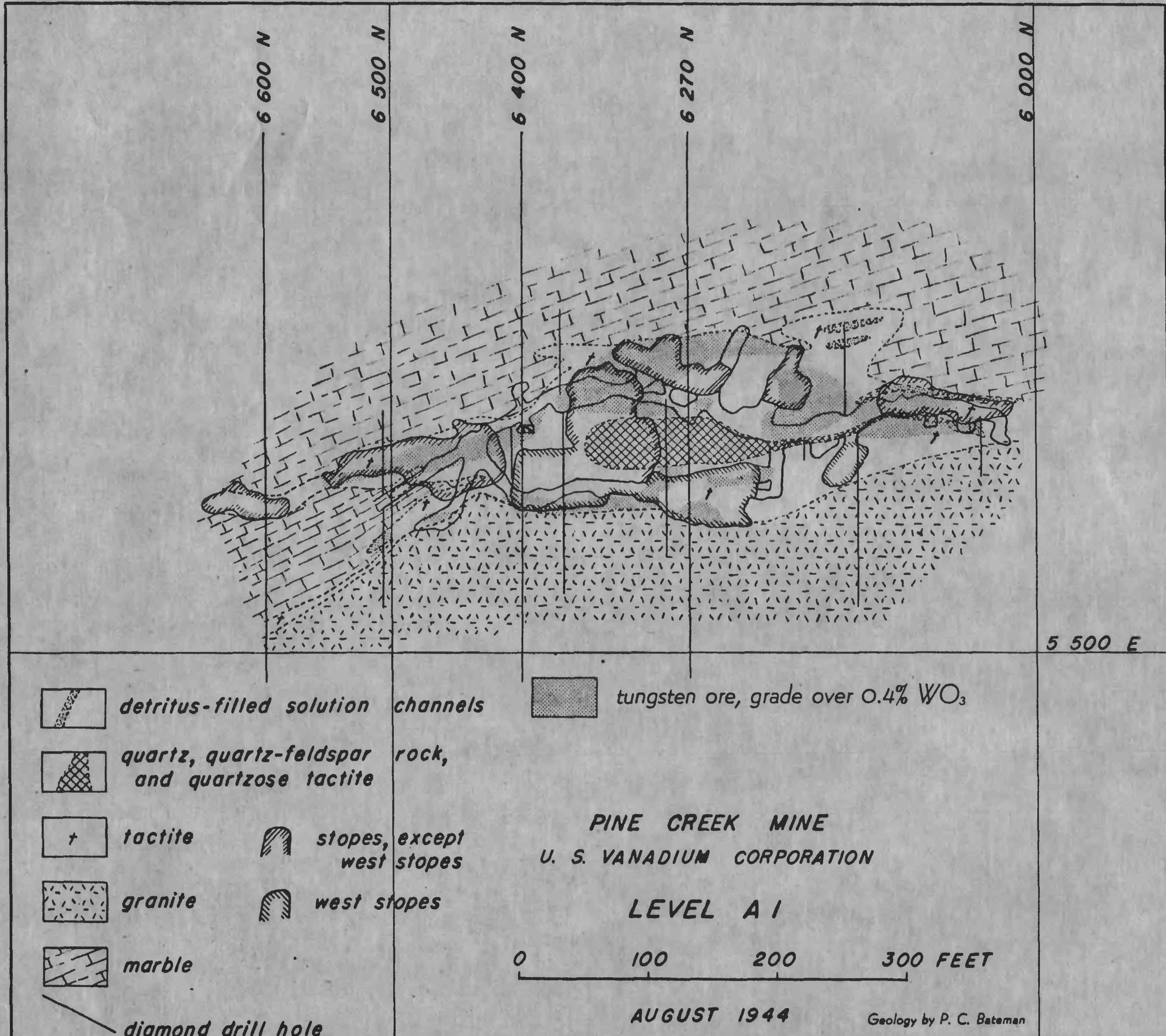
PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



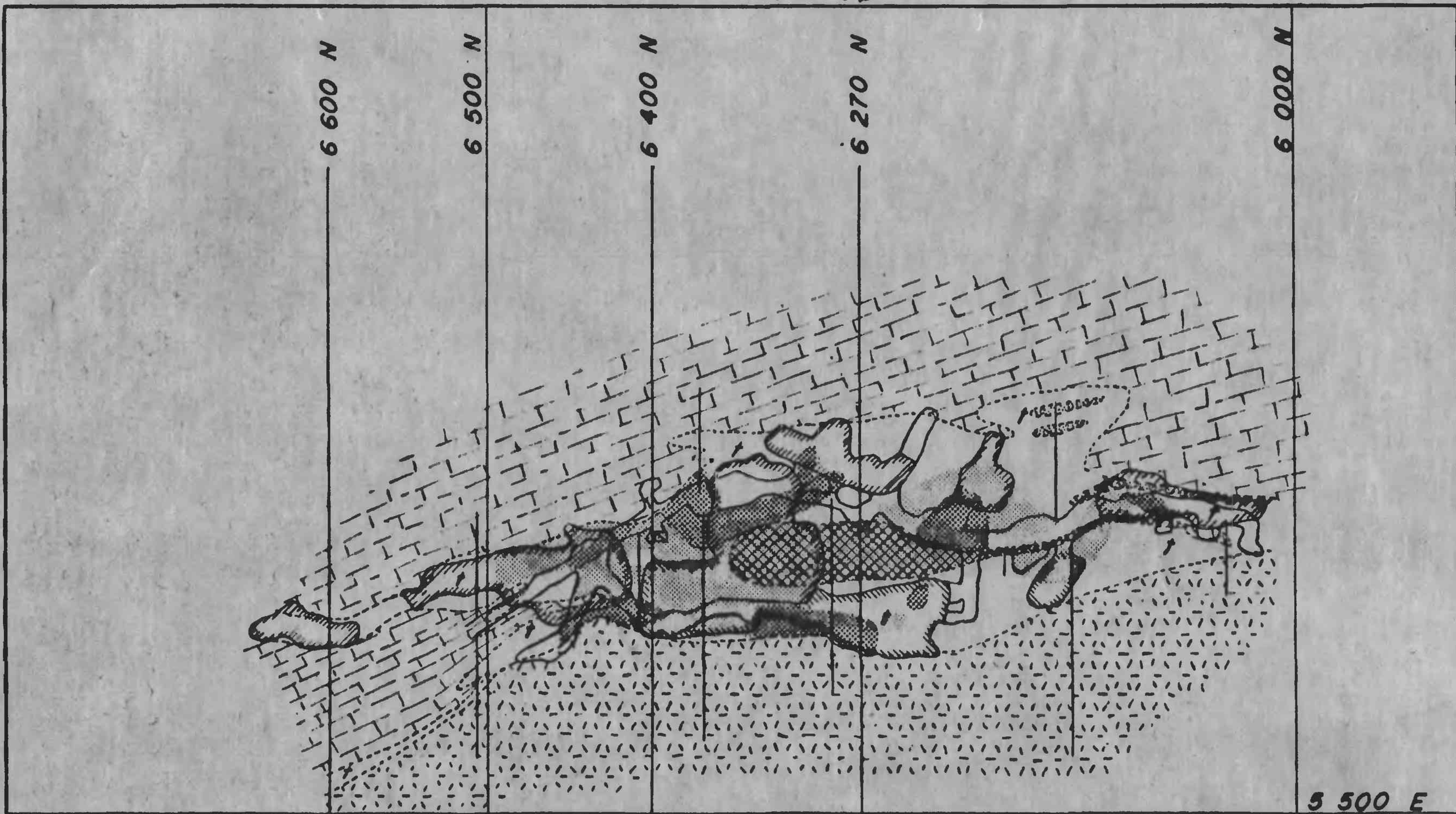
PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



detritus-filled solution channels

quartz, quartz-feldspar rock, and quartzose tactite

tactite

granite

marble

diamond drill hole

stopes, except west stopes

west stopes

molybdenum ore, grade over 0.7% MoS_2

molybdenum ore, grade 0.4 to 0.7% MoS_2

PINE CREEK MINE

U. S. VANADIUM CORPORATION

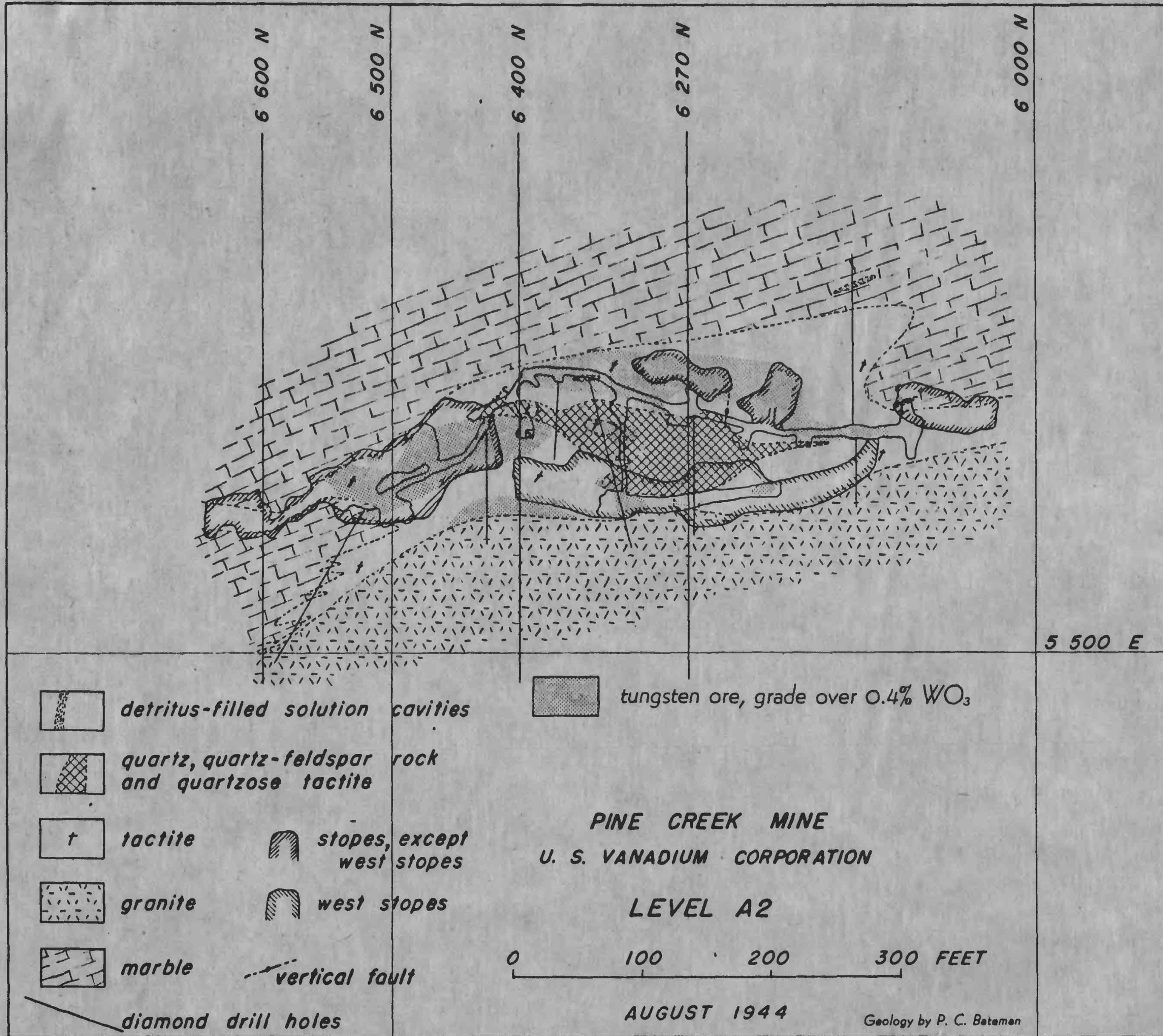
LEVEL A I

0 100 200 300 FEET

AUGUST 1944

Geology by P. C. Bateman

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



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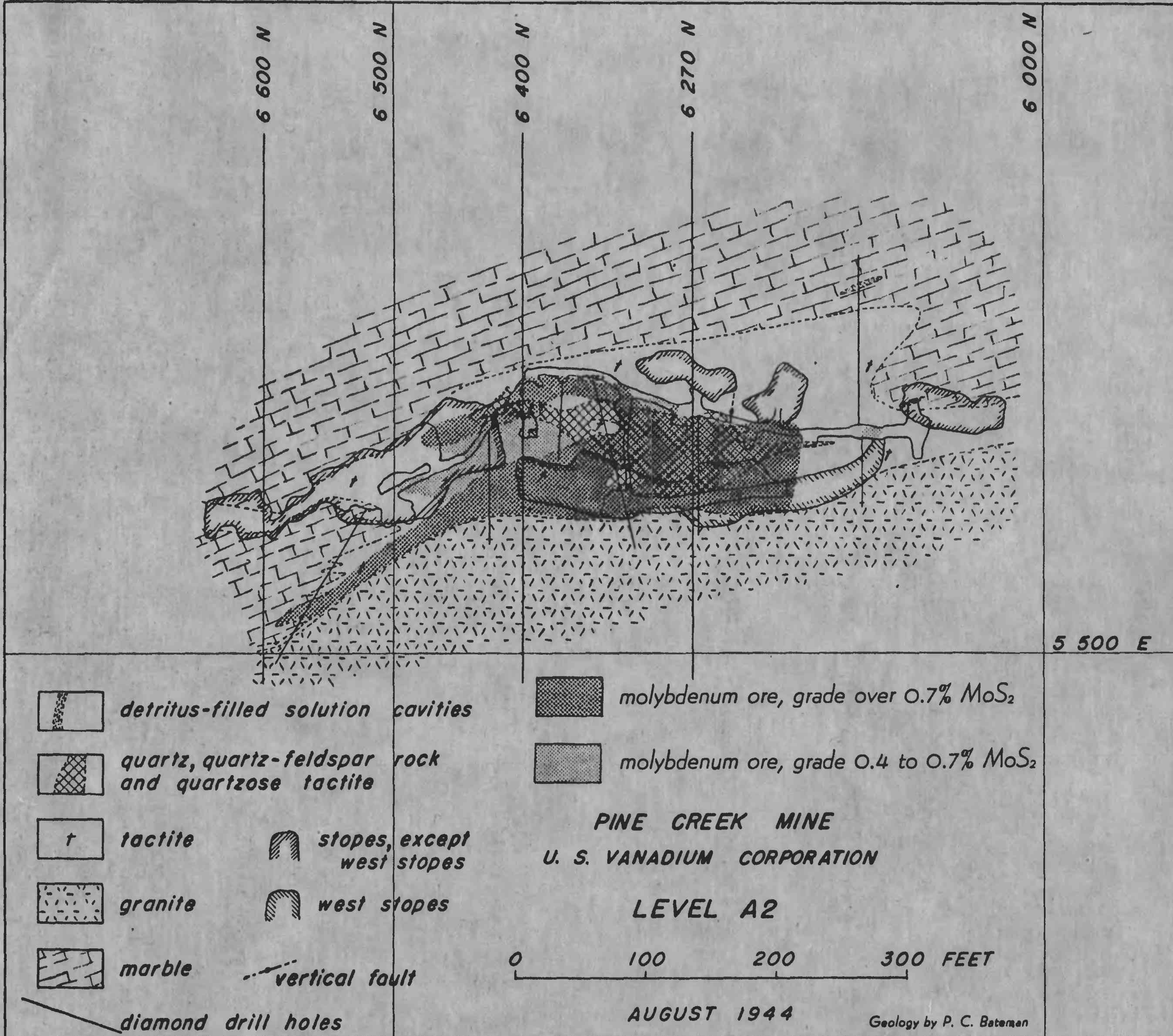

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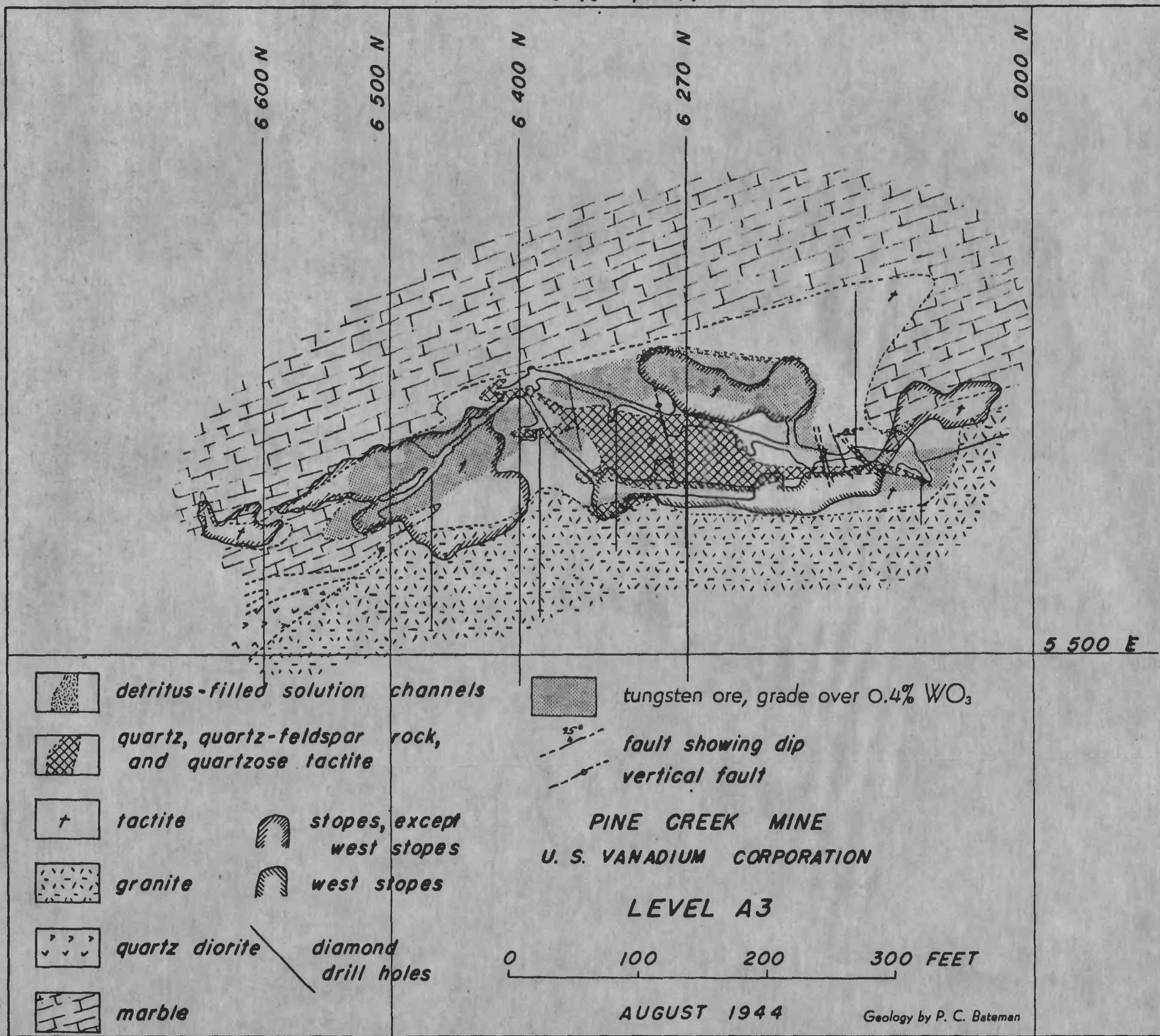

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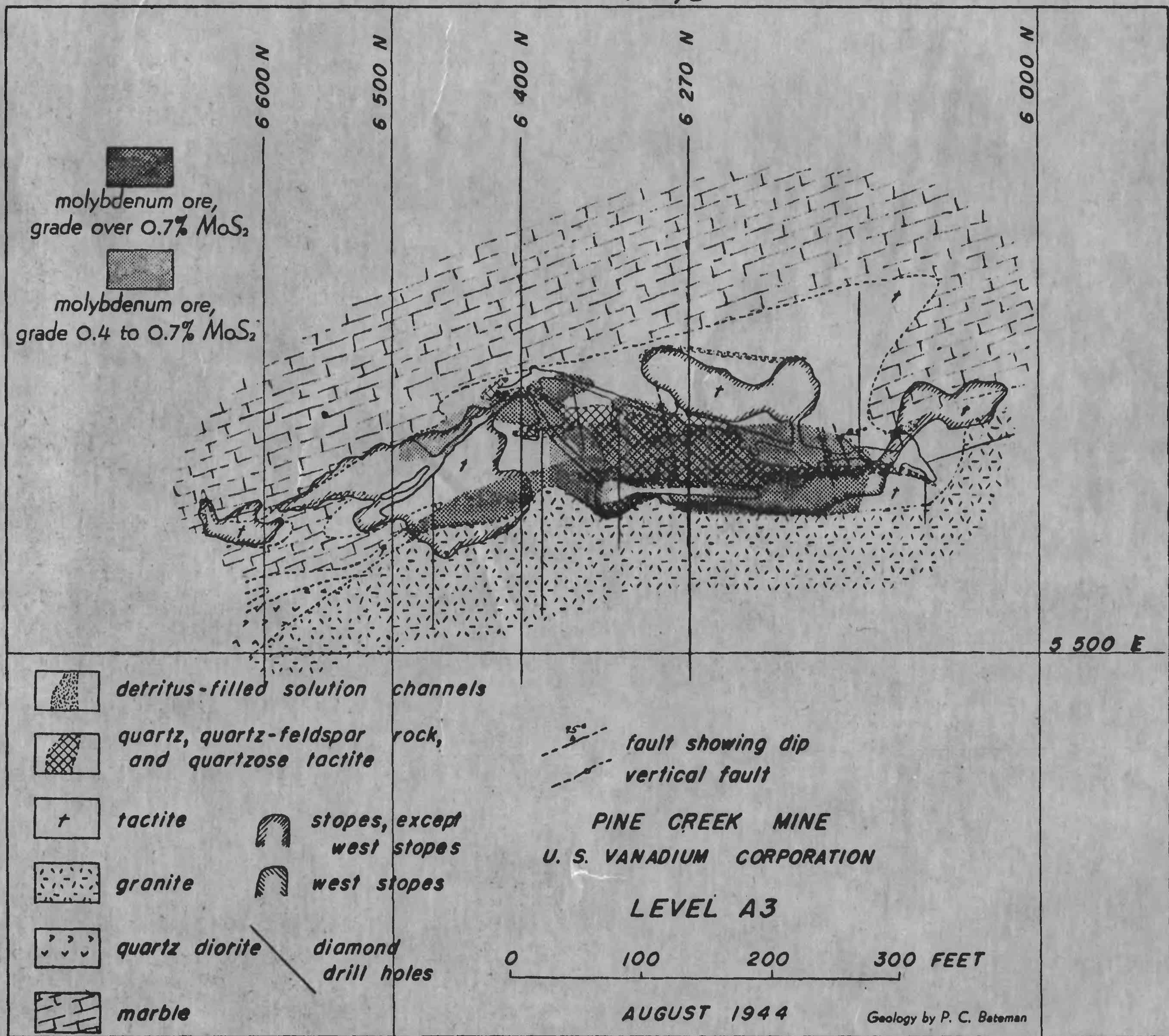

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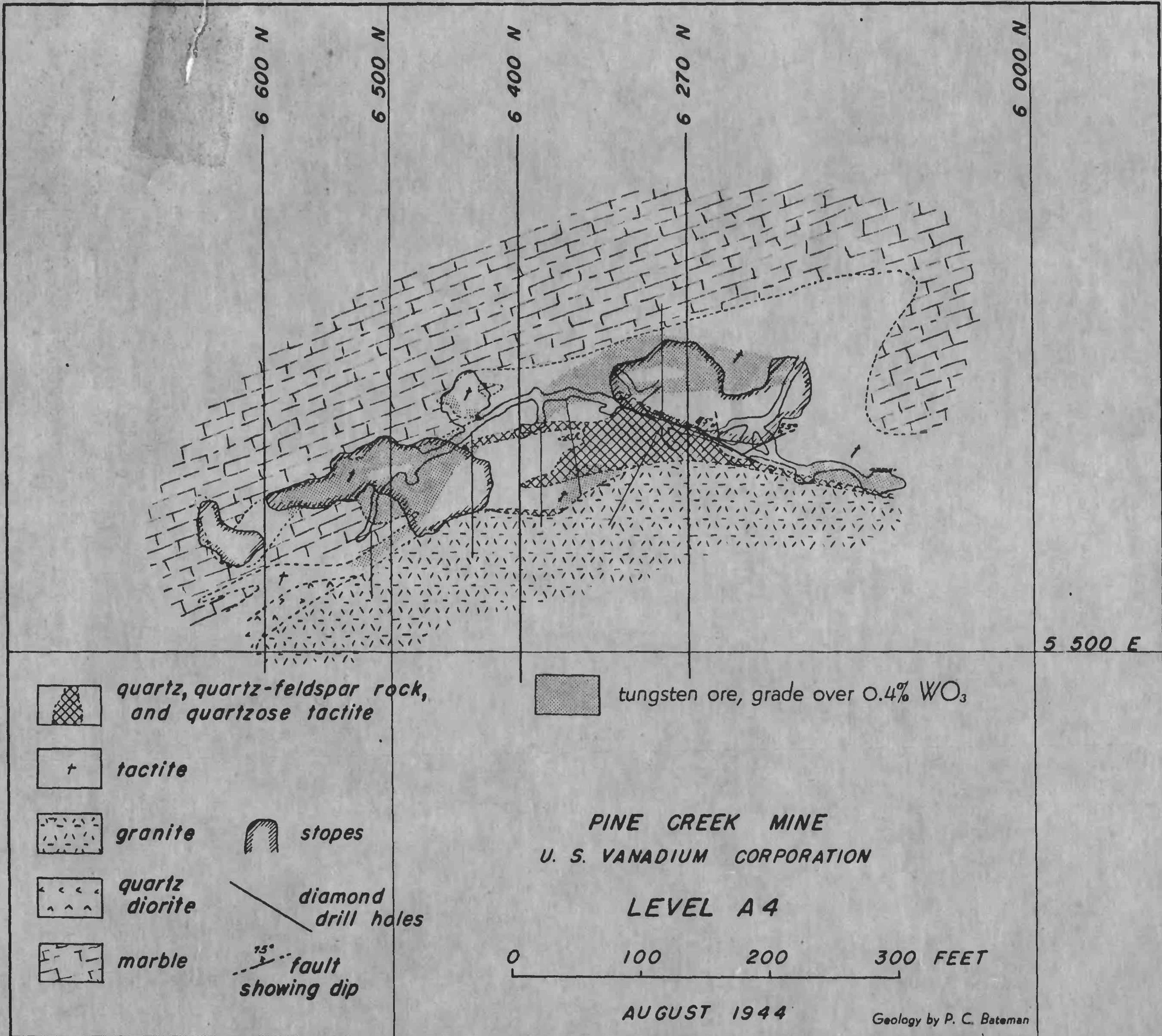

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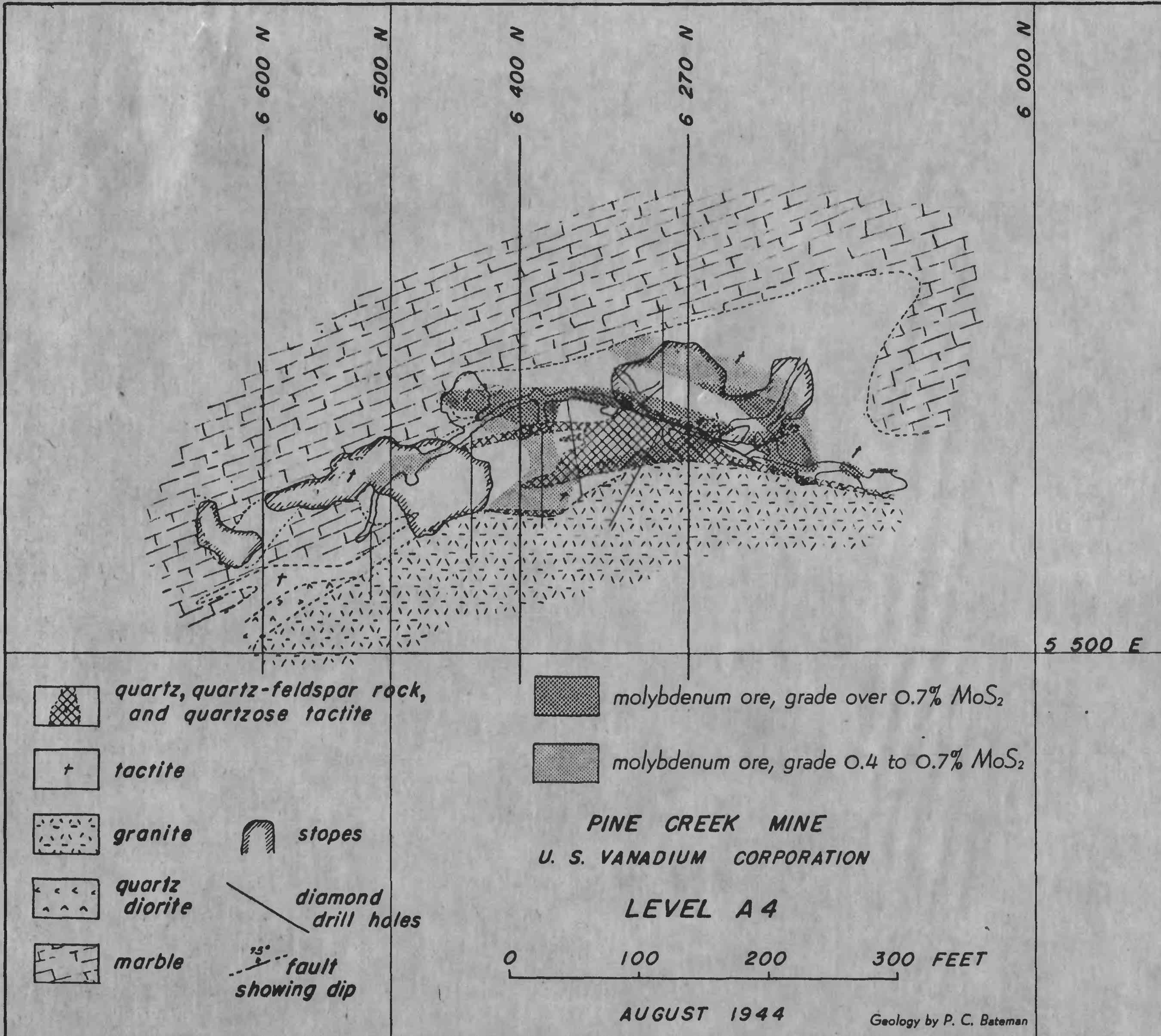
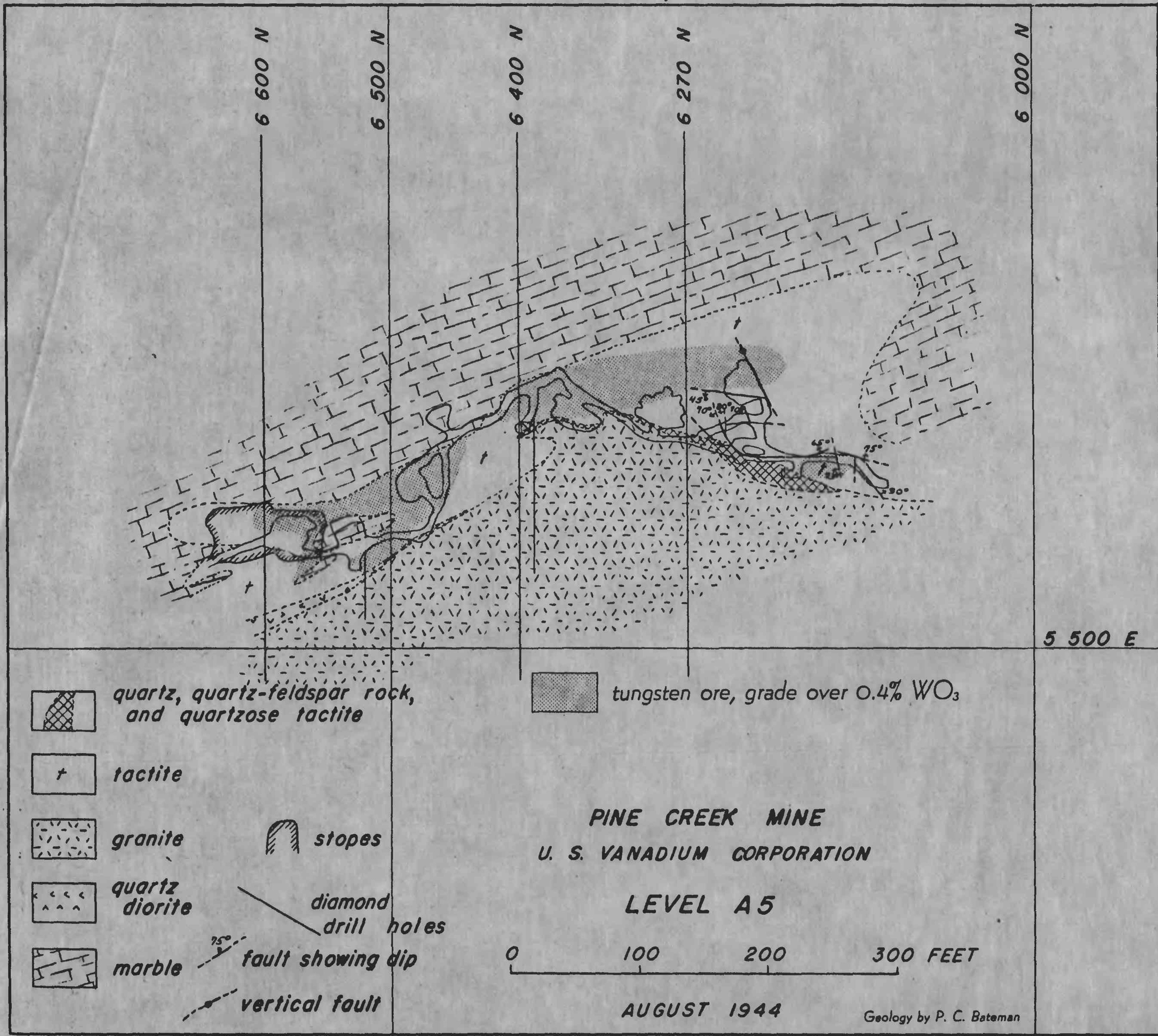


PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



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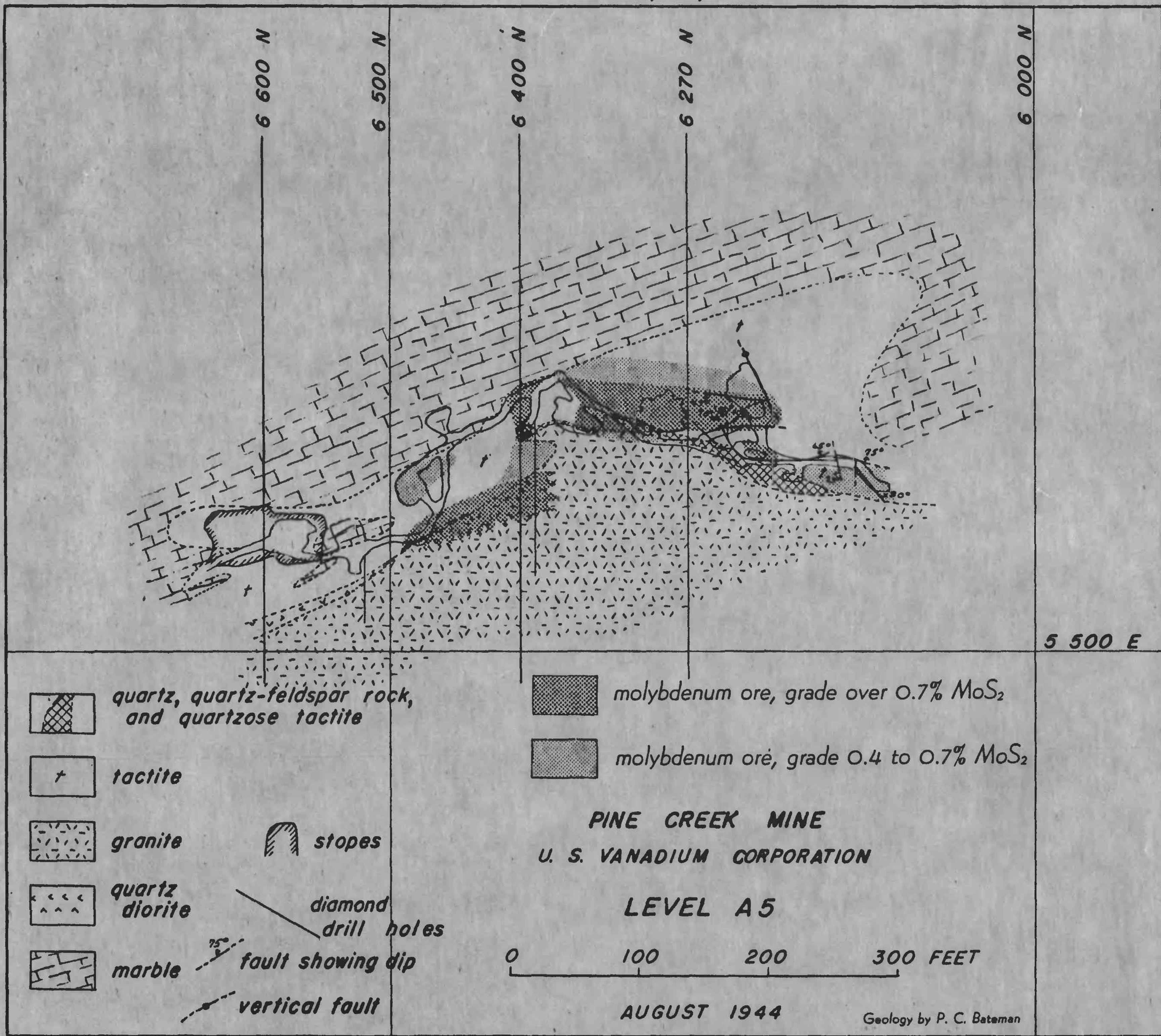

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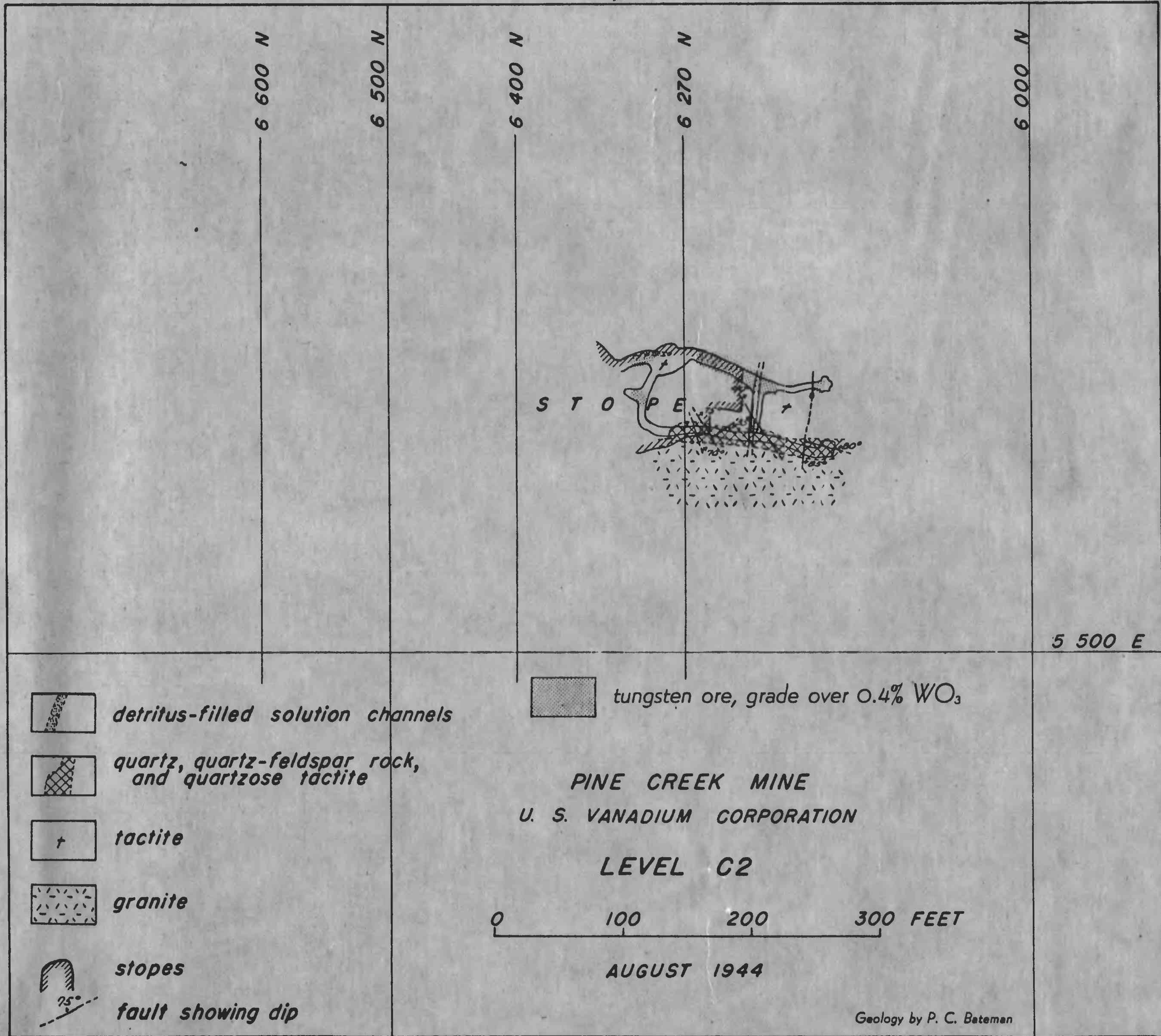
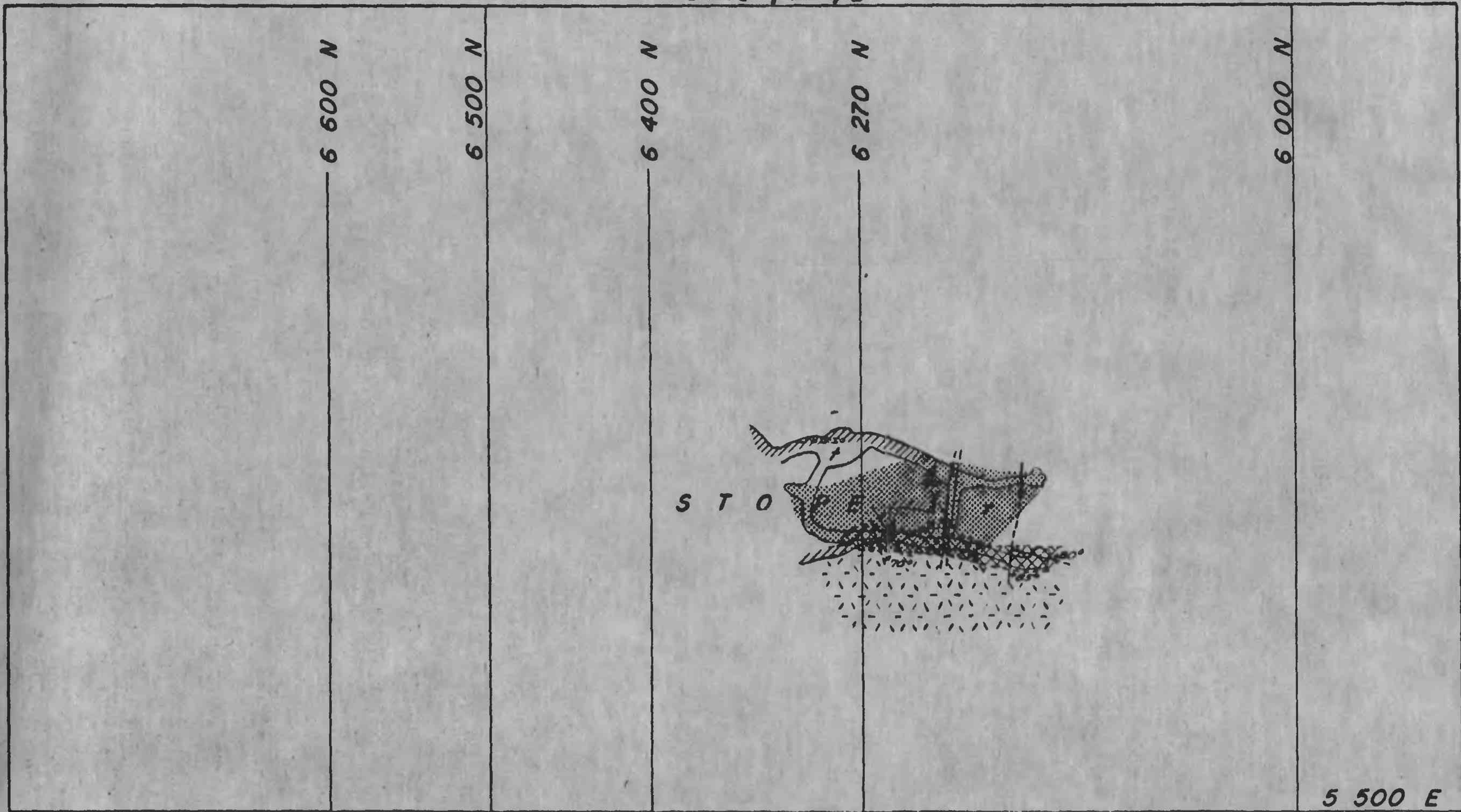


PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



detritus-filled solution channels

quartz, quartz-feldspar rock, and quartzose tactite

tactite

granite

stopes

fault showing dip

molybdenum ore, grade over 0.7% MoS_2

PINE CREEK MINE

U. S. VANADIUM CORPORATION

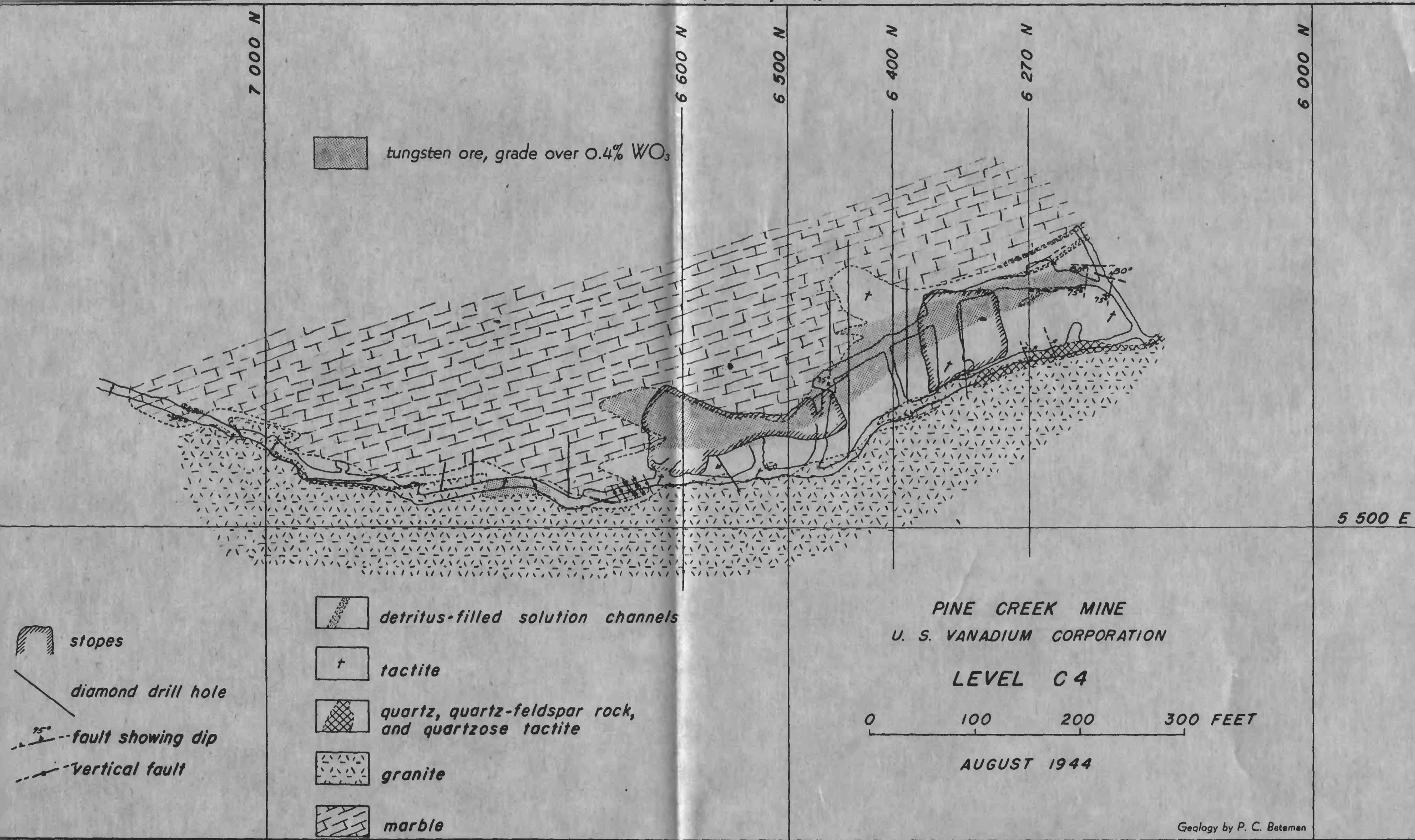
LEVEL C2

0 100 200 300 FEET

AUGUST 1944

Geology by P. C. Bateman

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



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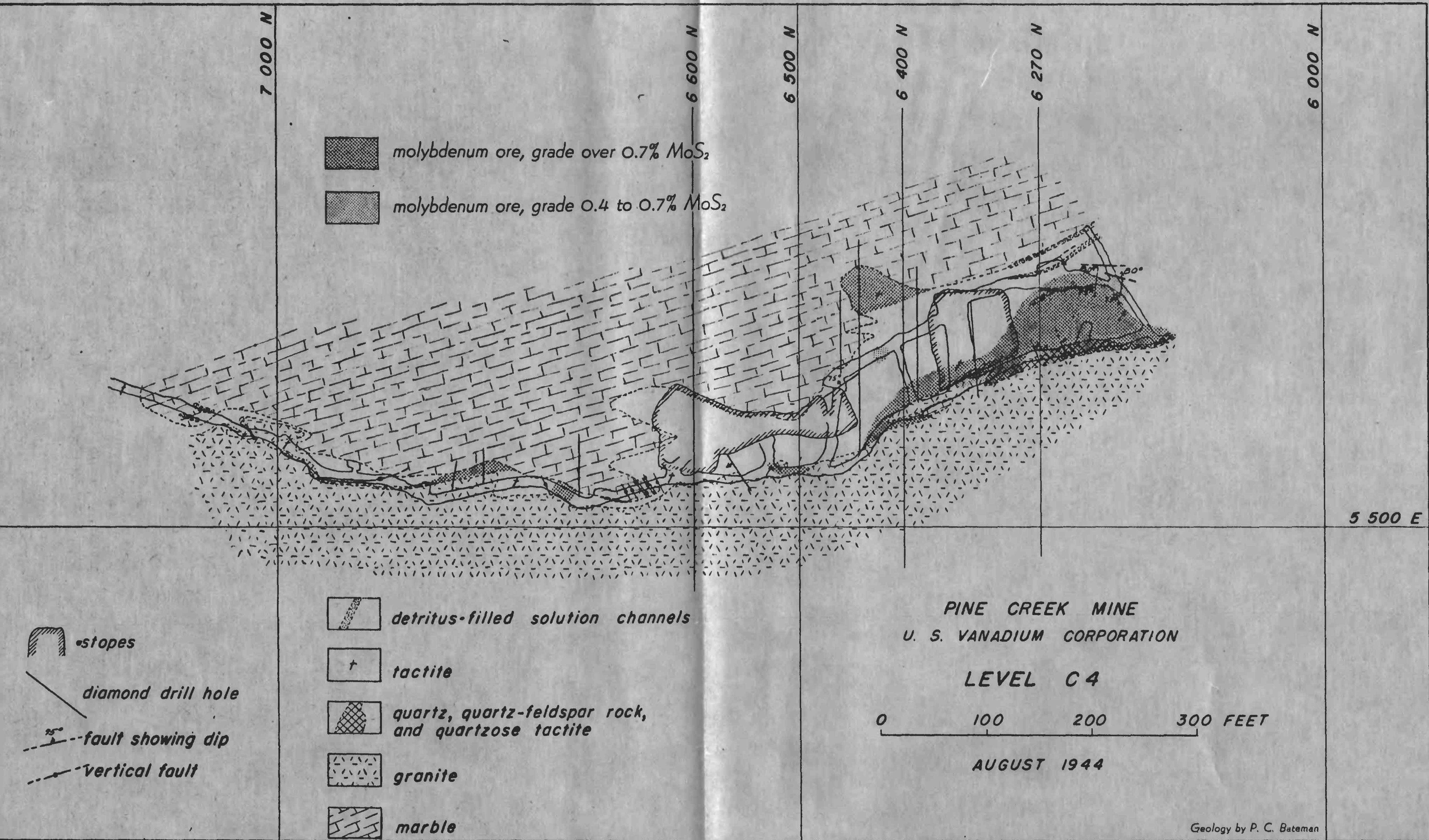

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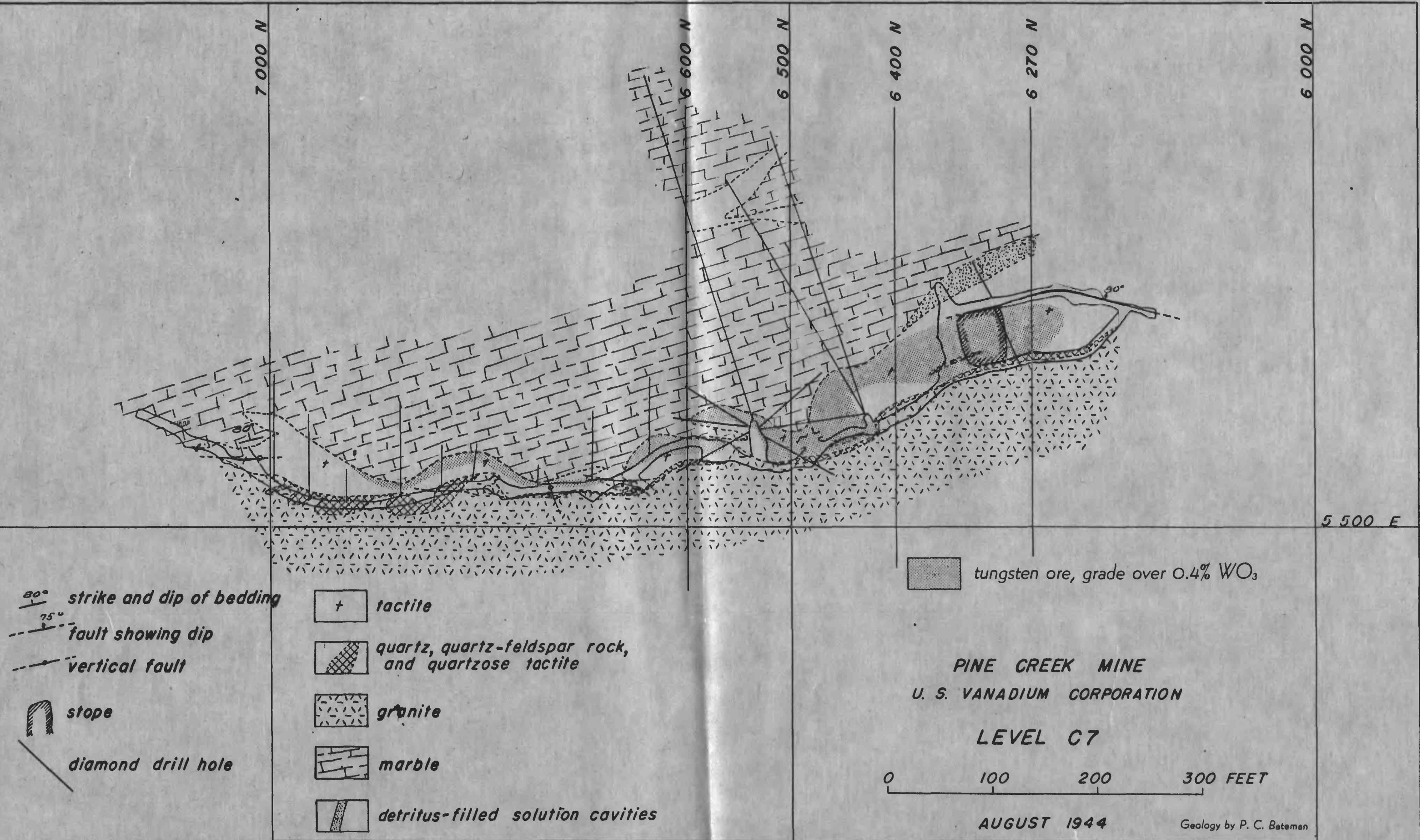

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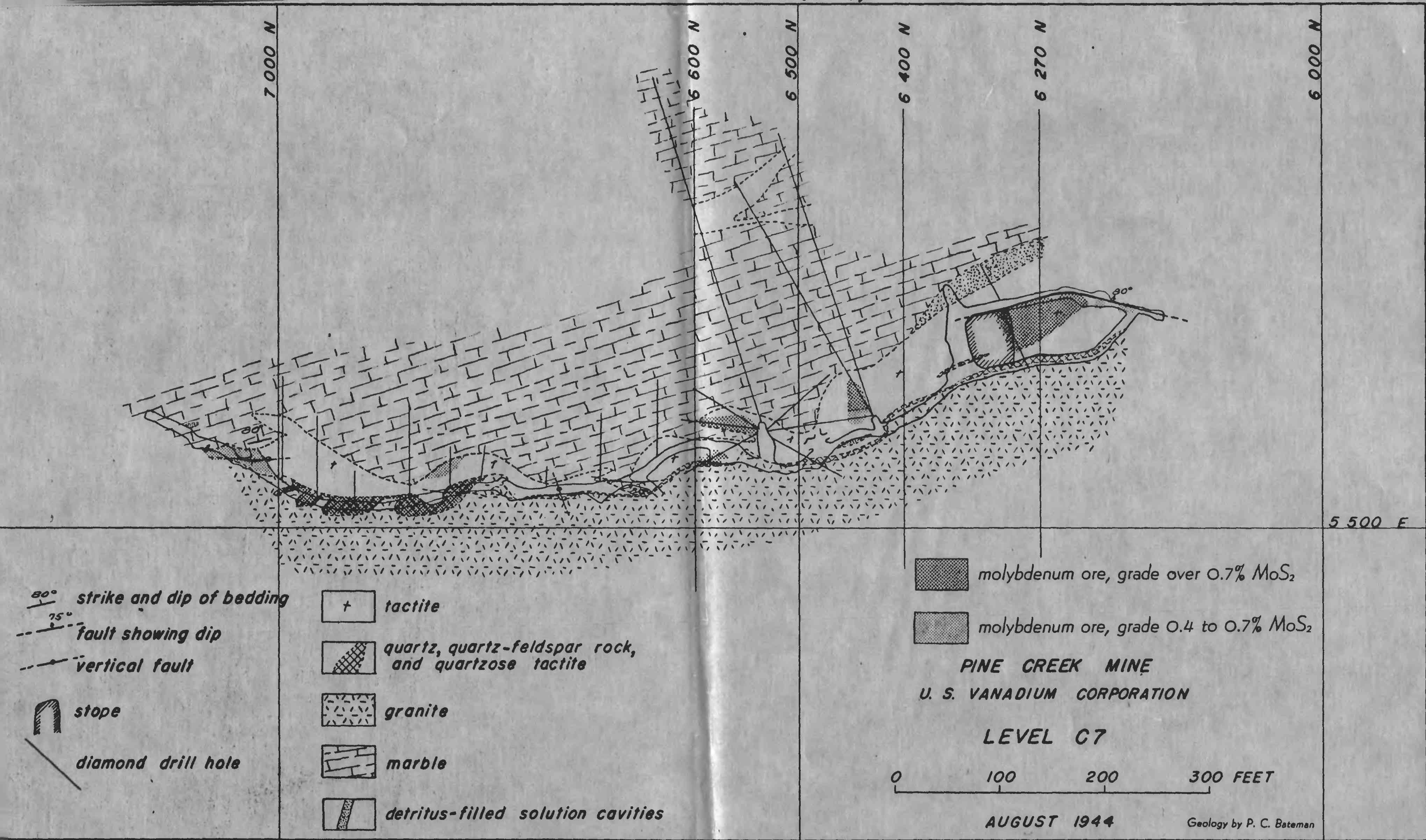

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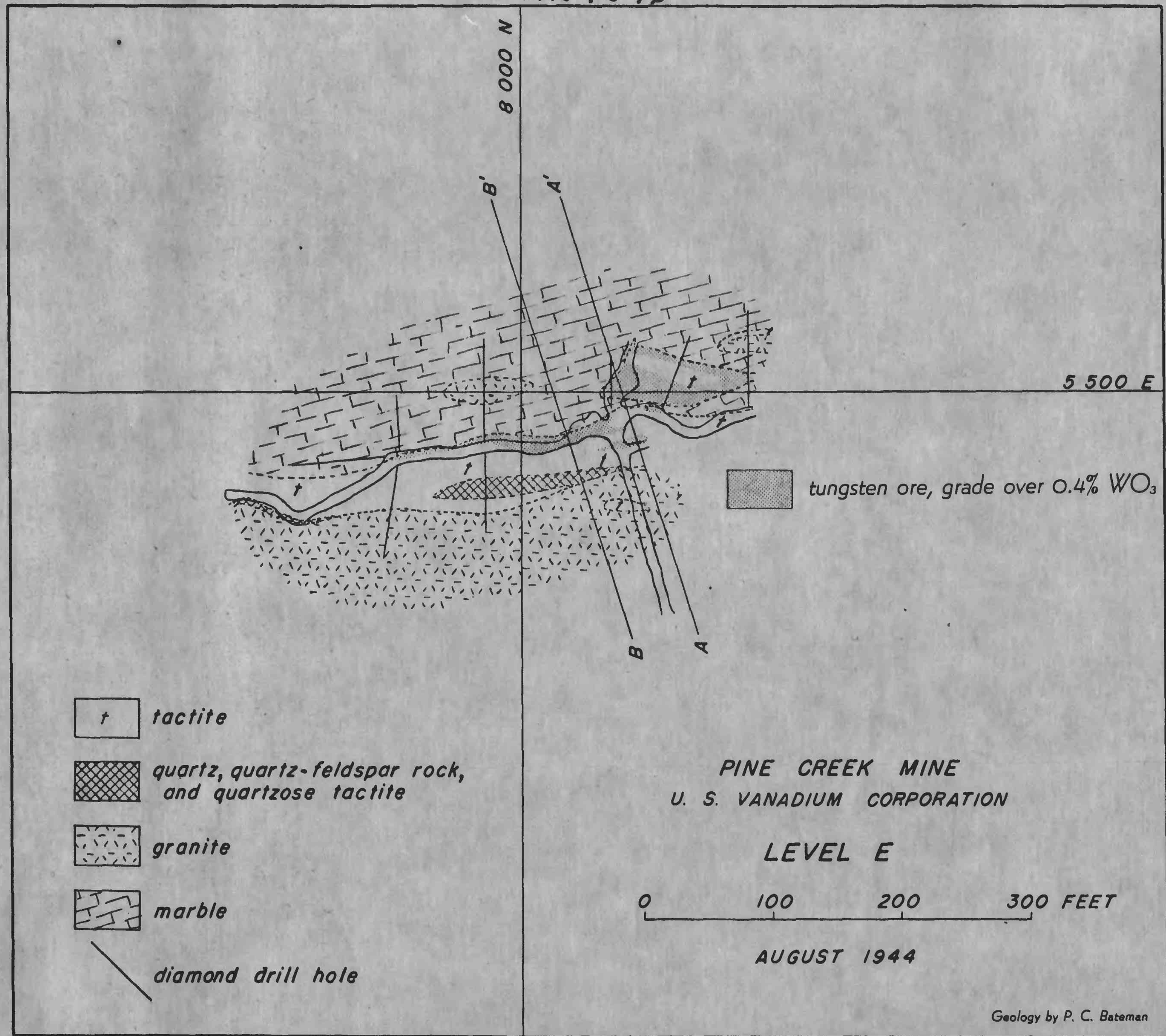

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

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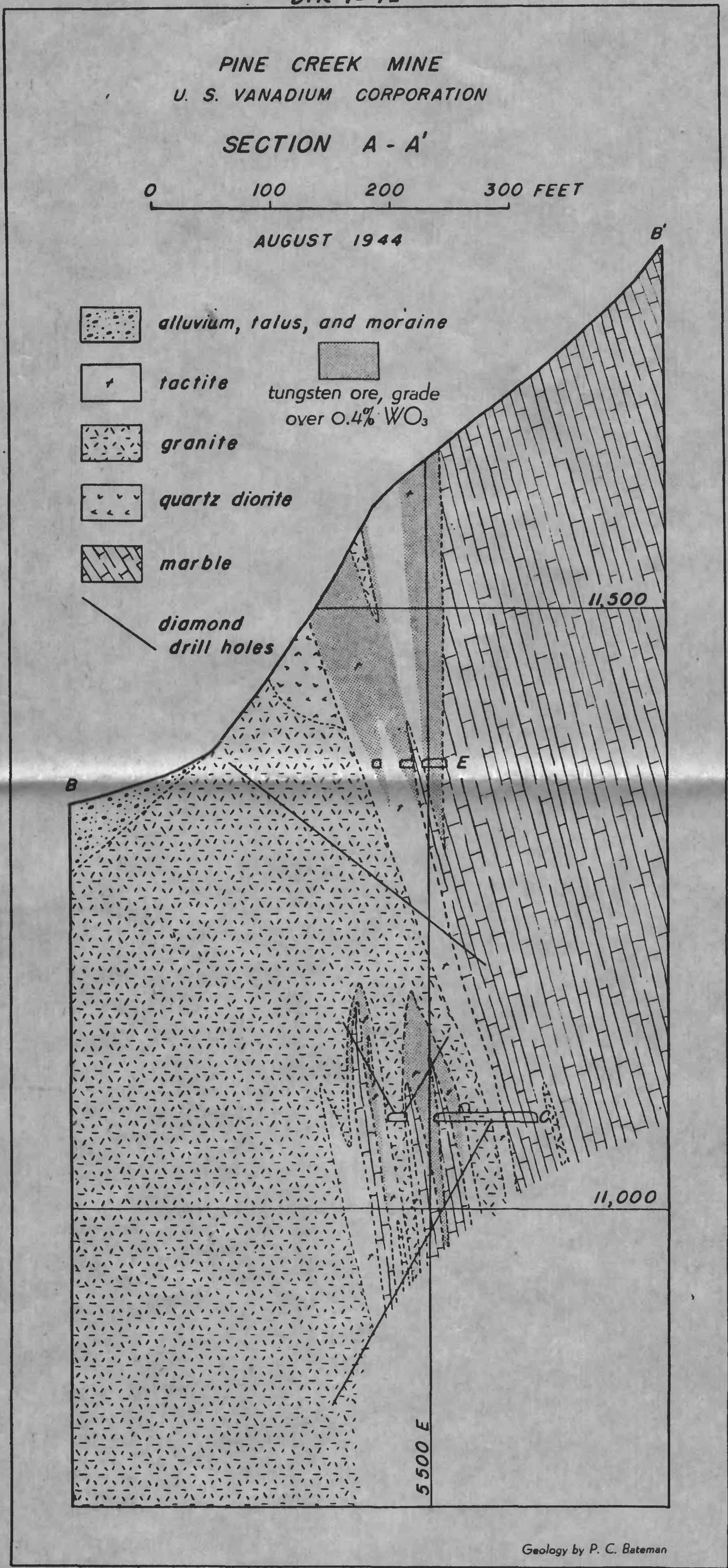

PINE CREEK AND ADAMSON TUNGSTEN MINES,
INYO COUNTY, CALIFORNIA

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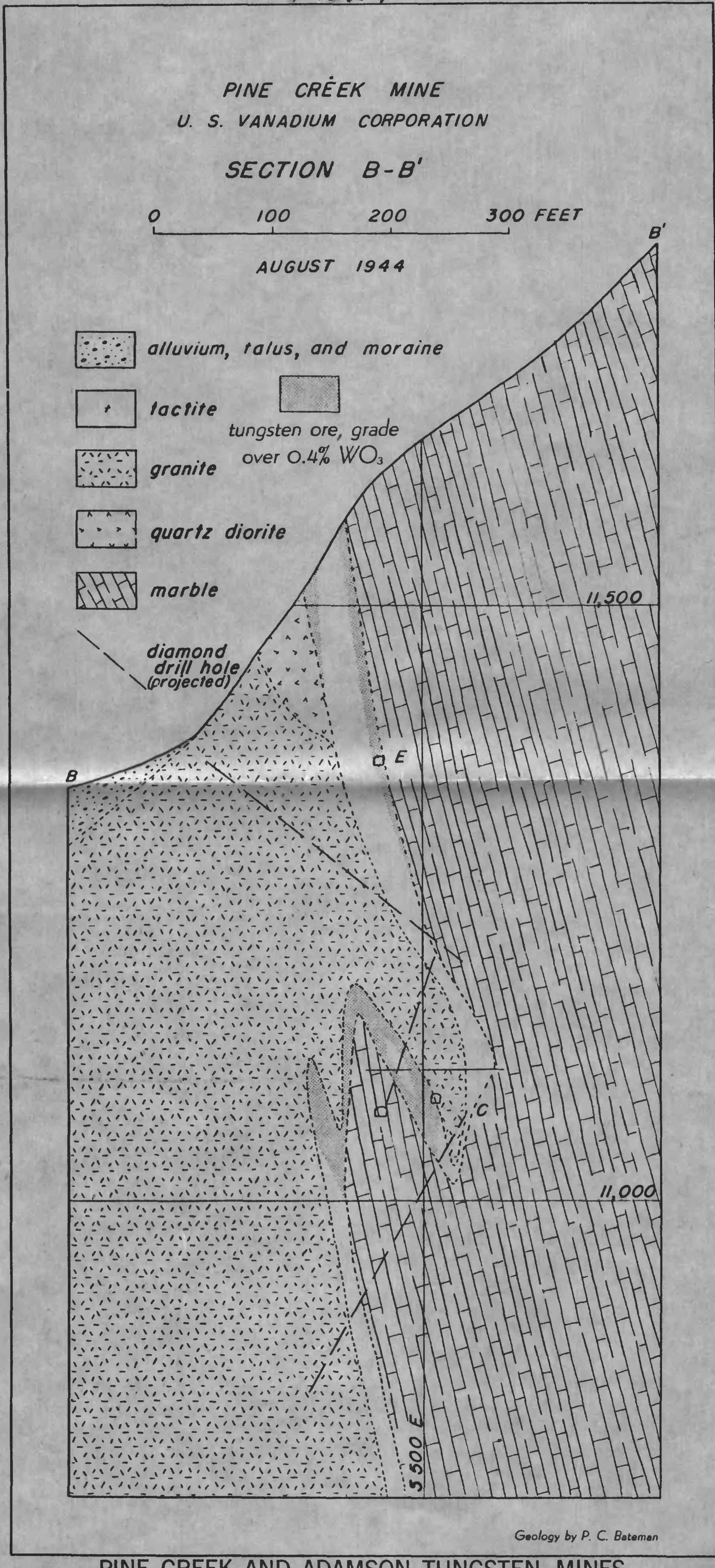
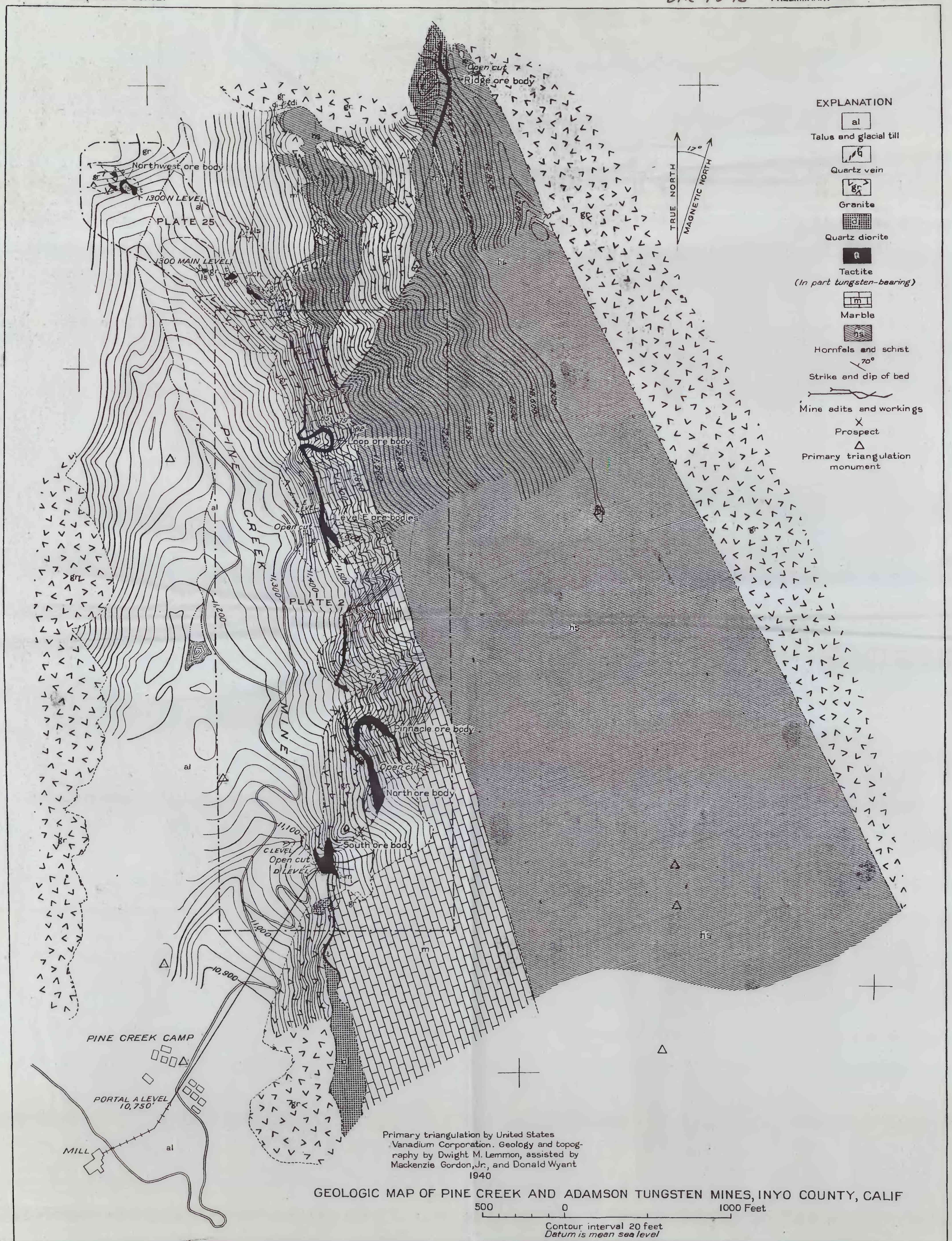


PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

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PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

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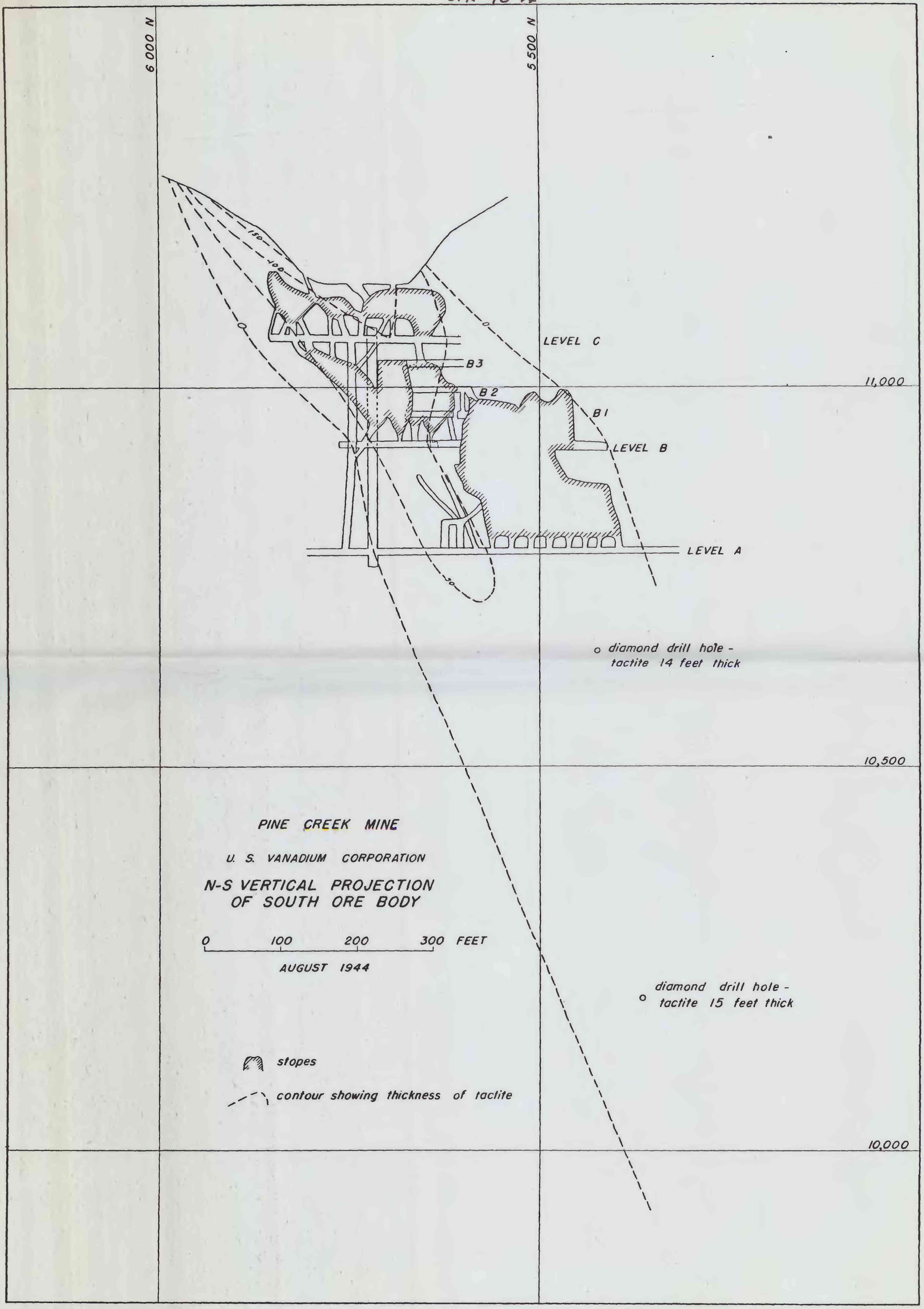
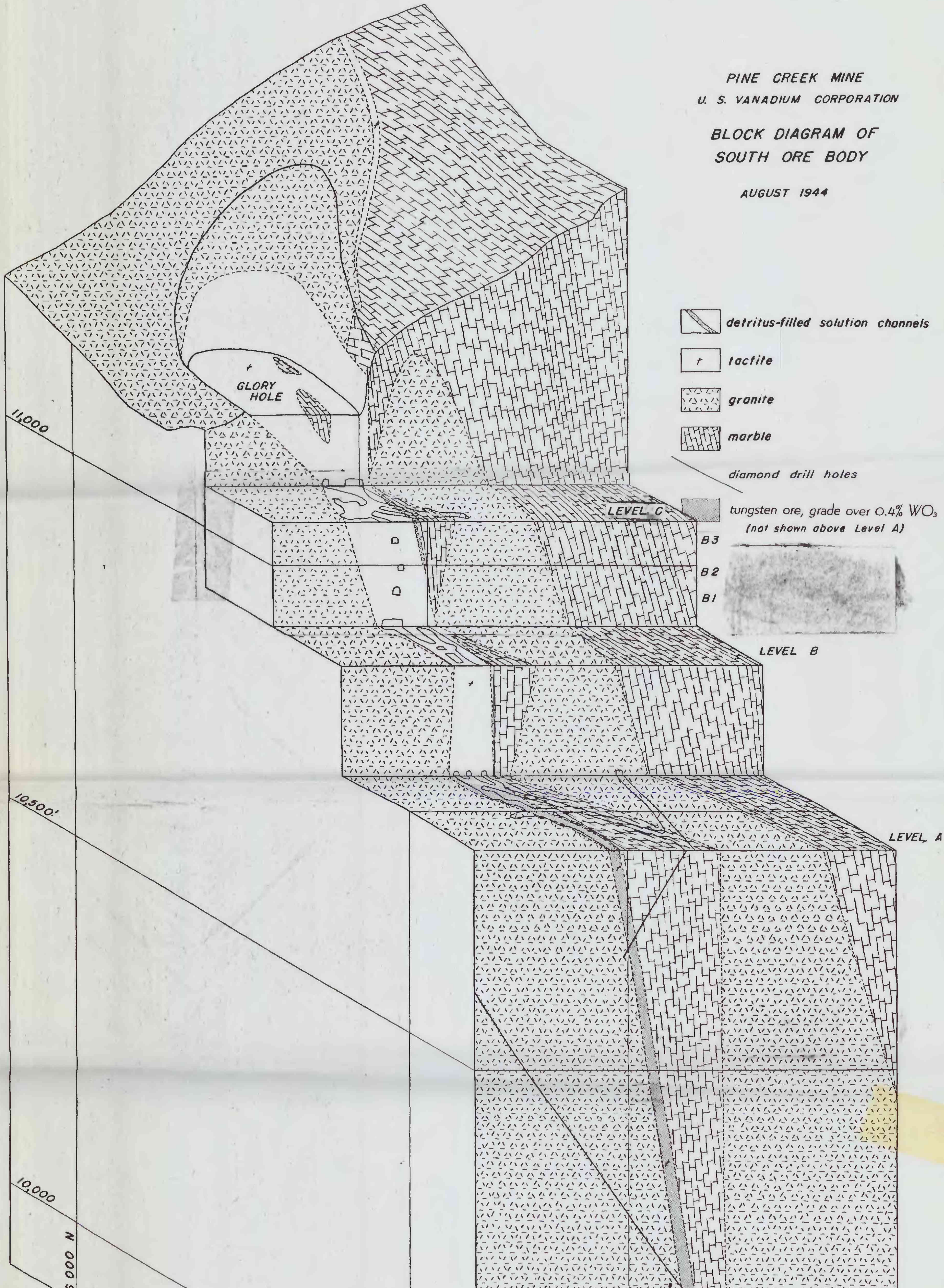


PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

PINE CREEK MINE
U. S. VANADIUM CORPORATION

BLOCK DIAGRAM OF SOUTH ORE BODY

AUGUST 1944



Geology by P. C. Bateman

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

OFR 45-96

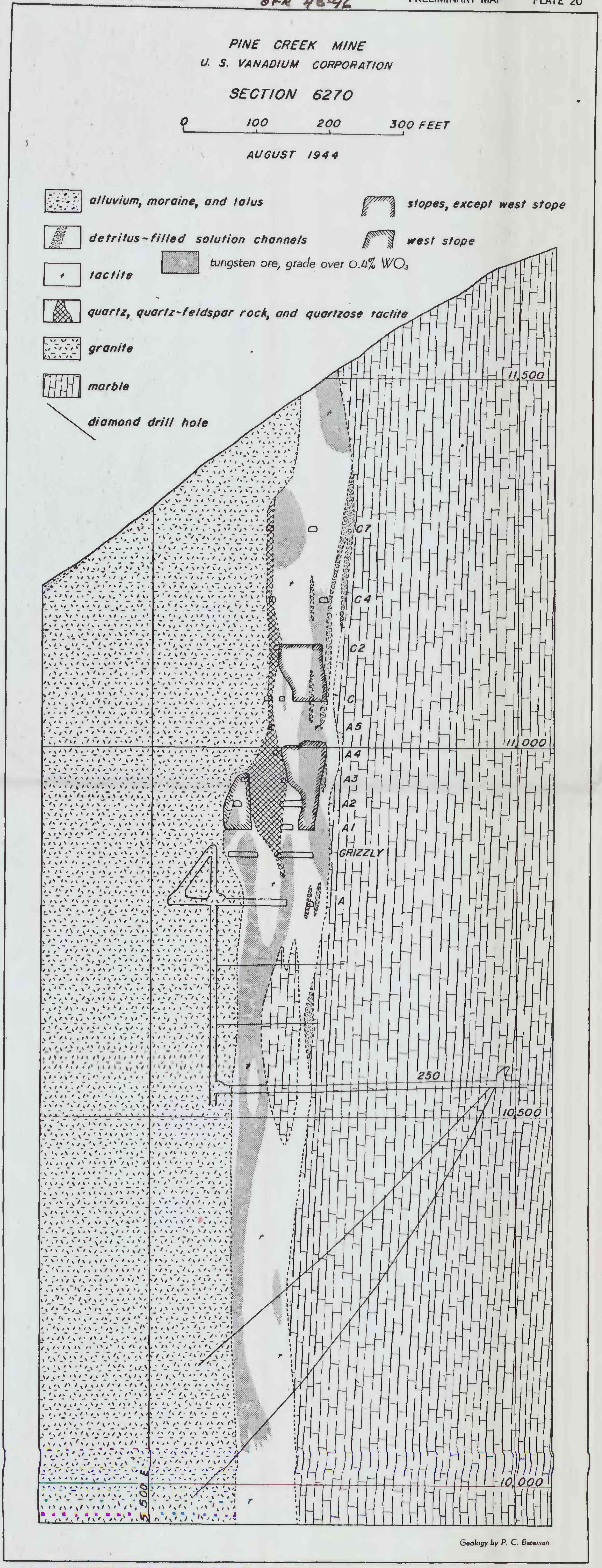

8 000 N
7 000 N
6 000 N
11,500
11,000
10,500
LEVEL E
LEVEL C
LEVEL A
LEVEL 250
CAVED
C 10
C 7
C 4
C 2
A5
A4
A 3
A 2
A 1
GRIZZLY
outlines of stopes - except west stopes
outlines of west stopes
PINE CREEK MINE
U. S. VANADIUM CORPORATION
N-S VERTICAL PROJECTION
OF NORTH ORE BODIES
0 100 200 300 FEET
AUGUST 1944

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

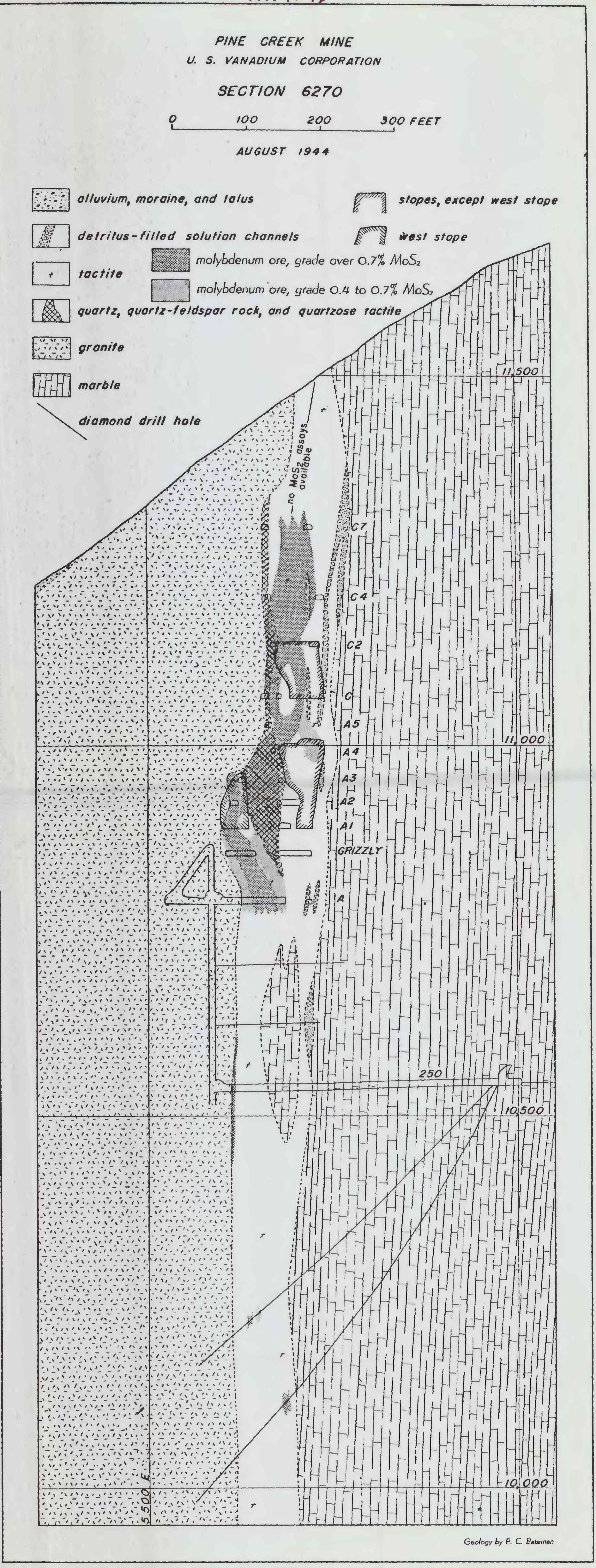
OFR 45-96

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP PLATE 2

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA



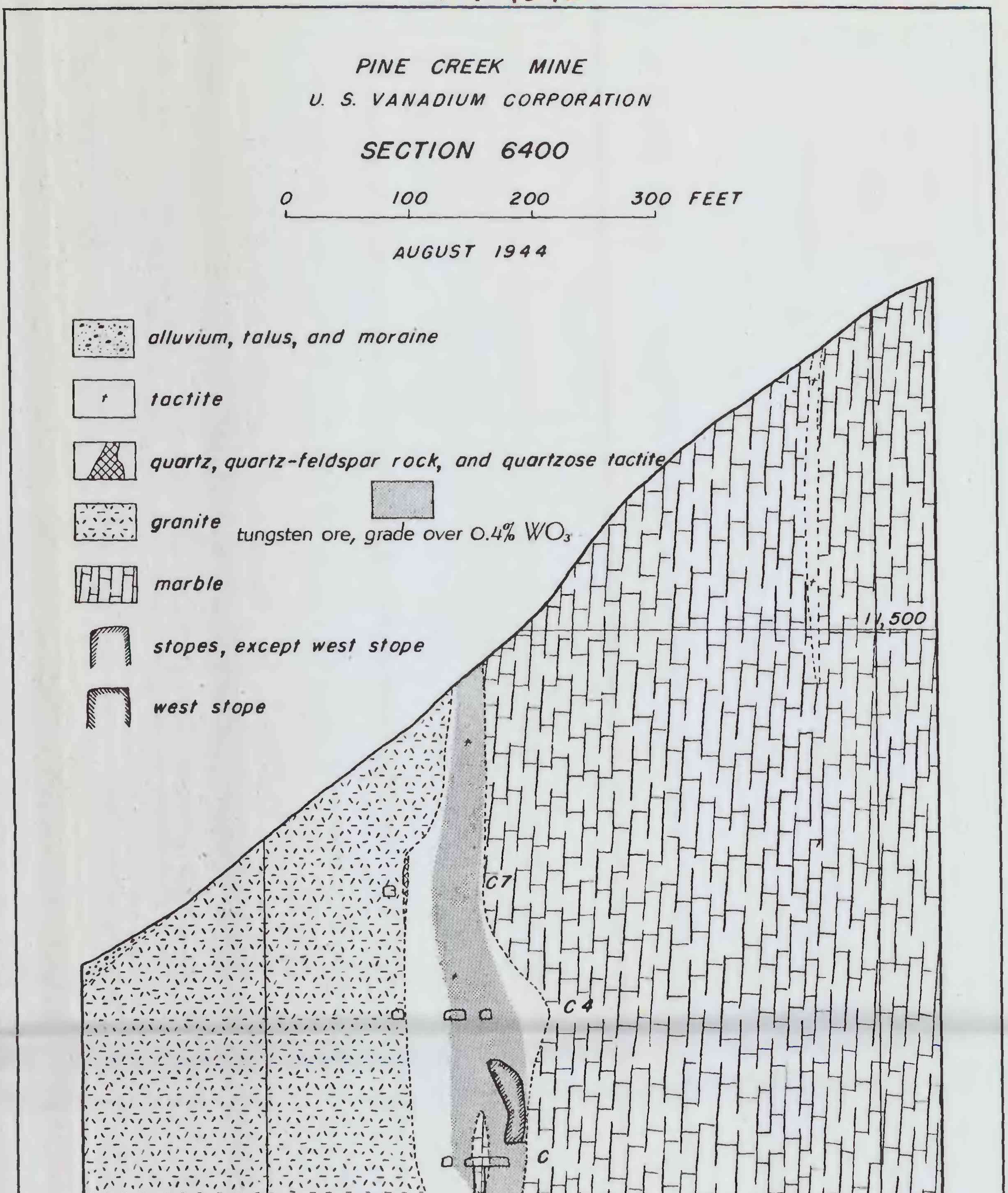
PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

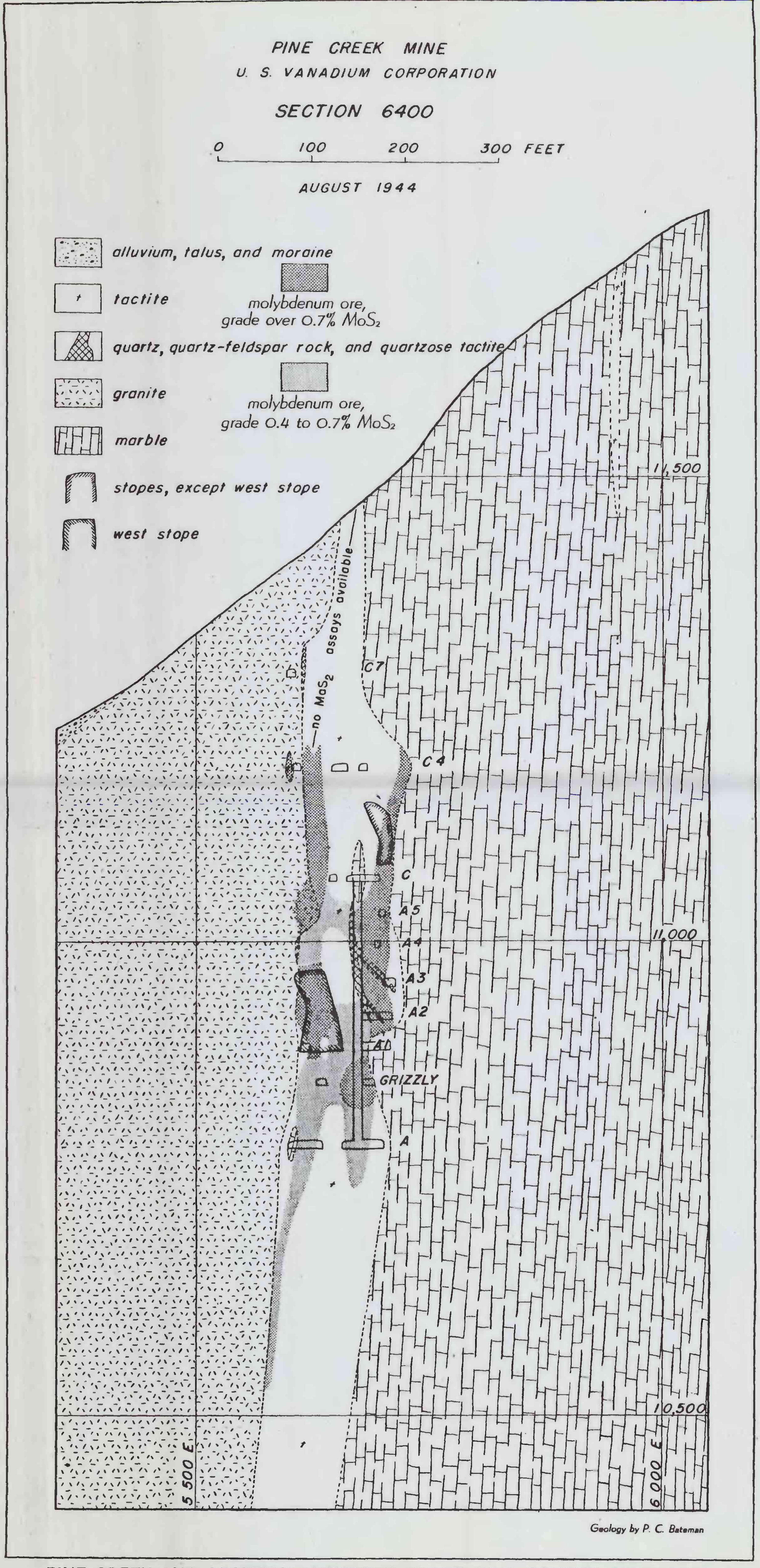
OFR 45-96

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP

PLATE 21



PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

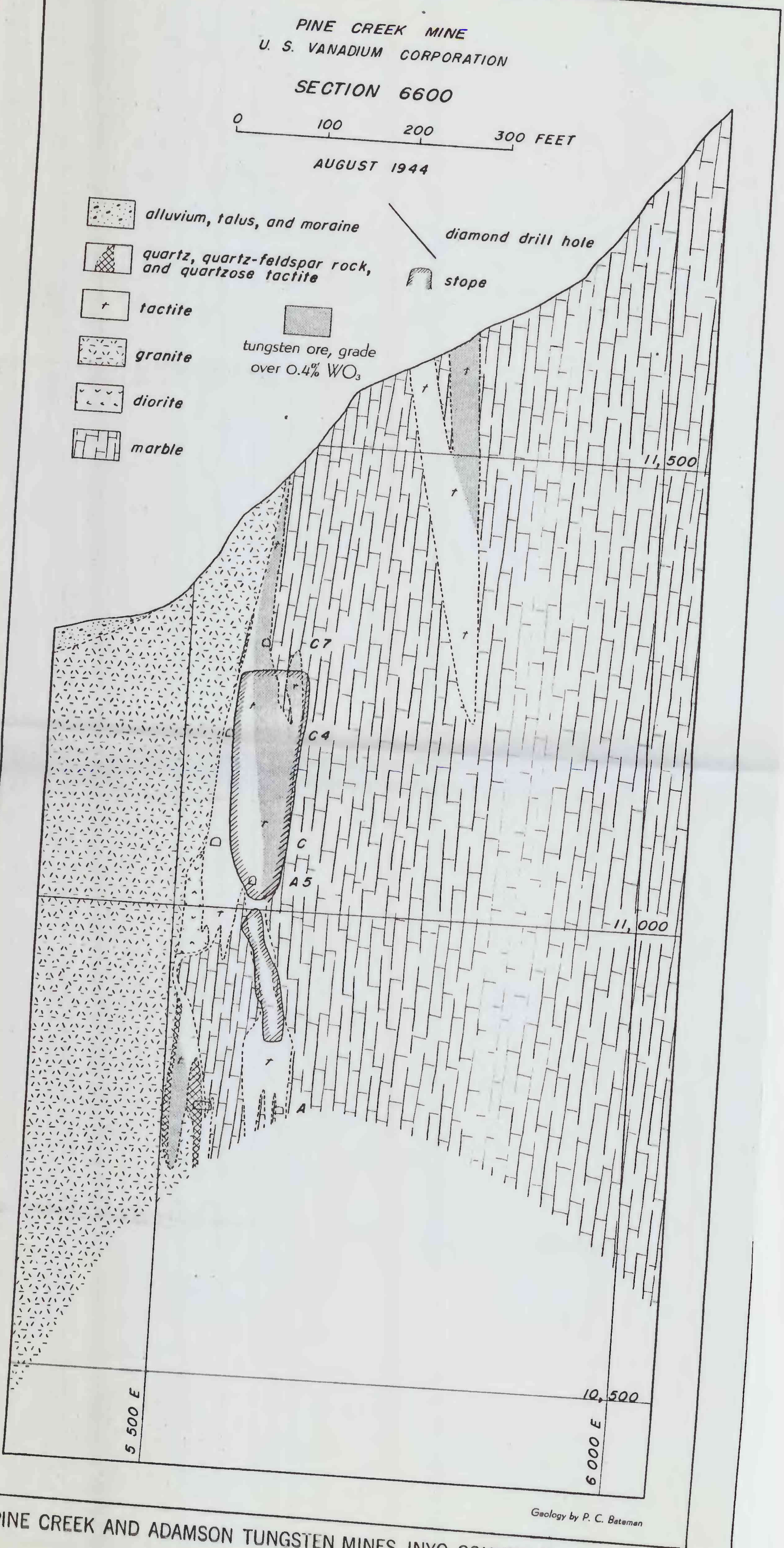


PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OFR 45-96

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP
PLATE 22



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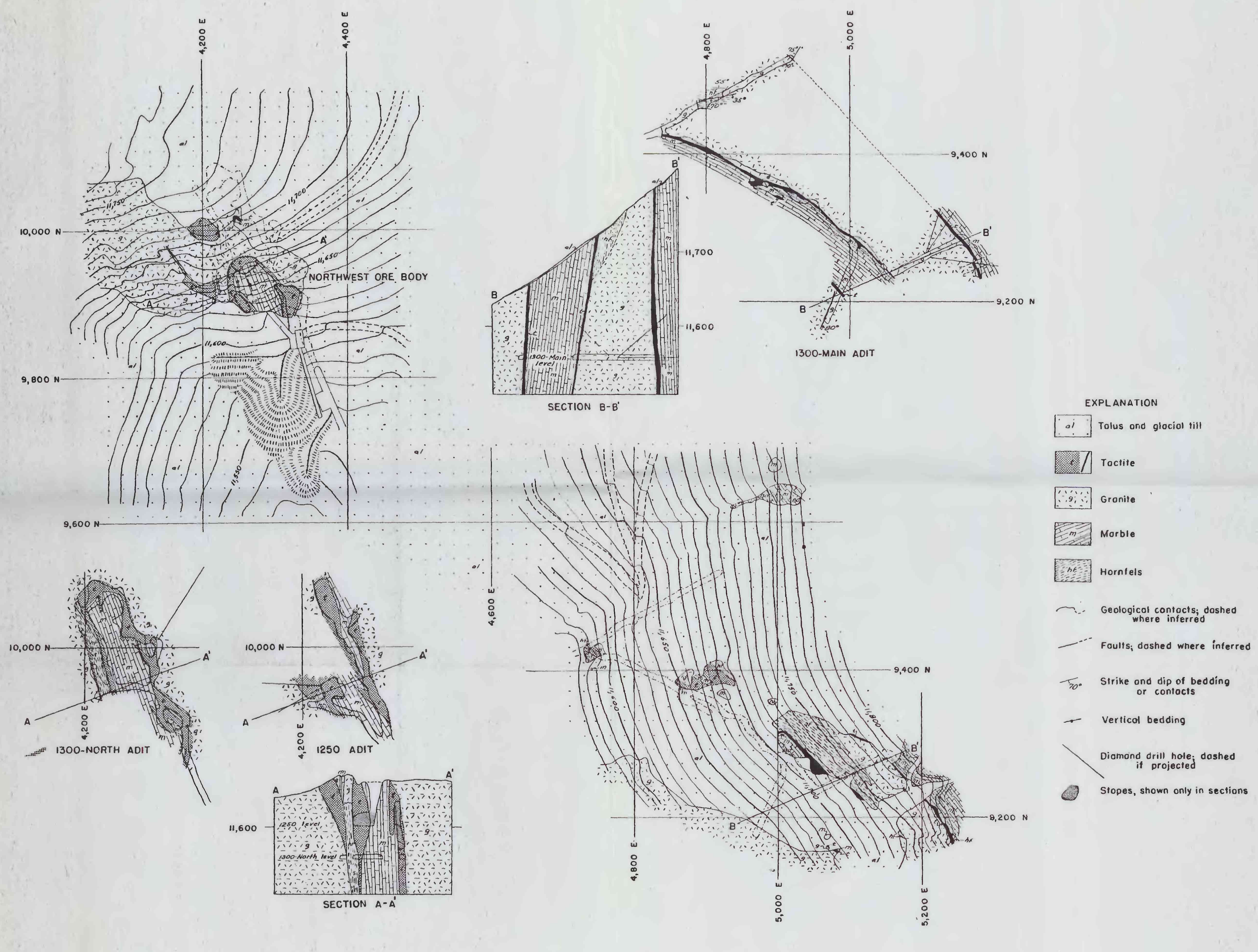

ADAMSON MINE, LOWER WORKINGS

0 100 200 300 400 FEET

Contour interval 10 feet

1944

Geology by P. C. Bateman and M. P. Erickson

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

OFR 45-96

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OFR 45-96

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP
PLATE 5

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OFR 45-96

STRATEGIC MINERALS INVESTIGATIONS
PRELIMINARY MAP PLATE 5 A

PINE CREEK AND ADAMSON TUNGSTEN MINES, INYO COUNTY, CALIFORNIA