economic handling of large tonnages of low-grade ore, chiefly on the dumps but augmented by rejects from shipping ore. The company, which had had a pumping agreement with the Golden Cycle mine, purchased that mine in or about 1916 and found deep development disappointing there also. Operating conditions caused by the World War and its after effects made matters worse and worse, so that neither mining nor the milling of dump ore could be continued without loss. Dividends ceased at the end of 1917. Prospecting in 1919 disclosed a vein southeast of the shaft, and its development led to the sinking of the shaft another 250 feet and the opening of levels 20 and 21, level 20 connecting with level 18 of the Golden Cycle mine. This work was completed in February 1922, but although some production was maintained, the deep development was disappointing, and in the following June the mine was sold to the United Gold Mines in exchange for Treasury stock. Since then the mine has been operated largely on a leasing basis and has produced a fair tonnage of low-grade ore, mainly from certain of its upper 16 levels. No attempt has been made to extend developments on levels 20 and 21.

The water problem in the Vindicator and Golden Cycle mines has apparently never been overwhelming, but the need of pumping was not removed until, in 1922 or later, level 18 of the Golden Cycle was extended westward into Portland ground and connected with a raise from the east end of the Roosevelt drainage tunnel, which was 65 feet below. Until then water from both the Vindicator and Golden Cycle mines was lifted to the La Bella tunnel, 300 feet below the collar of the Golden Cycle shaft. The pumping from the bottom of the Portland mine, 900 feet below the drainage tunnel, had no effect on the water level in the Vindicator mine.

The first water in the Vindicator mine, according to Lindgren and Ransome, was found on the 500-foot level and at one time was pumped at the rate of 100 gallons a minute. At a depth of 1,200 feet below the collar it was necessary to pump 500 gallons a minute, but in 1904, when pumping was suspended, the water stood a little below the 900-foot level. Between the 800- and 1,200-foot levels both the shaft and the

PRODUCTION OF VINDICATOR MINE, 1912-32, INCLUSIVE[a]

YEAR	CRUDE ORE HOISTED (Tons)	ORE SHIPPED			NET[b] VALUE	ROYALTIES FROM LEASES
		Tons	Gross Value At $20.00 An Oz.	Average Value Per Ton		
1912	96,934	21,819 [c] 10,775	$644,926 198,559	$29.50 18.50	.....	.....
1913	74,084	22,829 [c] 10,688	702,119 218,238	30.50 20.42	.....	.....
1914	76,295	26,343 [c] 13,638	712,400 323,667	27.04 23.73	.....	.....
1915	218,487	125,397 [c] 49,188	2,164,669 815,182	23.73 16.57	$1,718,022 546,363	..... $251,624
1916	319,197	119,130 [c] 61,152	1,324,873 970,857	19.27 15.88	1,001,709 642,411	 226,231
1917	205,691	39,799 [c] 47,119	973,537 716,804	24.46 15.21	742,939 467,246	 153,683
1918						
1919	143,400 55,648	19,922 [c] 20,772	718,136 291,065	....	588,885 186,323	 92,525
1920	26,438 47,978	3,524 [c] 18,199	158,899 268,874	....	133,363 194,697	 98,087
1921	31,950 52,290	4,273 [c] 33,184	127,640 444,900	....	99,165 291,254	 90,775

PRODUCTION OF VINDICATOR MINE, 1912-32, INCLUSIVE[a] Continued

1922	.....	18,388	226,095	12.30	29,420 [c] 71,926	 43,138
1923	.....	28,668	341,479	11.91	33,038 [c] 112,294	 73,737
1924	.....	31,189	217,574	6.98	9,806 [c] 49,147	 47,874
1925	.....	27,072	159,298	5.88	3,416 [c] 38,590	 34,742
1926						
1927	.....	41,920	205,104	4.98	4,858 [c] 46,085	 34,084
1928	.....	17,535 [c] 21,887	88,780 125,104	5.06 5.72	42,476 31,165	..... 26, 118
1929	.....	15,345 [c] 14,452	148,025 108,174	9.65 7.49	94,095 34,713	 27,395
1930	.....	20,341 [c] 14,886	172,491 124,591	8.48 8.37	106,067 49,416	 27,576
1931	.....	9,402 [c] 13,121	63,955 140,613	6.80 10.71	33,891 45,088	 40,832
1932	.....	5,754 [c] 27,259	18,433 175,524	3.20 6.44	4,651 48,754	 40,278

[a]Compiled from annual reports of the Vindicator Gold Mining Co., 1912-21, and annual reports of the United Gold Mines, 1922-32. (Quoted by C. W. Henderson in annual volumes of Mineral Resources, U. S.)

[b]After deduction of freight and treatment charges.

[c]Ore mined by lessees.

levels had remained dry and dusty until the veins were opened, when a large stream issued.[59] This statement shows that, even at comparatively shallow depths, the ground was not readily drained and accords with later experience after the completion of the Roosevelt drainage tunnel. Obviously a still deeper drainage tunnel would have to be extended to the Vindicator vein system if development of the mine were to be continued without pumping. The flow of water found on level 21, according to oral information from Clayton Kissell, of Victor, who has done some work on that level, is not very great. If the proposed tunnel should be extended to the Vindicator vein system an additional depth of nearly 1,200 feet below level 20, the present water level, would be drained.

Geology

The vein systems of the Vindicator and Golden Cycle mines are near the east margin of the large syenite mass. Although this area has been mapped on the surface as a unit, mine workings show that it represents a closely spaced group of complex bodies that are intrusive into breccia and latite-phonolite. Only a few of the lower levels in the Vindicator and none in the Golden Cycle mine have been accessible to us, but according to the evidence obtained, together with that presented in Professional Paper 54 (pp. 415-429), the upper levels of both mines are mainly in a mass of shattered latite-phonolite, the bottom of which slopes northward at a low to moderate angle and is underlain by breccia. The syenite, in spite of its prevalence on the surface near the Vindicator shaft, is reported to be less abundant than latite-phonolite on the upper levels. On and below level 10 it forms a group of prongs of northwesterly trend (fig. 40) that thicken and coalesce southeastward into a mass that encloses large lenticular bodies of breccia and latite-phonolite. The general pitch of this complex syenite mass is steep to the northwest, although single prongs pitch southeast, and its shape and position have been the principal factors that controlled the depo-

[59] Lindgren, Waldemar, and Ransome, F. L., U. S. Geol. Survey Prof. Paper 54, p. 416, 1906.

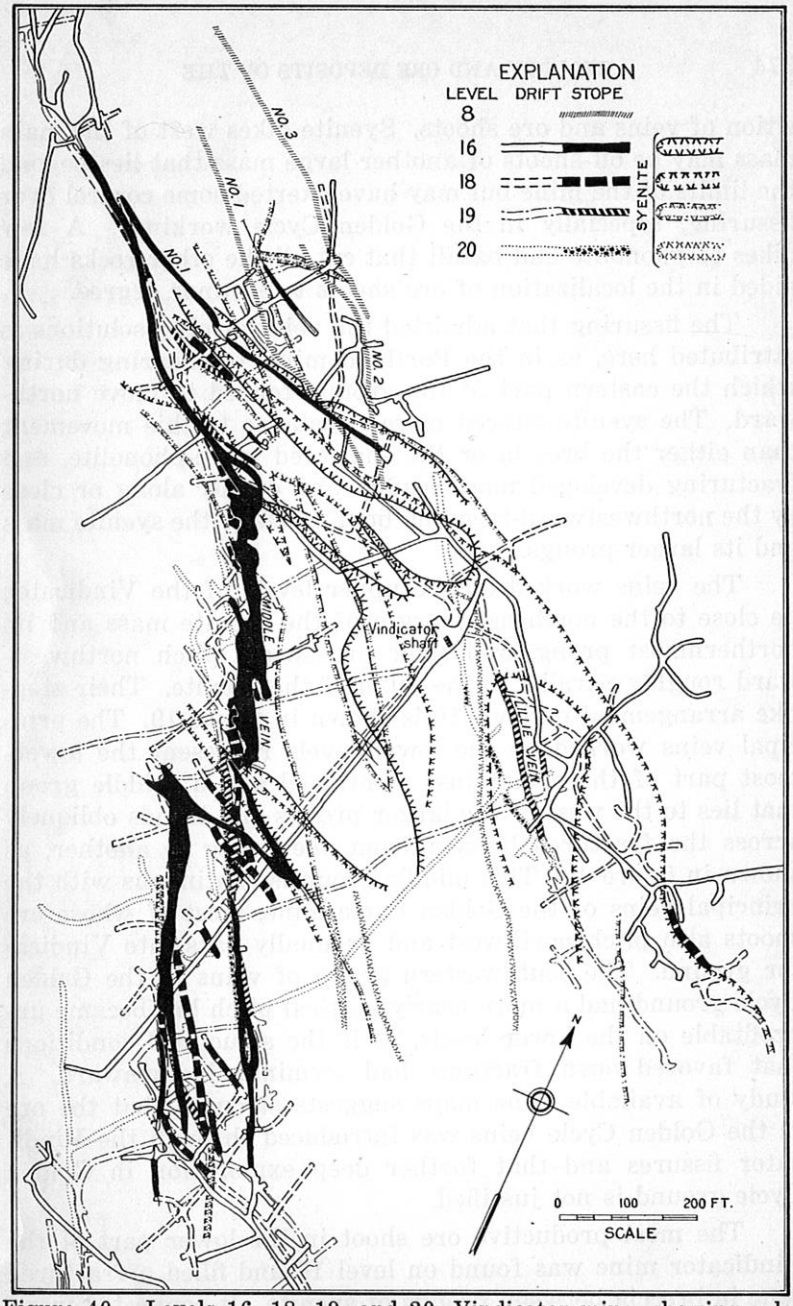

Figure 40.—Levels 16, 18, 19, and 20, Vindicator mine, showing relations of veins to the margins of syenite intrusions. By T. S. Lovering. (After Am. Inst. Min. Met. Eng. Tech. Paper 13, fig. 11, 1927.)

sition of veins and ore shoots. Syenite dikes west of the main mass may be off-shoots of another large mass that lies beyond the limits of the mine but may have exerted some control over fissuring, especially in the Golden Cycle workings. A few dikes of phonolite and basalt that cut all the other rocks have aided in the localization of ore shoots to a minor degree.

The fissuring that admitted the vein-forming solutions is attributed here, as in the Portland mine, to shearing during which the eastern part of the ground tended to move northward. The syenite offered more resistance to this movement than either the breccia or the shattered latite-phonolite, and fracturing developed most readily and openly along or close by the northwestward-trending boundaries of the syenite mass and its larger prongs.

The veins worked on the upper levels of the Vindicator lie close to the northeast margin of the syenite mass and its northernmost prong, and their ore shoots pitch northwestward roughly parallel to the pitch of the syenite. Their step-like arrangement on level 10 is shown in figure 19. The principal veins worked on the lower levels represent the lowermost part of the group just mentioned and a middle group that lies to the west of the larger prongs and trends obliquely across the fractured breccia from one prong to another, as shown in figure 40. This middle group is continuous with the principal veins of the Golden Cycle mine, most of whose ore shoots also pitch northwest and gradually pass into Vindicator ground. The southwestern group of veins in the Golden Cycle ground had a more nearly vertical pitch but became unprofitable on the lower levels, as if the structural conditions that favored open fractures had terminated downward. A study of available mine maps suggests strongly that the ore in the Golden Cycle veins was introduced through the Vindicator fissures and that further deep exploration in Golden Cycle ground is not justified.

The most productive ore shoot in the lower part of the Vindicator mine was found on level 16 and filled a fractured zone in breccia between prongs of syenite. It connected westward along an oblique cross fracture with a vein that followed

a syenite dike toward Golden Cycle ground. As the prongs diverged downward the fracturing became less pronounced, as shown on level 18, and the discontinuity of the southwestern pong on levels 19 and 20 caused the dying out of the ore shoot except along a syenite dike in the southern part of those levels.

The only productive ore shoot along the northeast margin of the syenite on levels 18 to 20 was southeast of the shaft. According to the company's annual reports for 1919-21, it was limited to a short interval above the intersection of the southwestward-dipping vein with a northeastward-dipping phonolite dike and ended upward against a basaltic dike. On level 19 the northwest end of this ore shoot was where the vein entered syenite. On level 20, below the intersection with the phonolite dike, stoping was begun at four places along the vein but was unprofitable. The only work done on level 21, which has been under water since 1922, was along this vein and was also discouraging.

The occurrence of ore below the developed levels is obviously dependent on the presence of favorable structural conditions similar to those at higher levels. The syenite certainly continues downward for a long distance, but whether it continues to narrow downward or sends out additional prongs that have favored the open fracturing of intervening masses of breccia cannot be predicted. It would be reasonable to believe that favorable structure may exist at intervals for a long distance below level 20 along the northwesterly pitch of the syenite and the accompanying veins and along the western syenite dike and any larger mass with which it may connect; but how far these possible areas of favorable structure may be from the shaft and how expensive exploration for them would be are unanswerable questions.

The Vindicator vein zone extends northwestward through the Hull City mine to the Findley and Shurtloff mines. The Hull City mine is comparatively shallow, but the Findley has been productive down to level 21 of the Eagles mine (altitude 8,673 feet), which is 60 feet above level 15 of the Vindicator. This part of the vein is more conveniently considered a little

farther on, and it will suffice here to state that the general southeasterly pitch of the Findley ore shoots suggests a common source with those of the Vindicator mine, where the fissure zone taps the roots of the Vindicator subcrater beneath the syenite mass.

Northeastern Part of the District

The northeastern part of the crater, as here defined, includes northernmost parts of the Last Dollar-Orpha May and Vindicator zones, the Isabella zone, and mines between and north of the Vindicator and Isabella zones. Only a few of the workings have been accessible to us, and our work simply serves to supplement that of the earlier surveys. The development of this part of the crater along a prevolcanic fissure zone of east-northeast trend and connecting parts of northwestward-trending zones is considered on pages 264-265. The upward extension of the east-northeast zone is expressed by a steplike group of fissures that extends from a point west of the Eagles mine to the Gold Band mine, on the north side of Grassy Creek. The zone is deflected northward by the Zenobia zone, of north-northeast trend, and the Free Coinage zone, of north-northwest trend. This east-northeast zone is believed to mark approximately the northern limit of the deeper, steep-walled part of the crater and to overlie a northeast branch of the Isabella subcrater. It evidently influenced the local effects of disturbances to a marked degree. Dikes of latite-phonolite, syenite, trachydolerite, phonolite, and monchiquite (basalt), as well as veins, have formed along this zone and the connecting zones and show that as a whole it has been one of persistent weakness.

The earliest fissuring in this part of the crater, as elsewhere, may have resulted from settling, as the positions of the fissures conform to such a movement, one set being roughly parallel to the granite contact and dipping toward it and the other nearly normal to it. Repeated disturbances along the underlying, prevolcanic fissure zone, due to minor explosions or upthrust of molten lava, could also account for at least

some of the fissures, especially those that diverge westward from the northernmost part of the Isabella zone. The beginning of regional compression also could have been effective, even before the intrusion of latite-phonolite, which is abundant throughout much of the area, although this rock is not so closely related to the effects of regional compression as the phonolite and basalt. The Isabella dike of trachydolerite, called the "Sevey dike" or "big basalt" in the School Section mine, was evidently intruded also before the major stage of regional compression. This dike was formerly supposed to have been younger than phonolite and other varieties of basalt, but Koschmann found that it was cut in the School Section mine by both phonolite and monchiquite ("little basalt"), and similar relations were found in the Eagles mine by C. O. Moss, formerly engineer for the Stratton Leasing & Development Co. The structural features of this dike are shown in figure 41. Although shown as a continuous dike on the small-scale surface map (fig. 1), its underground exposures betwen altitudes of 10,584 and 9,650 feet, mapped by Moss, have a marked steplike arrangement, and dip 60° or more north-northwest, toward the granite contact. Its relation to the contact at lower altitudes is inferred to be similar to those shown in figures 31 and 39. The position of its steplike fissure zone accords better with a settling movement than that of any fissure noted elsewhere. It is a striking fact that no other dikes of this rock have been recognized in other fissures in the vicinity, and this restriction suggests that the trachydolerite was intruded before the opening, by regional movement, of the fissures that contain the other basaltic dikes and the mineral veins.

South of the Isabella dike there are two prominent intersecting sets of fissures (fig. 42), one trending north-northwest and the other, called "cross veins," trending north-northeast. They have been studied by Loughlin in the Eagles mine and are also prominent in the Isabella mine. The presence of latite-phonolite dikes proves that both sets were formed at a very early stage, but the relative abundance of different kinds of dikes, as well as ore shoots, shows that the north-north-

westerly set has been the more open of the two ever since their formation. Both sets contain narrow zones of cleavage cracks, illustrated in figure 14. Those in the north-northwesterly set commonly strike northwest and dip northeast, and those along the north-northeasterly or cross set strike north and dip east or west. Their attitudes, together with the directions of slickensides, indicate a prevailing horizontal movement, although the western walls along both sets, with local exceptions, tended to rise. The actual movement was slight but complex—for

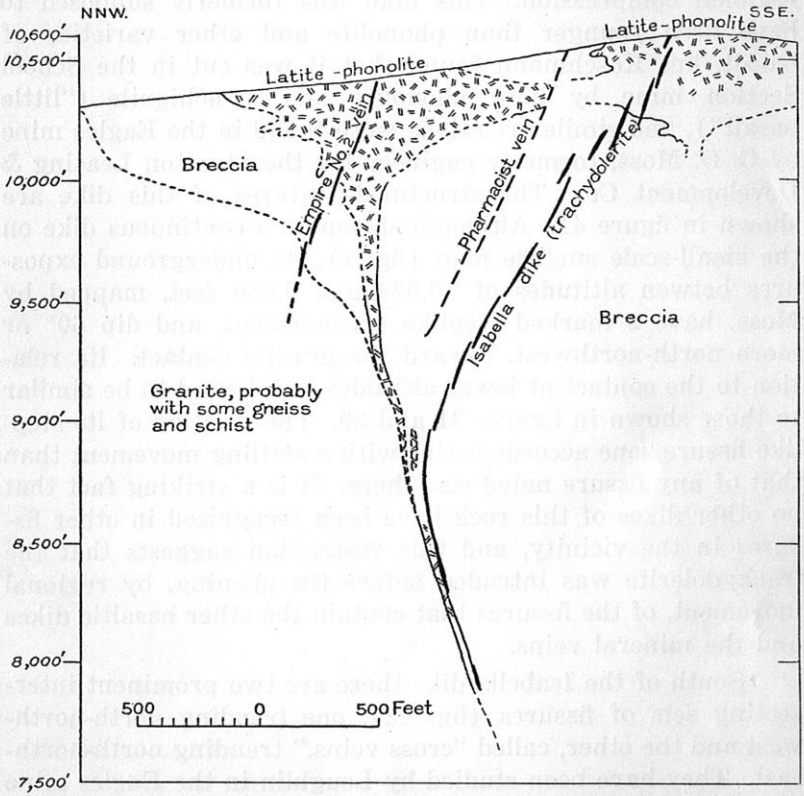

Figure 41.—Generalized cross section showing relation of Isabella dike to breccia-granite contact. The steplike structure of the dike is inferred from exposures in the Eagles and Zenobia mines, mapped by C. O. Moss, between altitudes of 10,584 and 9,650 feet. The relation to the breccia-granite contact is inferred to be similar to that shown in figures 31 and 39.

example, at some places cross fissures appear to have been offset a few feet by north-northwesterly fissures, in others the opposite relation is true, and in still others, fissures of one set branch and end against those of the other set, although a fissure almost in line with one of the branches may represent its continuation.

North of the Isabella dike the north-northwesterly set of fissures dies out as a whole, although its westernmost members, the Porcupine and Pikes Peak fissures, curve to north-northeast courses and intersect fissures of east-northeast trend. The Pikes Peak fissure, for example, is essentially continuous with the Zenobia fissure (fig. 42) and faults the east-

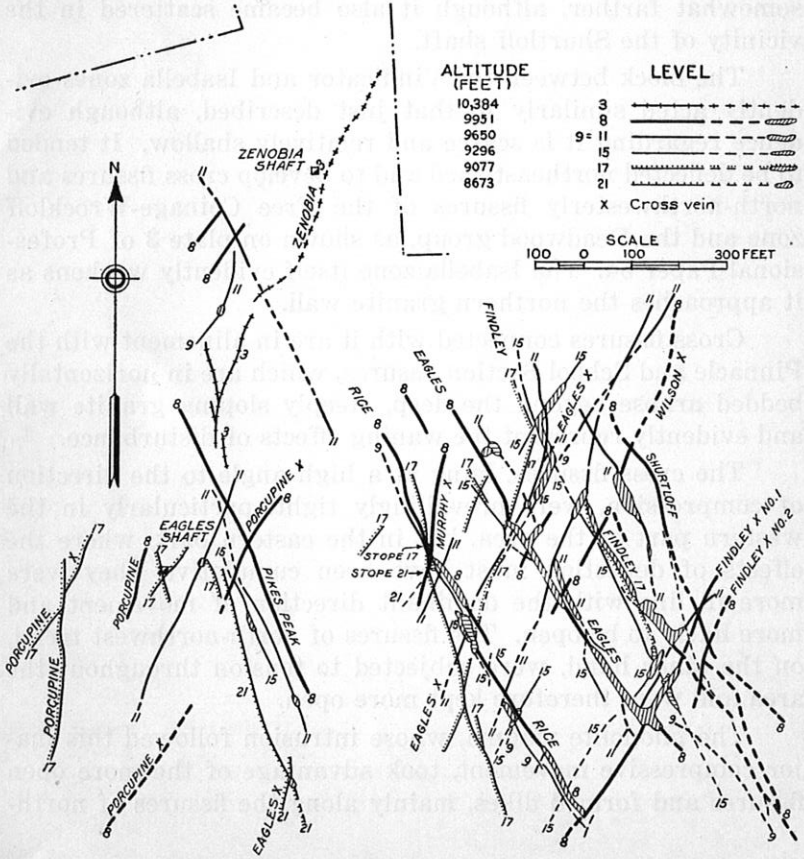

Figure 42.—Distribution of veins and ore shoots in the vicinity of the Eagles mine shaft. (After Am. Inst. Min. Met. Eng. Tech. Paper 13, fig. 12, 1927.)

northeast Pharmacist fissure, the west wall of the Zenobia fissure moving a few feet northward.

During the stage of major regional movement the large block of ground between the Last Dollar-Orpha May and Vindicator zones acted essentially as a unit. It was pressed northward but tended to be deflected northeastward by the southeastward-dipping granite wall and to develop local tight shear zones along both the cross fissures and those of north-northwest trend. The movement along the Last Dollar-Orpha May fissure zone became distributed along these local fissures, but that along the Vindicator-Findley zone, presumably because this zone was not so near the northern granite wall, persisted somewhat farther, although it also became scattered in the vicinity of the Shurtloff shaft.

The block between the Vindicator and Isabella zones evidently acted similarly to that just described, although evidence regarding it is scarce and relatively shallow. It tended to be deflected northeastward and to develop cross fissures and north-northwesterly fissures of the Free Coinage-Wrockloff zone and the Deadwood group, as shown on plate 3 of Professional Paper 54. The Isabella zone itself evidently weakens as it approaches the northern granite wall.

Cross fissures connected with it are in alinement with the Pinnacle and School Section fissures, which are in horizontally bedded arkose beyond the deep, steeply sloping granite wall and evidently represent the waning effects of disturbance.

The cross fissures, lying at a high angle to the direction of compression, were prevailingly tight, particularly in the western part of the area, but in the eastern part, where the effects of deflection must have been cumulative, they were more in line with the dominant direction of movement and more likely to be open. The fissures of north-northwest trend, on the other hand, were subjected to tension throughout the area and were therefore kept more open.

The phonolite magma, whose intrusion followed this major compressive movement, took advantage of the more open fissures and formed dikes, mainly along the fissures of north-

northwest trend but also along some of north-northeast and east-northeast trend, especially in the northernmost part of the area. The basaltic dikes and mineral veins followed in regular order. The veins have the same general features as in other parts of the district.

Eagles Mine

In the Eagles mine the minerals of the first stage are present along both the north-northwest and the cross fissures, but the ore shoots, formed at the end of the second stage, are limited, as shown in figure 42, to the fissures of north-northwest trend and to adjoining parts of certain cross veins. The vein-forming solutions moved upward and northward along the Vindicator zone as far as the junction with the cross fractures. There they spread to the north and west and sealed the fractures with early vein minerals. Renewed movement took place along the junction of the Findley and cross veins at considerable depth, and supplementary adjustment along the local north-northwest veins to the west reopened their upper parts, so that solutions of the ore-forming stage spread upward to the west and formed the shoots along the upper levels of the Eagles and Pikes Peak veins. Along the Pikes Peak vein they may have merged with solutions from the Last Dollar-Orpha May zone, as stated on page 342. With this process in mind, there is little to encourage deeper prospecting along the Pikes Peak and Eagles veins, although, as shown in figure 42, scattered small bunches of ore have been found at the deepest levels developed. The main course of deeper development should be southward and downward along the Findley vein.

Veins North of the Eagles Mine

The shallowness of the workings and their inaccessibility to us prevent a definite suggestion regarding the downward continuity of the veins north of the Eagles mine. The fact that the Zenobia vein is essentially continuous with the Porcupine and Pikes Peak veins suggests that this vein also was

supplied from the Orpha May zone and served as a connecting link with the Pharmacist and other veins of east-northeast trend; but the continuity and eastward convergence of the Empire and perhaps other veins of east-northeast trend suggest that they may have tapped another source, presumably along the junction of the prevolcanic east-northeast zone and the Isabella zone, and spread upward and westward along fractures in the breccia and adjacent granite. (See figs. 8 and 41.) The northwestward dips of the veins should bring them into contact with the southeastward-sloping granite wall at moderate depth, and it is hardly to be expected that ore shoots will be found in the granite very far from the contact or at very deep levels.

Victor-Isabella Group

There has been no opportunity for us to study mines in the Victor-Isabella zone, and the only data available are those in the Lindgren-Ransome report. The bottom of the Lee (Isabella) shaft, the deepest along this zone, is at an altitude of 9,332 feet. The reported exposure of granite on its lowest level (altitude about 9,340 feet), mentioned on page 264, tends to confirm the suggestion that a buried granite ridge lies west of the zone and that the zone overlies a subcrater. The relatively high position of this reported exposure of granite suggests that this subcrater may be shallower than the Vindicator and Portland subcraters and that the veins coalesce and tighten not far below the present deepest workings. There is the possibility, however, of deeper ore shoots within the trough, separated by an interval of low-grade ground below the shoots already mined. The lowest levels were under water at the time of Lingdren and Ransome's survey, and it is not known whether the Roosevelt drainage tunnel, whose direct connections reach within half a mile of the Lee shaft, has had any appreciable effect in lowering the water. The inferred granite ridge west of the Victor-Isabella zone would tend to retard drainage; if so, crosscuts from the lowest level of the Eagles mine (altitude 8,673 feet) or from still lower levels of the Vindicator mine would be necessary to provide permanent drainage.

School Section, Gold Band, Pinnacle, and Cameron Mines

The School Section (Block 8), Pinnacle, and Cameron mines are somewhat isolated to the north and northeast of the Isabella zone. Their country rock is in large part horizontally bedded, consists largely of granitic waste (p. 246), and overlies a coarse, angular, poorly stratified conglomerate. In much of the School Section mine, whose shaft is 750 feet deep, it is colored red by iron oxide and is called "rhyolite" by some of the miners; but it has been bleached to light gray near the mineralized fissures in that mine and throughout the other two mines, whose workings are all close to mineralized fissures.

The School Section mine contains dikes of latite-phonolite, trachydolerite, phonolite, and basalt (monchiquite). Latite-phonolite and phonolite are more abundant than breccia on level 2. The trachdolerite, called the "Sevey dike" or "big basalt" is well exposed on the upper four levels, where it is cut by phonolite and monchiquite ("little basalt"). Much of the latite-phonolite is vuggy, and the cavities, 3 inches or less in diameter, are lined with small crystals (rhombohedrons) of ankerite, which are in part covered by long slender crystals (scalenohedrons) of yellow calcite. In other places fine pyrite is present. These minerals, together with a little pale-purple fluorite seen only in the Maloney vein, are characteristic of the second stage of mineralization. No minerals representing the first stage were noted.

The School Section mine is evidently along the northeastern part of the dominant east-northeasterly fissure zone in this part of the area. Four veins, striking in general north-northeast to east-northeast—the Sevey, Wilson, Kissel, and Maloney veins—and one with a northwest strike, have been prospected and developed. The Sevey vein, found farthest south of the shaft, follows the Sevey trachydolerite dike. Where seen on the third level (450 feet below the collar) it follows a thin phonolite dike 4 inches thick that cuts the trachydolerite dike lengthwise. The ore in this vein occurs in

small shoots. It is of highest grade where the dike dips to the south but is of too low grade to be profitably mined where the dip is northward. The Wilson vein, which follows a phonolite dike, has a northeast strike and is about 30 feet south of the shaft at the surface, but on level 5 it is reported to intersect the shaft, showing a slight northward dip. The workings below the third level were inaccessible at the time of visit, and the extent and pitch of the ore shoot are uncertain, but available information indicates a southwest pitch, at least between levels 1 and 2 (250 and 350 feet below the collar). The Kissel vein has been more or less productive from about 50 feet above level 1 down to level 3 (450-foot level) and probably a short distance below. Near the east end it follows the "little basalt," which here lies along the Kissel phonolite dike; but to the west the "little basalt" leaves the Kissel dike, which the vein continues to follow, as is clearly shown on level 1. The Maloney vein, found about 650 feet north of the shaft on the 350-foot level (level 2), follows the south edge of a phonolite dike. It has been stoped to a maximum of about 35 feet above the level. The only cross vein, found about 300 feet west of the shaft, strikes about N. 65° W. It was stoped on level 1, and the available mine maps indicate that it was also found on level 2, but we have no further information about it.

The ore shoots so far found have been short and irregular. The steplike arrangement of the shoots is less distinct than in some mines but is locally present. Mr. Kyner, lessee, reports that the ore shoots pitch northeast, but the accessible workings were not sufficient to show such a pitch convincingly. A part, at least, of the Wilson shoot pitches southwest. Correlation of the local structure with that of the northeastern part of the district as a whole suggests that the nearest deep source of ore was to the southwest, beneath the junction of the Isabella and the east-northeast fissure zones. Accordingly, even though single shoots may pitch northeastward, deep prospecting to the southwest may be more encouraging. The localization of the veins within a major fissure zone favors general continuity of the vein group as a whole, though there are barren intervals between comparatively small ore shoots.

The east-northeast fissure zone continues beneath Grassy Creek, into the northeast embayment of the crater, and its weak north end is evidently exposed in the Gold Band mine. Only the 56-foot level of this mine, which is entirely in a large mass of phonolite, has been accessible to us, but data supplied by J. M. Miller, the owner, show that the "big basalt" dike and a smaller dike doubtfully termed the "little basalt" are present on the 200-foot level south of the shaft. The "big basalt" follows a curved course and is apparently near its end. The "little basalt" is exposed in only one crosscut. Four veins in the vicinity of these dikes have assayed from 0.10 to 0.62 ounce of gold to the ton. Ground water, which submerged all the School Section levels below level 4 in 1931, was bailed to the bottom of the mine for a time in 1933. The inflow is slow and occurs mainly during the spring, though Grassy Creek nearby is only about 170 feet below the collar of the shaft. The altitude of standing water was close to that in the Isabella mine, and as the two mines are on intersecting fissure zones, it may represent the general level for this part of the district.

Recent work at the Pinnacle mine by the Mexican Gold & Silver Mining Co. has been done through the Mitchell shaft, whose collar has an altitude of about 10,120 feet. The shaft is 630 feet deep, and eight levels have been driven from it. A winze below the bottom level had a depth of 400 feet in 1933. Production has come from the Mitchell vein, which coincides with a phonolite dike of northeast trend and vertical to steep northwest dip. The principal pay streak, which consists of a clay seam an inch or less thick, lies along the northwest wall of the dike and pitches southwest. Intermittent lower-grade streaks lie along the east wall and within the dike. The vein has been stoped at intervals, and the short drift from the bottom of the winze was also productive. The Whipp and Glenn workings, southwest of and almost in line with the present workings, were described by Lindgren and Ransome.[60] They were not productive below the 150-foot level of the Mitchell shaft, and their main ore shoot also pitched southwest. The

[60]Lindgren, Waldemar, and Ransome, F. L., op. cit., pp. 383-384.

McClure vein, north of the Mitchell shaft, strikes N. 85° E., dips 60°-75° N., and consists essentially of first-stage fluorspar and quartz. Although the bottom of the winze is 1,000 feet or more below the surface, ground water has thus far given no serious trouble.

The Cameron mine, operated by Cameron Gold Mines, Inc., is just northeast of the Pinnacle. Its shaft collar has an altitude of 10,066 feet, and its three levels have exposed the Whipp vein and the Mitchell dike and vein, as well as a branch vein that leaves the east wall of the Mitchell vein above level 3 and trends about parallel to it on levels 1 and 2. The ore shoots, like those in the Pinnacle, are thin seams along the dike and at intersections with minor cross fractures or irregular bends. Features of special interest in this mine are an unusually large amount of bedded breccia colored by a green variety of sericite west of the Mitchell vein on level 2 (325 feet deep) and the black "lake beds" cut by the shaft 40 feet below level 2, or at an altitude of 9,699 feet, from which fossil leaves were kindly furnished by Etienne Ritter, consulting engineer for the company.

The present workings of the Pinnacle and Cameron mines affords scant basis for suggestions regarding downward continuity of the veins. The veins trend toward the junction of the Isabella zone with veins of east-northeast trend and were evidently supplied from the local source beneath that junction. This relation and the southwest pitch of the ore shoots encourage the suggestion that other ore shoots may be found in steplike arrangement at favorable places and greater depth to the southwest.

Western Part of the District

The western part of the crater includes the McKinney-Elkton, Index, and Conundrum subcraters. The workings in it that we have studied include accessible parts of the Elkton, El Paso, Conundrum, and Abe Lincoln mines and the Ophelia (Moffat) tunnel.

Elkton Mine

Development and production

The Elkton mine, at Elkton, on the south-central edge of the breccia area, was originally operated by the Elkton Co., and was for many years one of the most productive mines of the district. Its production from 1893 to 1916 amounted to about 630,000 ounces of gold having a gross value of $13,022,100, an average of about 18,000 ounces a year; but production declined abruptly in 1916 and since that year has ranged from 1,000 to 7,000 ounces of mine and dump ore, with a total from 1917 to 1932 of about 44,000 ounces having a gross value of $909,480. The main ore shoot was continuous from the surface and maintained a length of 1,500 feet or more down to level 11, which was reached by 1912. Other ore shoots in the southern part of the mine coalesced with the main shoot on level 7. Below level 11 the ore shoot shortened abruptly, and on level 15, which was opened in 1915, it was not more than 400 feet long. (See fig. 43.) In that year the payment of dividends, which had been continuous for many years and amounted to more than $3,500,000, ceased. Connection with the Roosevelt drainage tunnel, on level 18, was made by the end of the year, but the ore found on level 17 in 1916 was much less in quantity and of poorer grade than that on level 16. Only one small shoot, about 30 feet long, was found on level 18. Before the end of 1916 the mine was placed entirely on a leasing basis, and since then it has been only a small, intermittent producer of newly mined ore. The company was evidently reorganized about 1922 into the Elkton Mining & Milling Co., which operated the mine until May 20, 1923, when it was taken over by the First National Bank of Cripple Creek, which continued to operate it on a leasing basis.

Geology

The workings, which include those from the Thompson, Elkton, Tornado, and Raven shafts (fig. 43), extend from the granite south of the crater wall to a point beneath the summit of Raven Hill. Only a small part of them have been accessible to us, but our observations, together with information ob-

tained from Professional Paper 54 and from Clayton Kissell, superintendent in 1927, give a fair picture of structural conditions. The principal geologic features (fig. 44) include the shattered granite exposed on the upper levels near the Thompson shaft, the steeply overhanging breccia-granite contact, two sill-like masses or "flats" of phonolite between the Thomp-

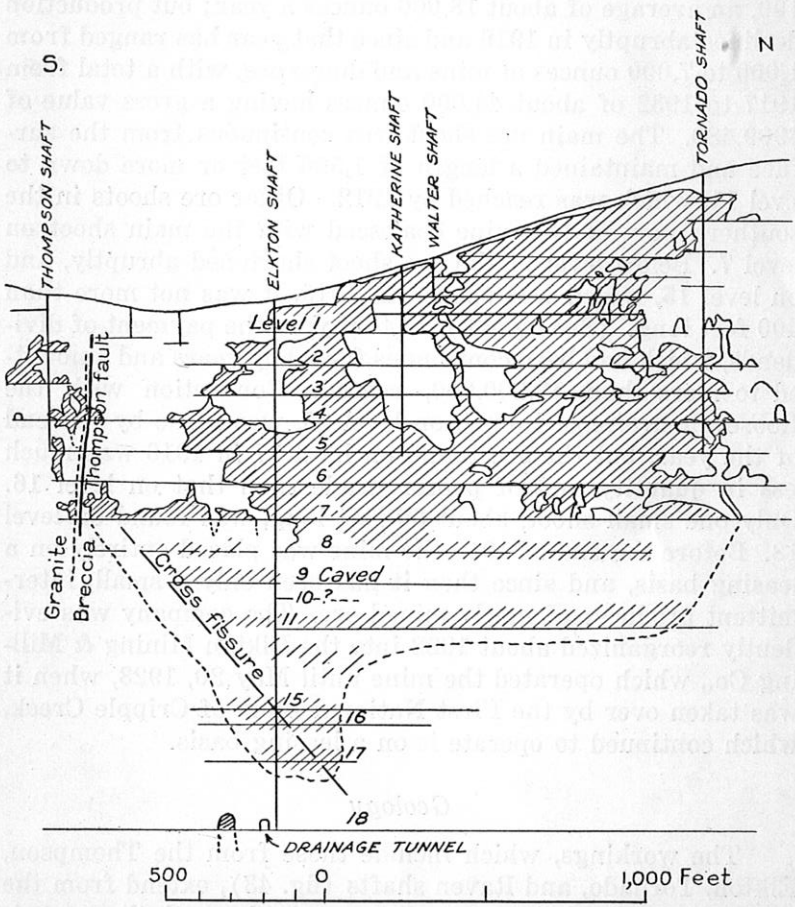

Figure 43.—Generalized profile of the Elkton ore body. All above level 8 is copied from U. S. Geol. Survey Prof. Paper 54, figure 35, p. 333; dimensions of ore shoots on lower levels are based on study of accessible ground and on mine maps.