east and whose general dip is very steep to the south-southeast. Its contact with the surrounding breccia of the main crater of the district is sharp, and dikes of latite-phonolite, phonolite, and basalt in that breccia are abruptly cut off by it, as shown in figure 3. Its upper part is nearly circular in cross section, but it lengthens and narrows downward. On the lowest levels (17 to 20) it becomes constricted in its central part and divides into two roots. The eastern root is the smaller, tapers rather rapidly so far as can be judged by the moderate amount of development around it, and is likely to shrink to a narrow dikelike mass within a few hundred feet;

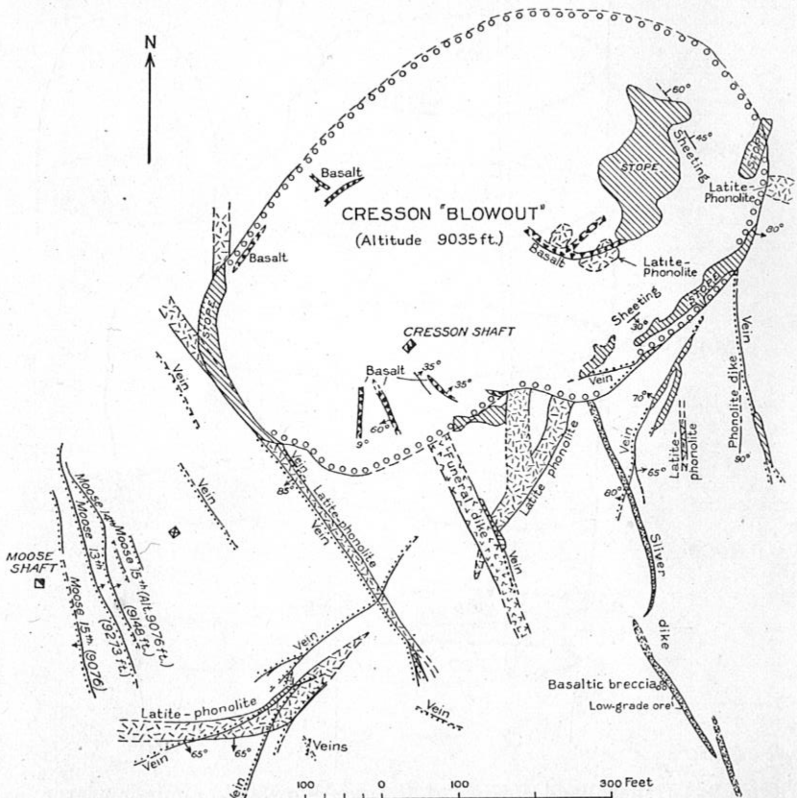

Figure 3.—Plan of level 10 of Cresson mine and of lower levels of Moose mine, showing relations of Cresson blowout to the breccia and dikes of the main crater and to veins and irregular ore bodies.

but the western root, although varying somewhat in outline, has not tapered appreciably as far as exposed and is likely to persist for another 1,000 feet or more. These roots have evidently been developed along a fissure zone of east-northeast trend and steep southerly dip, and they are localized at the intersections of that zone with dike-filled fissures of north-northwest trend.

The basaltic breccia, which is the principal constituent of the blowout, consists of fragments of different varieties of basalt, breccia from the main crater, different dike rocks, and to a small extent of pre-Cambrian granite cemented in a basaltic matrix. The fragments range mostly from less than 1 inch to 3 or 4 inches in diameter, but some, particularly those of latite-phonolite, are much larger. One immense pillarlike mass of latite-phonolite has been exposed from level 7 to level 14. So far as exposed it is vertical or dips southeast between levels 7 and 9 and dips steeply southwest between levels 9 and 13. It is nearly continuous with a large compound dike of north-northeast trend on the south side of the blowout and may also have connected with dikes on the north side, which are conspicuous on level 14. This pillarlike mass, unless studied closely, may be mistaken for a large dike cutting the blowout; but the normal basaltic breccia is intrusive into it at several places, especially along the south edge of the blowout.

The basaltic breccia, however, is cut by short dikes and some large irregular to sill-like masses of basalt. The dikes, shown in figure 3 and diagrammatically in figure 4, are short and are found both within the blowout and along its margin. Those within the blowout trend in several directions, and their exposures are too scattered to give an adequate impression of their arrangement. Several of them fill steeply dipping fractures, some parallel to the long axis of the blowout and others transverse to it. Some of both of the longitudinal and the transverse dikes have steplike arrangements, and a few follow local shear zones. Some of the transverse fractures have a roughly radial arrangement. Several of the dikes along the margin curve into the blowout for short distances before pinching out, but only two have been noted that extend outward from it, and neither of these has been followed beyond the margin. The close resemblance of these dikes to certain of the older basalt dikes in the surrounding ground prevents a positive statement that none of the late basalt dikes extend for any considerable distance outside of the blowout, but it is clear that as a whole they fill fractures of local origin. The largest irregular masses have been found near levels 11 and 18, and it would not be surprising if massive basalt should become the dominant rock of the blowout with increasing depth.

The most conspicuous fractures in the blowout, other than those filled by dikes, are "flats," most of which dip 45° or less in a southerly or southeasterly direction, regardless of whether they are along the margins or in the interior part. (See fig. 4.) They cut the late basalt dikes and are associated with steeply dipping fractures, some of them mineralized, that trend north-northwest and east-northeast, essentially parallel to the dominant mineralized fractures outside of the blowout. Some of the steeply dipping mineralized fractures, in fact, continue across the margin of the blowout. Some of the flats end against steeply dipping fractures, and others intersect them, whereas some of the steeply dipping fractures end against flats—in short, the different sets of fissures form parts of one system that is much more extensive than the blowout itself and, as shown beyond, is attributable to regional rather than local causes. These fractures, therefore, have no bearing on the origin of the blowout, although differences between the basaltic breccia of the blowout and adjacent rocks in resistance to compression and shearing doubtless had some influence on their distribution.

With these data in mind the origin of the blowout and its dikes is interpreted as follows:

The blowout was formed by a series of explosive eruptions. The essentially vertical direction of the explosive force is shown by the nearly vertical walls of the blowout and the large, pillarlike mass of latite-phonolite and by the almost total absence of basaltic breccia among fissure zones in the surrounding breccia. A few small isolated "pebble dikes" closely resembling the basaltic breccia have been found in mine workings near the blowout, but the amount of explosive force represented by them is negligible. The evidence failure of the late basaltic dikes to extend outward appreciably from the blowout is further evidence that the surrounding rock was not noticeably disturbed by the explosions.

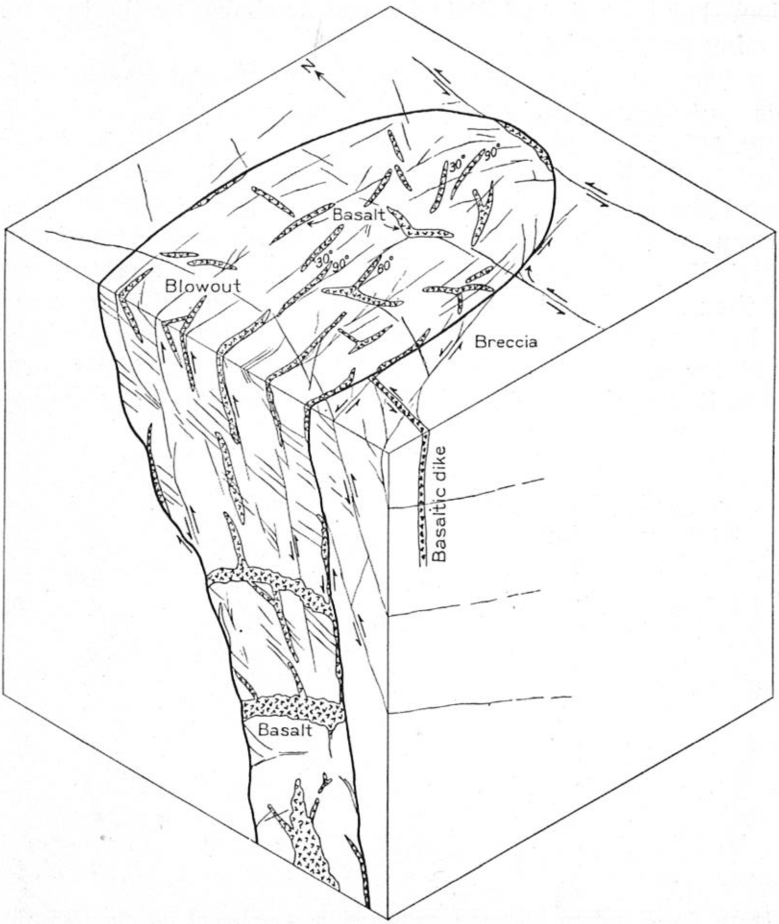

Figure 4.—Diagram showing general arrangement of dikes in the Cresson blowout; also the arrangement of flats and steeply dipping fissures in and adjacent to the blowout and the direction of shearing along the more continuous fissures. The origin of the fissures is explained on page 275 and in figure 13.

It may be inferred from general knowledge of volcanoes that some contraction and settling of basaltic breccia in the blowout must have taken place after each explosion and that some upthrusting was doubtless produced by the explosions themselves and by the rising lava that formed the dikes. The evidence for these local disturbances, however, is much less than that for external disturbances, as shown by the two following paragraphs.

The contraction and settling of an elliptical mass like the blowout would develop concentric fractures, as suggested in (fig. 5). Those closest to the margins would dip about parallel to the margins, and those in the interior would dip toward the margins. Any further shrinkage of the slabs between concentric fractures would develop minor transverse cracks having a radial arrangement, especially near the ends of the mass. Where the mass became constricted, as at *a* and *b* in figure 5, the material above the constriction would at first become wedged, the material below would settle away from it, and an archlike opening would develop. The wedged

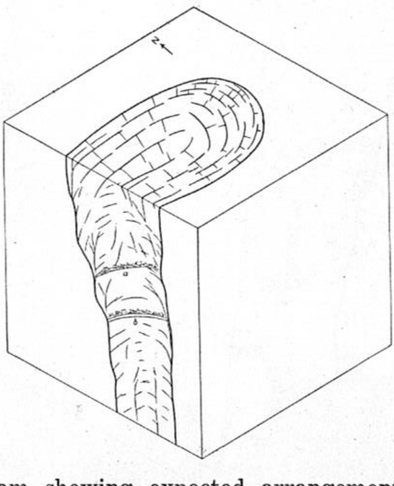

Figure 5.—Diagram showing expected arrangement of fissures that would result from the settling of a mass like the Cresson blowout. Concentric tension fractures dipping toward the walls would be prominent. At constrictions, like **a** and **b**, archlike openings would tend to form, and the rock above them would collapse. Local shear zones or faults would develop above the margins of the arches.

material above would then gradually slump and, like the roof of a broad stope, would develop marginal fissures or faults extending vertically for some distance and ending in branches, the largest of which would curve toward the interior of the mass. The lowest part of the slumping material would break into rubble that would grade upward into less and less shattered rock.

The effects of upthrust (fig. 6) would be to develop weak to conspicuous shear zones along the nearly vertical walls of the mass and above places where the walls changed from vertical to an upward and outward slope. Oblique tension cracks would form, especially along the outer sides of the shear zones, and would slope upward and outward from them. The mass between the principal shear zones would move upward as a whole and tend to develop a conjugate system of fractures that would dip at angles of 45° or less to the direction of upthrust. These conjugate fractures would strike about parallel with the long walls but would radiate toward the rounded ends of the mass. The radiating arrangement would be most conspicuous in the broad, upper part of the mass, where doming with radial tension would be most pronounced. Tension in blocks between the radial fractures would produce minor transverse cracks that would have a generally concentric arrangement, especially near the round ends of the mass. Concentric and radial fractures, therefore, could result from either settling or upthrust, but the concentric fractures would be a dominant result of settling, and the radial fractures a dominant result of upthrust.

Comparison of these considerations with the structural features of the Cresson blowout shows that the only strong suggestions of settling within the blowout after the final explosion are expressed by the marginal fractures filled by dikes and those filled by sill-like masses, and the exposures of these are too few to give an adequate impression of the effects of settling. Some of the transverse fractures filled by dikes may also have resulted from settling, but others, as well as the longitudinal fissures, are so arranged as to be attributable to disturbance along the fissure zone of east-northeast trend that underlies the blowout. This disturbance may have been caused by the intrusion of the late basalt, which was able to form dikes and sill-like masses from a few inches to several feet in thickness. The roughly radial arrangement of some of the dike-filled fissures suggests that they may have been formed by slight doming action of the intruding basalt. Even the marginal fissures could also be attributed to such a doming action if it were sufficient to produce slight shearing along the walls of the blowout. Certain dike-filled fractures that have a steplike arrangement are roughly parallel to the dominant sets of fissures outside of the blowout and therefore suggest that they may have been formed by external forces, especially because those forces, as shown beyond, were intermittently active both before and after the formation of the blowout. Evidence of settling, therefore, is obscure and cannot be clearly distinguished from evidence of deep-seated local disturbance and external forces that affected the region as a

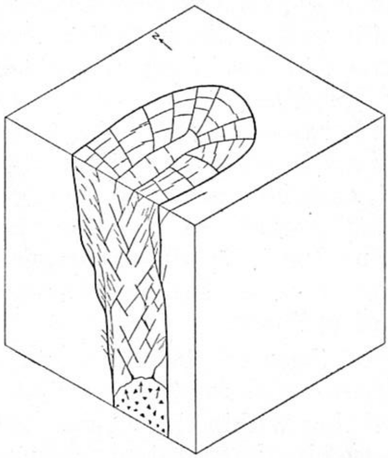

Figure 6.—Diagram showing expected arrangement of fissures that would result from the upward thrust of intruding lava in a mass like that of the Cresson blowout. The tendency to doming would develop prominent radial fissures, especially in the upper part. Shear zones would develop along margins and above constrictions, with complementary tension fractures sloping upward and outward. Conjugate fissures oblique to the direction of thrust would develop within the mass, some serving as minor shear planes and others as tension fractures.

whole. The fissures and shattered ground that contain ore bodies along and within the blowout were formed after the processes that produced the local dikes had subsided, and they are not related to local settling or upthrusting except in so far as fractures originated by those processes were reopened by later regional forces.

Main Crater—Its Physical Features and Subdivisions

Fissures filled by basaltic dikes and those filled by veins in the main crater were attributed by Lindgren and Ransome[30] to slight settling after the breccia had become firmly cemented. We adopted this view for a time, but as our work progressed we were forced to conclude that although the settling of the breccia and the local thrusting action of intrusive masses may account for fissuring to a minor degree, it was caused mainly by regional forces. The evidence for this conclusion is embodied in the rather detailed description that follows and is specifically discussed on pages 270-282.

Two striking features of the main crater are its irregular outline and the presence in it of the two large masses or "islands" of pre-Cambrian granite and schist, which are evidently connected with each other and with the surrounding pre-Cambrian area at moderate depth, and which separate the main crater from the Globe Hill crater to the north. Analysis of structural evidence, to be discussed presently, shows that the main crater south and east of the two islands separates downward into a group of subcraters or roots analogous to those in the Cresson blowout. These subcraters are named for convenience the "Conundrum," "Index," "McKinney-Elkton," "Queen-Ajax," "Portland," "Vindicator," and "Isabella." The abundance of intrusive masses in the southeastern part of the Cripple Creek district, from which most of the gold produced in the district has come, suggests that it contains the principal vents of the area, and other available evidence also points to that conclusion, although any barriers separating the eastern from the southwestern part are well below the level of the Roosevelt drainage tunnel. It will be convenient, therefore, to describe the eastern part first.

[30]Lindgren, Waldemar, and Ransome, F. L., op. cit., pp. 167-168.

The irregular south boundary of the crater is well exposed in the Portland, Ajax, and Queen mines. (See fig. 7.) On the upper levels of the Portland and Ajax mines it dips steeply to the north and east, with gently sloping benches at irregular intervals. Below level 11 of the Portland mine (altitude 8,989 feet) it is continuously steep. It trends northward with easterly dip from the Independence mine for about 800 feet and then turns northwestward with northeasterly dip, forming the boundary of a northwestward-pitching granite prong that is closely paralleled by a fissure zone containing dikes and veins. The west side of this prong is very imperfectly exposed but is, in part at least, overhanging. West of the prong a deep embayment extends southeastward for an unknown though short distance beneath the westward-trending outcrop of the contact and about in line with the Montana vein of the old Granite mine. The west side of the embayment is also overhanging below level 12 of the Ajax mine and trends northwestward toward the contact exposed on the middle and bottom levels of the Queen mine, beneath Eclipse Gulch.

On level 20 of the Ajax mine a large mass of granite has been cut at one point about 200 feet within the breccia and appears to lie parallel to the main contact, as if it had been separated from the main mass by explosive activity along a fissure zone. Two large lenticular slabs of granite in similar position have also been found on levels 7 and 8 of the Queen mine 275 and 70 feet respectively from the main contact. Their positions, similar to that of the large pillarlike inclusions of latite-phonolite in the Cresson blowout, implies that the explosive force of eruption at moderate to great depths acted mainly upward along fissure zones, shattering the more fractured rock but leaving large unfractured masses almost in their original positions. In contrast, the shelving contacts on the upper levels of the Portland and Ajax mines, shown by the contour lines in figure 7, imply that at shallow depths the explosive force expanded and developed flaring walls. The direction of the force from below and the degree of fracturing already undergone by the granite doubtless controlled

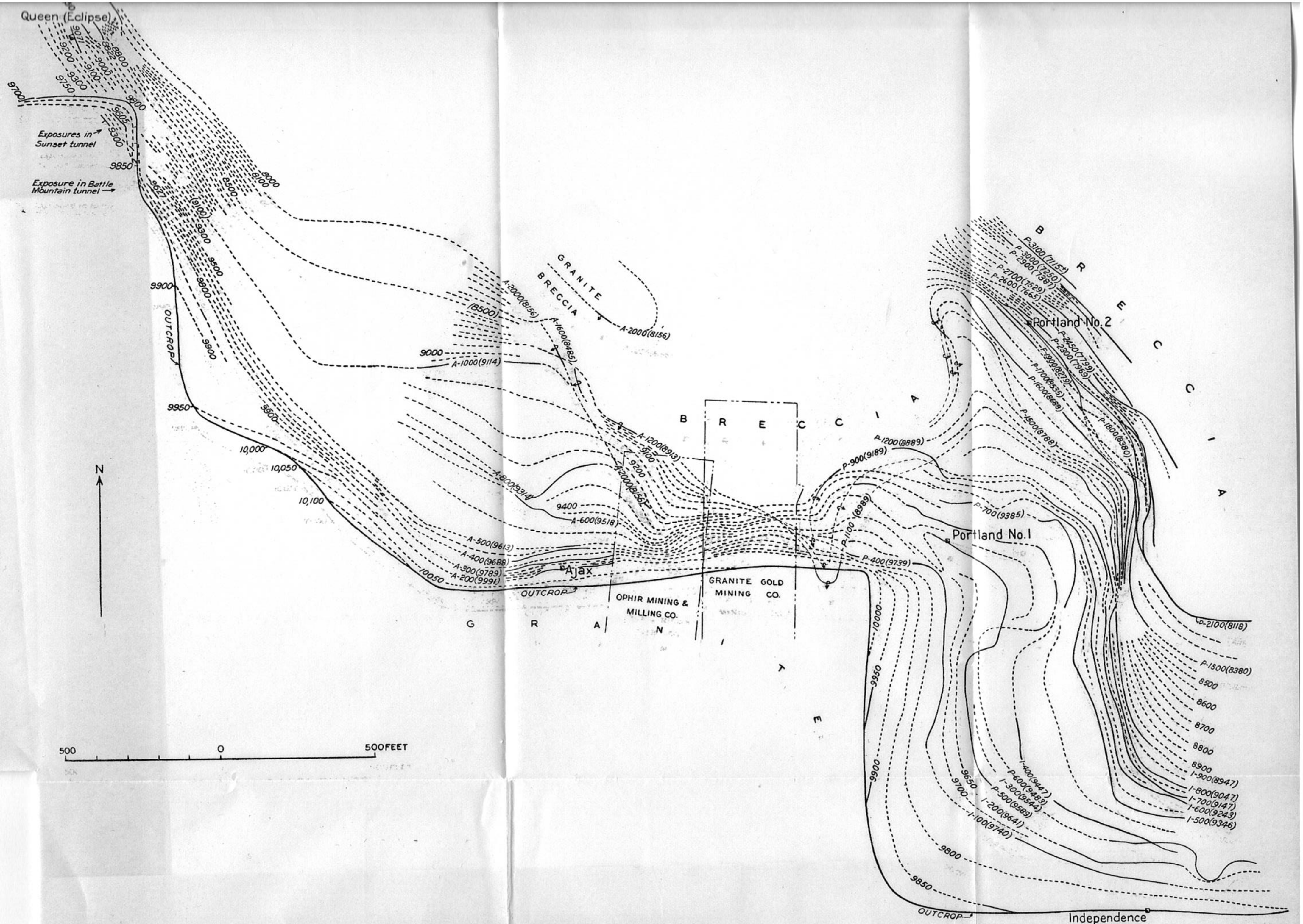

Figure 7.—Contour map of breccia-granite contact in the Portland, Granite (Ajax), and Queen mines.

the amount of flaring along the upper parts of the contact. "Flats," or fractures dipping at small angles, which are common in the granite, would favor the development of shelving or flaring walls.

The outcrop of the contact near the Queen mine makes a right-angle turn from northerly to westerly, as it does near the Portland mine, but shallow mine workings prove that it is overhanging for a depth of at least 500 feet, or to an altitude of 9,300 feet. From that level downward the contact, as exposed near the Queen (Eclipse) shaft, dips steeply and rather uniformly northeastward down to the 1,600-foot or Roosevelt tunnel level (altitude 8,110 feet) where it is locally vertical. It is not present in the main Roosevelt drainage tunnel 800 feet northwest of its lowest exposure, and the nearest exposures to the west are in the southern part of the Elkton mine, a third of a mile away, where the contact is overhanging, with a general easterly trend and steep southerly dip. The meager evidence available in the Queen mine, therefore, indicates another northwestward-pitching prong of granite similar to that in the Portland mine. Evidence between the Portland and Queen mines indicates the presence of a subcrater or root between the two granite prongs, and the distribution of ground water accords with such a feature, which may be designated the "Queen-Ajax subcrater." Its relations to the entire complex crater are shown in figure 8.

East of the Portland mine on the south and the granite "island" on the north the contact of the main crater has been exposed at only a few isolated places, and in view of the irregularities already described, only broad inferences regarding it can be made. According to oral information from Mr. J. T. Milliken, the south end of the bottom level of the Golden Cycle shaft (No. 49, fig. 8), three-quarters of a mile northeast of the Portland No. 2 shaft, is in a breccia containing large fragments of pre-Cambrian rock, which implies that the contact is near, as suggested in figure 8. The relation of the contact to the surface south and southwest of the Golden Cycle shaft suggests that it slopes moderately, as it does in the Independence mine (fig. 7); but the isolation of ground water

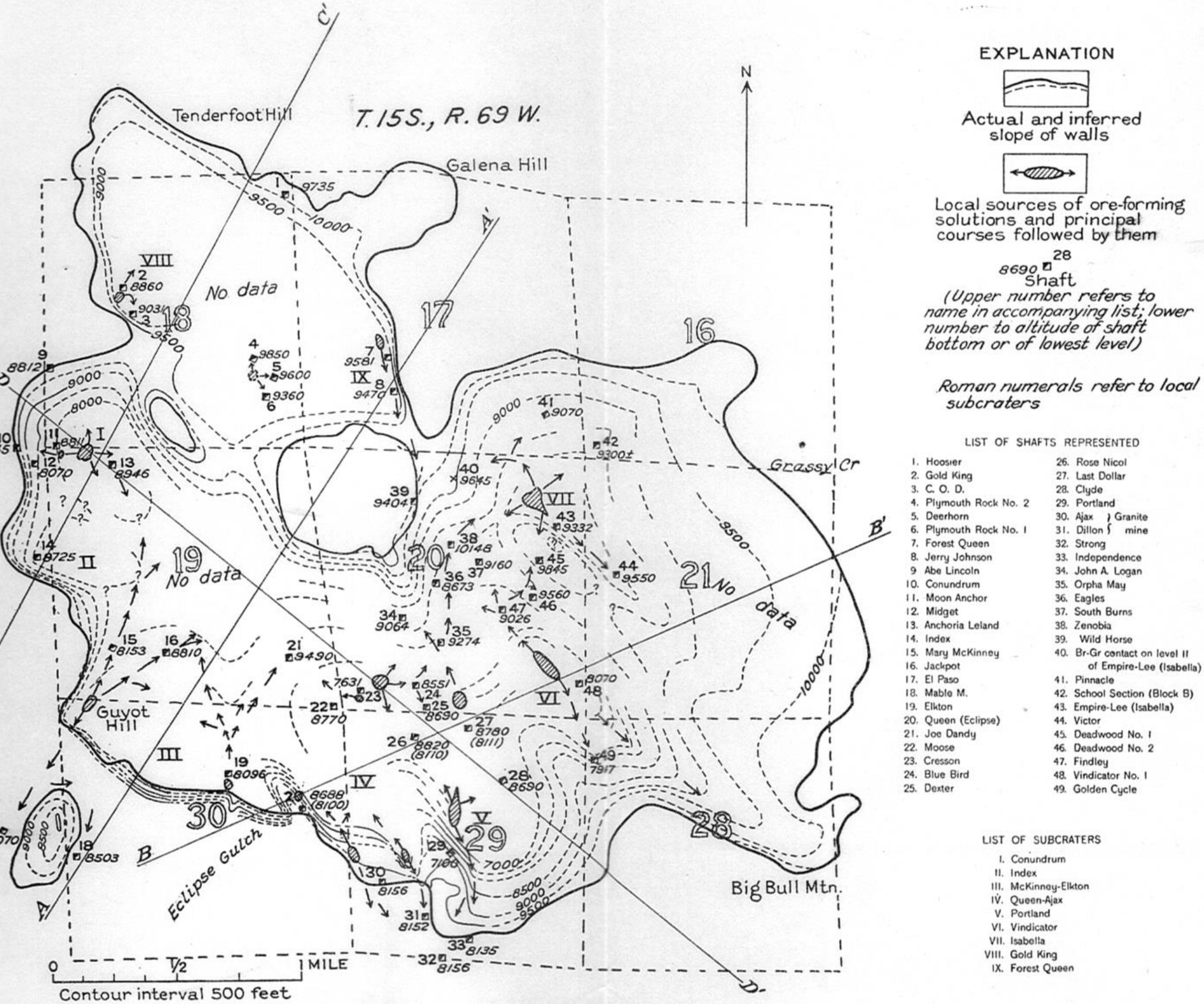

Figure 8.—Outline of composite Cripple Creek crater showing (1) slopes of its walls and positions of subcraters by contour lines; (2) local sources of ore-forming solutions and the general upward courses followed by them; (3) the positions of the deeper shafts with altitudes of their bottoms or deepest workings. A-A′, etc., lines of sections in figure 9.

in the Golden Cycle and Vindicator workings from that in the Portland suggests the presence of a barrier similar to the granite prong in the Portland mine, which separates two deep reservoirs of ground water. The local syenite stock has at least in part isolated the water in the Golden Cycle and Vindicator workings, but south of the stock a granite barrier seems likely, as suggested in figure 8. Such a barrier would separate two subcraters, the Portland on the southwest and the Vindicator on the northeast.

On the northern slope of Big Bull Mountain, southeast of the Golden Cycle shaft, the contact turns southeastward, and shallow workings seen by Lindgren and Ransome[31] show that it is nearly vertical and has evidently been developed along a fissure zone in general alinement with the fissure systems of the Golden Cycle and Vindicator mines. This embayment at Big Bull Mountain may be regarded as a part of the Vindicator subcrater.

From Big Bull Mountain northward to Grassy Creek there are no underground exposures of the contact, and its relations to the surface suggest that the breccia rests on an irregular granite slope, partly an old erosion surface and partly the flaring crater wall. The generalized contour lines in figure 8 and section B-B′ in figure 9, which show the inferred slope of the contact in this vicinity, are in part based on evidence in the following paragraph.

On level 14 of the Lee shaft of the Isabella mine and a little south of the shaft (fig. 8), massive granite bordered by breccia with abundant granite fragments was reported at an altitude of about 9,340 feet.[32] It was under water during the first resurvey and was too isolated to be definitely interpreted either as a large mass enclosed in breccia or as the top of a granite ridge on the floor of the crater; but as all the large enclosed masses found elsewhere are near the crater walls and do not appear to have been moved or rotated appreciably (p. 261), it is reasonable to infer that the granite in the Isabella mine is at or near the top of a buried granite ridge. Such

[31]Lindgren, Waldemar, and Ransome, F. L., op. cit., p. 29.

[32]Idem, p. 389.

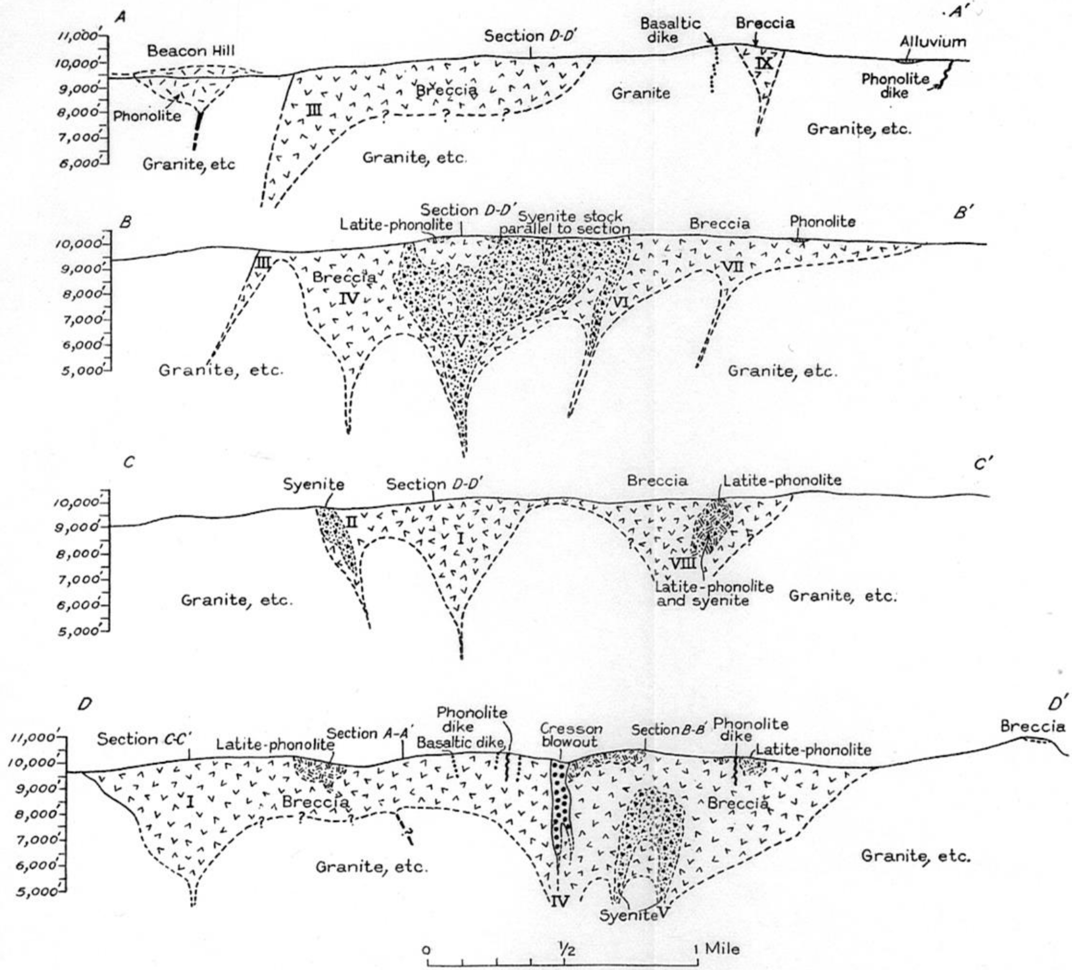

Figure 9.—Cross sections through the Cripple Creek crater. For lines of sections, see figure 8. Roman numerals indicate subcraters.

a ridge apparently marks a barrier between two fissure zones, the Isabella and the Vindicator, each of which trends northwest and is believed to follow the major axis of a subcrater. The fact that water in the Isabella group of mines does not drain into the deeper mines of the Vindicator zone supports this interpretation. If the east wall of the Isabella subcrater should prove to be as close to the fissure zone as the granite mass on the west is, the breccia-granite contact between the Isabella mine and its position on the surface to the east would slope about 1 foot in 7, or not much more steeply than the slope of the contact on the surface south of Grassy Creek, which is 1 foot in 9. Such an inference would be extreme, but it emphasizes the probability of a relatively gradual slope of the breccia-granite contact east of the Isabella subcrater, as suggested in figures 8 and 9.

Northeast of the Isabella group of mines the only underground developments accessible to us were the School Section, Pinnacle, and Cameron mines. Granite has been reported from the bottoms of the Pinnacle and School Section mines, but that in the Pinnacle mine proves to be the coarse, subangular, poorly stratified conglomerate or breccia overlain by well-bedded rock described on pages 245-248. Similar material was found on the 650-foot level of the School Section mine and, according to oral information from William Kyner, is identical with the rock called "granite" on the bottom or 750-foot level, which was under water when the mine was studied. This material, which is horizontally and continuously embedded, doubtless rests on a granite floor outside the northern and northeastern limits of the Isabella subcrater.

The embayment of breccia northeast of the School Section mine and across Grassy Creek is so related to the topography as to suggest that it rests on an old erosion slope of granite and is covered by an intrusive sheet of phonolite. The workings of the Gold Band shaft, however, are said to show phonolite to a depth of 200 feet and also the northern terminations of the Isabella ("big basalt") dike and the closely related "little basalt" dike. There seems to be, therefore, a fissure zone of northeast trend along which the basaltic dikes branched from the main crater and along which some earlier intrusions and even some explosive eruptions may have taken place.

About 800 feet east of the granite "island" and 800 feet below the Emma No. 2 shaft house a west drift along the Empire No. 2 vein on level 11 of the Isabella mine (altitude about 9,650 feet) cut a mass of granite and continued westward in it for 400 feet, and a crosscut from a point near the west end of the drift extended southward in granite for another 400 feet.[33] The breccia for some distance east of the contact contains much granite. The granite is of the gneissoid Pikes Peak type, whereas that of the granite island is of the Cripple Creek type. The intervening area lies along the projected northeastward trending contact between the two granites to the southwest and northeast of the main crater, as shown on plate 2 of Professional Paper 54. The exposure is so extensive that it is much more probably a part of the main granite mass than an inclusion in the crater, and it implies an average local slope of about 45° for the crater wall.

Shallow workings along the southeastern edge of the granite island, as shown in plate 3 of Professional Paper 54, indicates a southeastward-pitching prong, which is reproduced here in figure 8, although the deepest levels of the Eagles and Logan mines, nearby, have not exposed the granite contact; however, the abundant granite fragments in breccia on level 4 of the Zenobia mine and the large granite blocks on level 21 east of the Eagles shaft suggest that the contact is near. The arrangement of dikes and fissures in the vicinity also suggests the presence of such a granite prong.

Farther west there are no underground exposures of the contact along the south side of the granite island and no workings sufficiently deep to give even an approximate idea of the position or slope of the contact. The Cresson mine, whose bottom level has an altitude of 7,631 feet, is midway between the granite prongs of the Portland and Queen mines on the south and that of the granite island on the north, about where the Portland and Queen-Ajax subcraters may coalesce. No

[33]Lindgren, Waldemar, and Ransome, F. L., op. cit., pp. 29, 394.

workings west of the Cresson mine are deep enough to indicate any barrier between these subcraters and those to the northwest, but the generally nonproductive character of the intervening area suggests that relatively shallow barriers may exist.

The western part of the main crater differs in some respects from the eastern part, principally in the absence of exposed granite prongs and in the overhanging position of its southern contact (fig. 9, section A-A′) between the Queen mine and Guyot Hill. This overhanging position, suggested by the slight southward bulge across Eclipse Gulch, has been clearly exposed in the upper levels of the Elkton mine and in the Roosevelt drainage tunnel, 1,900 feet farther west. The contact where cut by the Roosevelt tunnel trends N. 65° W. and dips 81° SW. It is followed by a distinct phonolite dike, and small quantities of latite-phonolite, syenite, and basalt are exposed within the breccia close by it. The adjacent granite is much shattered, and somewhat farther away the strongest fissures and the largest phonolite dikes in the granite strike N. 65°-87° W. and dip 70°-90° SW., or nearly parallel to the contact. These relations point to the development of the contact along a fissure zone of west-northwest trend and to its repeated reopening to admit the dike rocks. One gouge-filled fissure striking N. 45° W. and dipping 70° SW. in the breccia near the contact points to some late, probably postmineral movement along this zone, although the contact itself, sealed by the phonolite dike, is fairly tight. It recalls the south side of the Cresson blowout, but no evidence of mineralization except some impregnation of pyrite has been found along it, for reasons that are suggested on pages 252-260.

West of Guyot Hill the contact turns to a north-northeast course and where exposed on level 4 of the Mary McKinney mine appears to be about vertical.[34] The principal vein in the mine is about 250 feet from the outcrop of the contact and strikes N. 90° E., about parallel to it, but, although the vein dips 65°-70° W., at least on the upper five levels, it has not

[34]Lindgren, Waldemar, and Ransome, F. L., op. cit., p. 314.

reached the contact at a depth of 1,382 feet (altitude 8,153 feet),[35] and the contact therefore must be about vertical or slightly overhanging.

Here also the approximate parallelism of the contact and vein imply development along a fissure zone along which repeated disturbance took place. This fissure zone is approximately in line with the lower course of Cripple Creek, which, as indicated by a study of the geologic map in the Pikes Peak folio, marks a possible prevolcanic synclinal fold (p. 234), if not a zone of faulting. The relation of the fissure zone to a possible syncline suggests development as a compression fissure or strike fault formed during the period of folding.

The general overhanging attitude of the contact from the Elkton mine to the Mary McKinney mine prompts the sugfestion that the southwestern part of the main crater overlies a local subcrater, the McKinney-Elkton, that was developed at the intersection of the two fissure zones. The position and slope of the northern wall of this subcrater are wholly conjectural, but in view of the force of explosion, which, if directed by the overhanging walls, was evidently upward to the northeast, it would not be surprising to find that the wall slopes at a moderate angle and joins a buried floor or ridge (fig. 9, section A-A′) that separates the McKinney-Elkton subcrater from the Queen-Ajax subcrater on the east and the Index and Conundrum subcraters on the north.

Northwest of the Mary McKinney shaft, in the vicinity of the Index mine, the contact follows a prevailingly west-northwest course, roughly parallel to that between Guyot Hill and the Elkton mine. It lies between granite and a lenticular mass of syenite, and the relation of its outcrop to the surface indicates a vertical to steep northeasterly dip, but there is no exposure of it at moderate depths, according to Lindgren and Ransome.[36] We have made no studies in this vicinity except in shallow workings of the Ophelia (Moffat) tunnel. The west-northwesterly trend of the contact suggests development along one of the prevolcanic fissure zones, and the syenite

[35] Oral information from J. T. Milliken, 1934.

[36] Lindgren, Waldemar, and Ransome, F. L., op. cit., pp. 306-308.

mass, together with local dikes of phonolite and basalt, suggests a local deep source of supply; furthermore, the moderate slope of the contact farther north implies that the local syenite mass must be in an embayment or a small and presumably shallow subcrater, which is here called the "Index subcrater."

Farther north, in the Conundrum and Abe Lincoln mines, the contact trends north and dips steeply eastward near the surface but at moderate to low angles on the lower levels, where the dip averages about 45°. At its lowest exposure (Conundrum level 14), at a depth of about 1,300 feet or an altitude of 8,445 feet and 925 feet east of the outcrop, it has again steepened to 80°. The Midget shaft, 340 feet from the contact at the surface (altitude about 9,700 feet), is in gneiss at level 9 (altitude 9,125 feet). On level 8 of the Abe Lincoln mine the poorly exposed contact is 900 feet north of the Moon Anchor shaft, has an altitude of 8,812 feet, trends N. 50° E., and dips about 30° SE. The average dip between the Abe Lincoln and Moon Anchor shafts must be equally low, but the evidence of repeated explosive activity in the vicinity of the Moon Anchor shaft[37] suggests that the contact may steepen below the present workings, as it does on the lowest Conundrum level. To the east and close to the northwest end of the schist "island" the contact is exposed at an altitude of about 9,000 feet in the northernmost working of the Anaconda tunnel.

The general trend of the breccia area between the schist island and the west boundary suggests local development of the crater along a fissure zone of northwest trend, parallel to those that dominated development in the eastern part of the crater; but the dominant direction of phonolite dikes, both in breccia and in the gneiss to the west, is east-northeast. This east-northeast zone may not have been developed much before the period of phonolite intrusion (p. 250), but as it parallels one of the dominant directions of prevolcanic fissuring it may be a prevolcanic zone that was reopened during the phonolite period. The intersection of the east-northeast zone with the

[37]Lindgren, Waldemar, and Ransome, F. L., op. cit., pp. 300-302.

northwest zone would have been a favorable place for explosive eruptions and the development of a local subcrater. Lindgren and Ransome[38] concluded that the breccia in this vicinity filled an embayment of the main crater. The small additional amount of information available since their study supports their conclusion, but in view of the complexity of the crater and the significance of dikes and veins, considered on pages 402-405, we go somewhat farther and suggest the presence of a subcrater, called the "Conundrum subcrater," shown in figures 8 and 9.

Although the foregoing data leave much to be inferred regarding the outline of the crater at great depth, they consistently indicate, as shown in figure 9, that the crater has been developed along certain fissure zones in the pre-Cambrian rocks, the dominant zones trending northwest, as in the Queen, Portland, Vindicator, and Isabella mines; north-northeast, as in the Mary McKinney mine; and west-northwest, as along the south boundary west of the Elkton mine and near the Index mine. Zones of east-northeast trend are indicated by the shapes of the large syenite stock and the Cresson blowout beneath the east-central part of the crater and by certain dikes in the northeastern part of the district and in the Conundrum group of mines. All these directions conform to those expected from the direction of compression and uplift in prevolcanic time.

Fissuring Within the Crater and in Surrounding Rocks

Fissuring in so irregular a mass as the breccia and in the surrounding rocks is complex and may be attributable to different forces. We have compiled maps showing fissures at different levels throughout the mines that we have studied in the district, but adequate reproduction of these maps would require a set of large colored plates, whose preparation would be too slow and far too expensive for the present paper. Significant details of fissuring, however, are shown in the illustrations that accompany the mine descriptions, and an idea of the distribution of the main fissure zones can be gained from

[38]Idem, pp. 25-26.