# The Aztec Mine, Baldy, New Mexico

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The Aztec mine is not widely known, by reason of its isolation and the relative insignificance of its tonnage; financially, however, it has an enviable record and geologically it is extremely interesting.

The town of Baldy, Colfax County, the mine camp, at an elevation of 10,000 ft. (3048 m.) is 8 mi. west of Ute Park, the terminus of a branch of the A. T. & S. F. Ry. The mining tract was designated by the Maxwell Land Grant Co. as the Aztec Reservation, and lies on the east slope of Mt. Baldy, the summit of which, 12,491 ft. (3807 m.), is one of the highest in the state.

Rich copper float was found on the northeast slope of the mountain in 1865, and discovery work was begun the next year. At the same time, gold placers were found on Willow Creek, on the southwest side of the mountain, and the Elizabethtown settlement followed shortly. Gold washing lasted many years. In 1867, placer gold was found also on Ute Creek, the tracing of which to its source led to the locating of the Aztec mine by Lynch, Dogherty, and Fosley in the following year.

The early production came from the contact of shale and sandstone or from sandstone immediately above the contact. Exact record of production is lacking, but L. C. Graton[1] gives estimates ranging between $1,250,000 and $1,500,000, of which about $1,000,000 was taken out in the first four years.

After the exhaustion of the early bonanza, production continued intermittently until 1909, when the Maxwell Land Grant Co. undertook systematic development, through four adits at intervals of 75 ft. vertically or approximately 100 ft. on the dip of the contact, which was thought to contain generally a quartz-pyrite vein. The two intermediate adits almost immediately reached ore, the most southeasterly in Fig. 2. This ore, however, was not mined until 1911–12; its grade was about $20 and

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[1] Ore Deposits of New Mexico, U. S. Geol. Survey, *Prof. Paper*, 68.

it was mostly quartz. Adits No. 2 and 3 were discontinued after the ore was found and Nos. 1 and 4 were then driven.

Late in 1911, the southeasterly orebody on No. 4 level was reached. This was typically silicification and enrichment of flat-lying beds of sandstone from narrow and steep fractures; shaly layers in the sandstone seemed to account for vertical localization of the enrichment. The type was like that of enrichment in flat beds in the Black Hills of South Dakota, except that the verticals were fainter and the beds less subject to replacement. Development northwesterly provided a meager ore supply into 1914.

In that year, it was decided to cross-cut from No. 4 level to the old workings lying to the west and slightly above the level. This work almost at once opened a bonanza, consisting mainly of altered shale enriched with free gold to a value of $50 to $100 per ton; 80 to 90 per cent. of the gold could be amalgamated and another 5 to 10 per cent., with a little pyrite, was readily caught on a Wilfley table. Although this new orebody was only 500 ft. distant from the old workings, its discovery, by downward prospecting along the contact, would have been delayed by the presence of folds and water-bearing fissures in the intervening barren ground. Subsequent development of this orebody has failed to find the slightest continuity with any other ore, and it shows no indication at the surface.

From 1912 to 1920, the mine produced $1,680,718 in bullion, varying from 856 to 889 fineness in gold and 105 to 142 in silver, and $243,079 in concentrates. Shortly after the discovery of the bonanza, the cost of producing gold was as low as $2 per ounce, but in 1919 it rose to $13.50 because of the large amount of timbering required and other operating difficulties.

In addition to our own conclusions, gained by several years' connection with the mine, the one as consulting engineer and the other as superintendent, we have the advantage of observations recorded by a number of other investigators. L. C. Graton[2] studied the district, in 1905, for the Geological Survey. In 1916, Edward H. Perry and Augustus Locke reported on the geological conditions at the mine. In 1918, O. H. Hershey made a study of the faulting systems and the ore occurrence. In the following description, dealing principally with the geological features of the Aztec mine, in addition to our own observations we have drawn freely from the written reports of these engineers.

## Geology and Mineralization of District

As described by Mr. Graton, the Cimarron Range owes its elevation to faulting with accompanying upbending of the flanking strata. Unlike

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[2] *Op. cit.*

most of the high ranges in the northern part of New Mexico, its crest consists of sedimentary strata, although the pre-Cambrian basement is exposed in places. The sedimentary rocks belong chiefly to the Cretaceous and are broadly divisible into Dakota (?) sandstone, Colorado, Montana, and Laramie (?). Cutting the Cretaceous rocks are numerous intrusive masses of monzonite porphyry, which in many places is quartz-bearing. The faulting occurred at the close of the Cretaceous and was accompanied or closely followed by the intrusion of porphyry.

The primary gold deposits are of two types: quartz veins and contact-metamorphic deposits in calcareous sedimentary rocks; most of the gold has been obtained from the former. These veins are closely associated with intrusions of porphyry but, owing to the abundance of sedimentary rocks, many veins appear to be wholly contained in them. A common position for these veins seems to be at the contact of sills of porphyry with shales of Colorado and Montana age; several such veins are known on the Baldy side of the mountain, notably the Rebel Chief group. These veins and those like the Aztec vein, which occur between the Montana shales and the Laramie (?) formation, are locally spoken of as contact veins. While they do actually lie at the contact of different rocks, their position is probably due solely to the fact that fractures formed more readily at such places. These veins apparently differ not at all from those that do not occur at contacts, and it is probable that the character of the veins is not influenced by the fact that their walls are of different materials. In composition, these are essentially quartz-pyrite veins. Unquestionably, the veins have some relation to the porphyry and probably represent products derived at slightly later time from the same source as that of the porphyry. In other words, the ore-bearing solutions are believed to be the final product of magmatic differentiation, the most abundant and characteristic product of which was monzonite porphyry.

The contact-metamorphic deposits are fewer in number, and have produced less than the veins. They occur in sedimentary rocks at or near the contact with quartz-monzonite porphyry. The metamorphic effects are different in different deposits and are probably dependent on the chemical character of the sedimentary rocks. In the Ajax deposit, the original rock was probably a calcareous shale.

## Structural Geology at Aztec Mine

Mr. Hershey describes the structural geology. The original plane of division (locally known as the contract) between the sandstone series and the Montana shale, in places, remains in its original condition, but generally there has been slipping of the rigid sandstone over the soft shale, producing at the top a thin gouge or selvage of 6 to 8 in. of soft

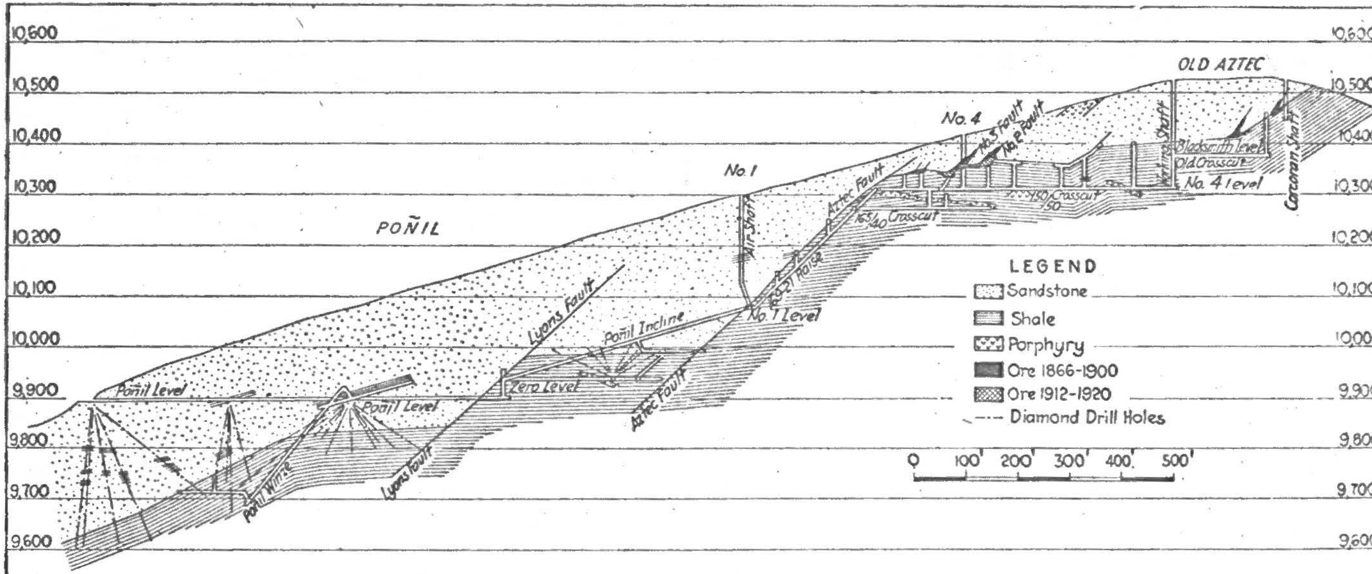


FIG. 1.—NORTHEAST-SOUTHWEST SECTION OF AZTEC GOLD MINE.

crushed shale. Where there has been no actual displacement, that is, cutting across of the beds, the contact is regarded as original. He recognizes two main periods of faulting, Fig. 1. The first period produced a group of faults of relatively small displacement. While they fault the sandstone, they do not penetrate deep into the underlying shales, but curve to low dips and practically follow the original contact. The second period produced two notable faults of large displacement, called the Aztec and the Lyons fault. The former dips northeastward from 20° to 45°, generally about 35°. Nearly everywhere it has a thick, soft gouge under a hard sandstone roof. The shales under it have been partly crushed to a depth of several feet. In places the disturbed zone contains large fragments of sandstone under the main gouge. In Fig. 1, it appears that the displacement on the plane of the Aztec fault has been about 550 ft. (167 m.). The Lyons fault, as exposed in the Poñil workings, is accompanied by a black gouge and dips northeastward at 35°. It is a normal fault and appears to have a displacement of 450 ft. (137 m.). Grooving and striation, observed on both fault planes, is practically straight down the dip.

## The Aztec Orebodies

Mr. Hershey distinguishes three types of ore deposits, probably formed at three distinct periods. The first is the so-called "shale ore." This is remarkable for its high gold content, whereas contact-metamorphic ore deposits usually carry gold in relatively small quantities. A somewhat similar deposit appears to occur at the Ajax mine on the southwestern slope of Mt. Baldy. There the gold is distributed through a dark, heavy, finely granular rock, consisting of nearly colorless pyroxene, amphibole, epidote, magnetite, a little zoisite, scapolite, and specularite. The Aztec shale ore is a dark green, heavy, finely crystalline rock in which the microscope might show the same minerals as are present in the Ajax ores. In the field, the Aztec ore seems to consist of greenish grains that may be zoisite or a small green garnet; there is also considerable calcite in places. The gold is embedded in the green mass in ragged grains up to nugget size, which can often be seen with the unaided eye. There is little pyrite or other sulfide present. The ore occurs at the original contact or a few feet below it and has been involved in the crushing of the shale, for it abounds in curved slickensided faces with a greasy feel. Underground, it is difficult to distinguish from the shale.

The second type of mineralization is that accompanying faults Nos. 2 and 3, Fig. 1. Its essential minerals are calcite and pyrite. The ore occurs in seams and bunches scattered through a zone of broken ground accompanying the fault gouge. Other carbonates, such as rhodochrosite, may be present and probably a little quartz. Much of the pyrite is coarsely crystallized and there may be a small amount of chalcopyrite with it, but this is not easily recognized underground. The gold content runs from $8 to $50. The metal is fine grained and not visible. Where these fault veins lie at low angles, practically coinciding with the shale-ore lenses, the gold content is relatively high. Good ore continues up along the fault into the sandstone but gradually weakens. Down the dip from the shale-ore lenses, the fault veins contain much pyrite but little gold, and soon pass into non-commercial sections. These facts lead to an inference that the mineral-bearing solutions ascended along the fault

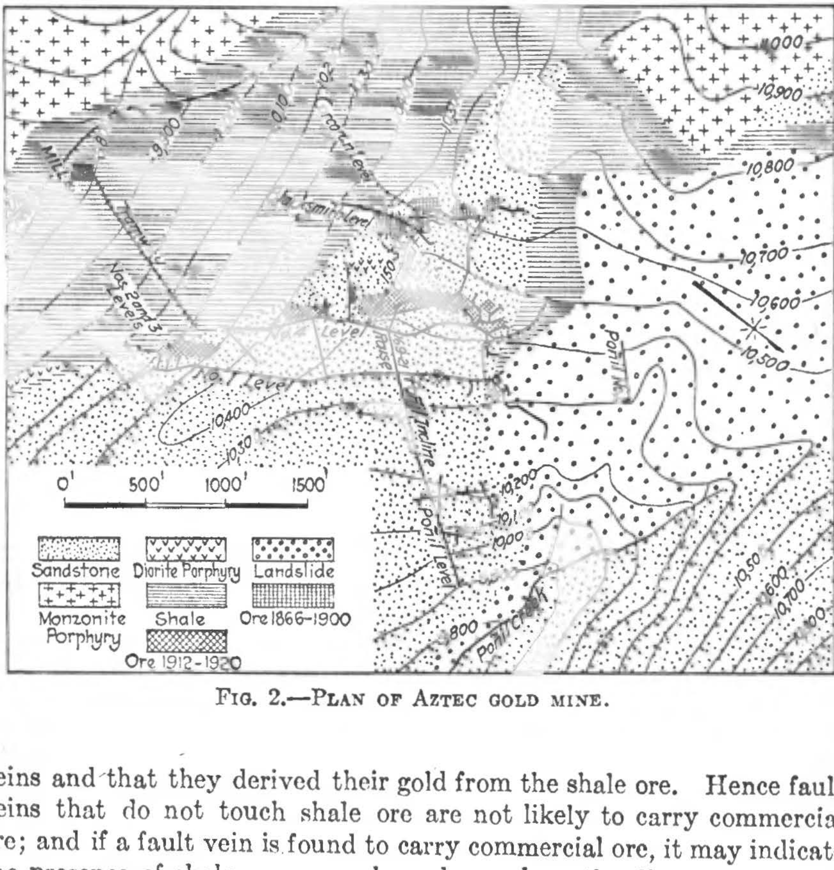


FIG. 2.—PLAN OF AZTEC GOLD MINE.

veins and that they derived their gold from the shale ore. Hence fault veins that do not touch shale ore are not likely to carry commercial ore; and if a fault vein is found to carry commercial ore, it may indicate the presence of shale ore somewhere down along the dip.

The third type of deposit is genetically connected with Aztec, Lyons, and other faults of that system. It occurs almost exclusively in sandstone and its most characteristic mineral is chalcopyrite. The gold content is relatively low, and free gold is rarely or never visible. Movement along the fault fractured the relatively brittle sandstone, forming little fissures in which the solutions circulated. The resulting mineralized zones vary from a few inches to many feet in thickness.

The orebody at the extreme northwest that was commercially important seems to us to be of a different type from those described. It was extremely high-grade ore having the characteristics of contact metamorphism. It lay just between the contact of shale with overlying sandstone partly altered to quartzite, and though seemingly a part of neither, it extended a short distance upward along the steep, small fractures, fading away into the sandstone. Beside masses of coarse and fine native gold, this ore contained quartz, limonite, garnet, pyroxene, and other silicates, a little pyrite and chalcopyrite and always an appreciable amount of bismuth telluride. The latter mineral, tetradymite, was identified by A. J. Weinig. Native gold in coarse particles was embedded in it, yet practically uncombined with tellurium. The gold amalgamated readily. A similar occurrence of ore having the same mineral components and apparently derived by similar processes at Dolcoath mine in the Elkhorn mining district, Montana, is described by W. H. Weed.[3]

The quartzite close to the ore is hard, glassy and somewhat stained on its fractures with a brilliant green and blue film of very recent copper oxidation products. While the ore is quite hard and tough, the shale beneath it is soft. It is barren, strongly iron-stained throughout and sometimes copper-stained in the uppermost few inches, just under the quartzite. The change from high-grade ore to barren shale under it is sharply marked. The hardening alteration of the shale so pronounced under the bes tdevelopment of shale ore is entirely absent here and an opposite condition exists, notwithstanding the presence of the dioritic sill and its much closer approach to the shale-sandstone contact.

At the time Mr. Graton visited the property, the Old Aztec orebody alone was known. He describes the main underground workings as being near the contact of the shales of Montana age with overlying coal measures, which are commonly regarded as Laramie. The ore is in some respects unusual. It occurs mainly in coarse sandstone just above the contact with the shales and it consists of a number of veins of which a few are at the actual contact with shales and nearly all are parallel to the bedding of the rocks. The lode thus formed strikes about west-northwest and has a variable dip, which averages about 25° to 35° northeast. A few veins, which are apparently branches or offshoots from the main lode, cut upwards almost vertically through the sandstone. The walls of the narrow fractures in the sandstone, which constitute the veins, are covered with a thin layer of dark material, presumably limonite, and this is said to have been fairly bristling with free gold in the rich ore. It seems probable that this was once rich auriferous pyrite, which was later oxidized. The stopes from which the ore of the main lode was

[3] W. H. Weed, U. S. Geol. Survey, 22 *Ann. Rept.*, pt. 2, p. 506.

extracted are disconnected, and as all are not on the same fracture they overlap in places. Several of the stopes of the main flat lode extend out to the surface of the steep hillside.

### Derivation of the Orebodies

In describing the shale ore, the first of his three groups, Mr. Hershey says that this is obviously shale which has suffered contact metamorphism. The minerals it contains are those formed by contact metamorphic action. The causative igneous rock is not definitely known but somewhere a mass of porphyry may have been intruded across the original contact and the metamorphism spread outward from it along the shale layer under the sandstone. The porphyry may have been removed by erosion or it may exist in some unexplored section.

The dioritic sill that underlies the principal productive orebodies on the No. 4 level, and which is separated from them by 40 to 100 ft. of much less altered and absolutely barren shale, might have produced the metamorphism; assuming that the ore represents a layer of shale that was slightly calcareous and thus amenable to an alteration different from that of the non-calcareous shale.

At present it is known only that the shale-ore lenses seem to occur in a relatively narrow belt elongated in a north-northwest direction. The orebody as a whole lies flat but in detail is somewhat undulating, a common form being that of a trough. The shale orebody is much complicated by the presence of faults Nos. 2 and 3 and a fissure running obliquely between those faults. Toward the northwest the Aztec fault appears to have encroached upon the orebody and perhaps dragged part of it down below No. 1 level. At the extreme northwest, the Aztec fault seems to swing sharply toward the north, thus permitting another lens of shale ore to appear under it.

In connection with Mr. Hershey's suggestion that metamorphism may have originated in a porphyry dike on or intersecting the sandstone shale contact, it is worth noting that diamond drilling did encounter intrusion at a point 2500 ft. northwest from the principal orebodies and lying on the contact between the two sedimentary rocks.

Perry and Locke noted that the most promising localities for the occurrence of shale ore were the intersections of east-dipping faults of small displacement with flat-lying contacts of shale and sandstone, including among the latter not only the main Montana-Laramie contact, but those existing at the boundrics of shale beds within the sandstone.

They described the ore as chiefly an alteration of shale at or close to the contacts of shale with overlying sandstone. It is soft and greenish gray, consisting largely of chlorite, carrying scattered grains of pyrite and native gold, with occasional gray metallic specks which may be telluride or selenide of gold. Rhodochrosite and calcite are not uncommon, while the lack of quartz of the same generation as the ore makes it an unusual one.

The sill of fine-grained porphyry, probably everywhere in the vicinity of the principal mine workings and lying 40 to 60 ft. below the main contact, is a variety not known elsewhere here. The shale underlying the ore and overlying this sill has undergone a hardening alteration, producing a dark gray rock lacking in shaly structure and carrying disseminated pyrite. Whether or not this alteration always or usually occurs under ore is not known. However, the effect of the sill is undetermined, although it could have constituted the source of the gold. The hardening alteration of the shale is an effect and not a cause of the mineralization.

Perry and Locke think that the reasons for localization of the ore at the main shale-sandstone contact are probably complex. Their most plausible hypothesis depends on the fact that, while the shale is somewhat plastic and does not readily maintain open spaces for the migration of solutions, the sandstone is brittle and does readily maintain such spaces. It depends, again, on the fact that the shale is more readily replaceable by ore minerals than the sandstone. According to this hypothesis, the sandstone would furnish the path for travel of gold, and the shale would furnish the matrix for its reception. Furthermore, the east-dipping faults break the sandstone and the shale. The extension of the orebodies in a direction parallel with that of the faults is plausibly attributed to the effect of the faults in cracking the brittle sandstone and crushing the more plastic shale. At the same time, the dip of the bedding in various parts of the workings indicates the possibility of an anticline with a northward trend, the axis of which coincides with the most productive part of the orebody. The apparent preference of the ore for the main contact cannot be explained by any particular abundance of soluble minerals in the shale in that locality, because no such abundance has been observed.

It seems to us that the granodiorite intrusive has been one of the controlling factors in ore derivation. The fact that this variety of porphyry is not known elsewhere (and, conversely, so far as known, the ore has not been found disassociated from it) is outstanding. Coupled with the presence of the sill everywhere in the shale, under the ore in the No. 4 level workings and over it in the Old Aztec workings, there is a good fracture zone at each of these main orebodies. In neither case does the sill join the orebody but the faults of small displacement do. They have crushed and opened the sandstone above the original contact, forming channels where solutions and gases could travel. The hardened shale, overlying the sill, was also fractured and cracked, maintaining small open spaces, however, to a much less degree.

Many areas of original contact were investigated by diamond drilling and mine exploration. The only mineralization found was below the Poñil level where the contact was slightly folded and where fracturing had resulted. Elsewhere the contact was tight and barren.

In all, there is evidence that mineralization has followed or been connected with fracturing and a little evidence that fracturing has followed folding.

Regarding Mr. Hershey's second group of orebodies, the veins accompanying faults Nos. 2 and 3 extending upward from the No. 4 level workings, he thinks the facts point to the inference that the mineralizing solutions were ascending along the fracture planes in the sandstone, having derived their gold from the adjacent and underlying bodies of shale ore. Thus he concludes that any fault veins which do not communicate with bodies of shale ore are unlikely to carry profitable ore; and conversely, any fault vein found to carry good ore, will, if followed downward, probably lead to a body of shale ore.

As to his third group, the copper mineralizations in sandstone adjacent to the principal faults and others of the same system, he argues that movement along the faults fractured the relatively brittle sandstone, forming little fissures in which the solutions circulated. The mineralized zones vary from a few inches to many feet in thickness. As the sandstone is usually over the fault the ore rests upon the gouge or occurs along seams over it, suggesting deposition by descending water; but when the sandstone is under the gouge, the same argument points to ascending solutions. The crystallized calcite and chalcopyrite are minerals not often formed by descending meteoric waters and would indicate solutions ascending.

## Prospecting

Exploration for additional orebodies was conducted by drifting and diamond drilling, with particular attention to the regions of original shale-sandstone contact. Of drifting, slope sinking, and similar work, a distance of 9883 ft. was accomplished during the years 1918–1921, at a total cost of $15.89 per foot. During the same period, diamond drilling aggregated 18,276 ft. at an average total cost (including sampling, assaying, etc.) of $4.59 per foot. The average length of 77 holes was 237 ft., and many of the holes drilled from the surface encountered unusual difficulties in penetrating the talus deposit.

"Two large and high-grade orebodies were found at opposite ends of the deposit on No. 4 level, two small bodies were found on No. 1 level, an extensive but low-grade deposit was opened on the Ponil level; otherwise only scattering high assays near the lowest level reached rewarded the work."

## Mining

The principal mine entries followed the Aztec fault and the main ore zone lay just southwest of No. 4 level and the fault, Fig. 2.

This zone, paralleling the Aztec fault a distance of 800 ft., had a maximum width of 80 ft. and lay 30 to 60 ft. above No. 4 level. Within it was a more or less continuous extent of ore. A generous provision of branch openings on the level and raises was made for the efficient movement of ore from stope faces to loading chutes on the haulage level.

The considerable length of the raises made them useful for ore storage at all times and, in the later days of the mine when painstaking mining around the margins of the ore was necessary, tonnages from narrowly limited areas were segregated in these raises and milled as separate lots. The practice was invaluable in avoiding the mistake of degrading good ore from one stope with ore from another place of lower grade. Hand sampling was the first guide to stoping but actual mill result governed; this practice materially extended the life of the mine.

The mine was mapped on coördinates approximately paralleling the Aztec fault with 100-ft. blocks, counting from the southeast end of the property. Abscissas were laid off from an arbitrary base. A factor of ten was used and block 170/50 was 1700 ft. northwesterly and 500 ft. southwesterly. Within that block a drift, crosscut, or raise took designation from the coördinates at its beginning; for example, raise 213/57. Samples were recorded in the same way. The working map was on a 10-ft. scale to accommodate the great amount of detail and in time the single large sheet gave way to maps of individual blocks, 100 ft. square, on which were entered the hand samples taken and the records of the mill lots extracted.

Timbering was by square sets, where the ground was heavy, or soft; and by posts or stulls, where it was hard. At times, waste from development served in large part to fill the sets, but frequently waste raises into the overlying sandstone were necessary; these served also to prospect the sandstone: they never found ore. Much of the ground was heavy, requiring careful timbering. Some of the best ore was overlaid by material that required spiling before the ore could be drilled and blasted. Timbering was by far the largest single item of expense in the extraction of the ore, though the cost of timber was reduced by the operation of a sawmill, a few miles from the mine.

## Milling

The mill is a ten-stamp amalgamation and concentration combination and by it a recovery of 85.81 per cent. was obtained in later years. As is frequently the case at small and out of the way mines, the provision of dependable and economical power, at moderate initial expense, was one of the serious problems. In early days of the present operation a steam plant was in use, it having been handed down from a previous period of operation. Water for power was available during one month in the spring of the year. Upon development of a considerable supply of ore and needs for power expansion, the semi-Diesel type was selected and Muncie engines in 30- to 80-hp. units placed in the mill to furnish power for all purposes. A 35–40 gravity fuel oil gave better results than a heavier oil. Careful attention to lubrication, condition of the cylinders and piston rings, amount of water passing through the jackets, condition of fuel nozzle, and the amount of water used in the bypass is necessary for best results. The engines are simple, easy to operate, and satisfactory.

## Costs

On a basis of 30 tons, daily, mined and milled during the years 1918–1920, inclusive, the following costs prevailed.

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|---|---|
| Mining | $4.91 per ton |
| Milling and marketing | 3.54 per ton |
| General | 1.62 per ton |

The total cost of power was $0.0396 per hp.-hr. Fuel oil cost $0.151 per gal. and lubricating oil, $0.967. Fuel oil was used at the rate of 0.708 lb. per hp.-hr. and lubricating oil, 0.041. Trucking 16 mi. the round trip, with practically no back haul, cost $6.86 per ton of freight hauled. The mine is 2500 ft. higher than the railroad.

During the years 1918–1921, inclusive, the cost of mine development, including direct and indirect charges, was $15.89 per ft. over 9883 ft. of work. Of this amount, $7.59 was the cost of explosives, labor of breaking ground, mucking and placing timbers. Diamond drilling 18,276 ft. cost a total of $4.59 per ft., distributed as follows:

| | |
|---|---|
| Direct charges: | |
| Drilling, only | $3.10 |
| Pipe lines and stations | 0.37 |
| Power | 0.66 |
| Water | 0.12 |
| | $4.25 |
| Indirect charges: | |
| Assaying, surveying, sampling and supervision | 0.34 |
| Total cost | $4.59 |

The shortest hole was 40 ft. and the longest 748 ft. An average length of 237 ft. was obtained in 77 holes drilled.