GEOLOGY
of
THE INDEPENDENCE PASS DISTRICT,
Lake & Pitkin Counties, Colorado.
with
SPECIAL REFERENCE TO TUNNEL SITES
for
DIVERSION OF WATER FROM THE WEST
to the
EAST SLOPE OF THE CONTINENTAL DIVIDE

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ILLUSTRATIONS

Geologic map of Independence Pass district, Colorado

Cross sections of Independence Pass district, Colorado

Geology of the Independence Pass district, Colorado

with special reference to tunnel sites for diversion of water from the west to the east slope of the Continental Divide

By J. W. Vanderwilt and A. H. Koschmann

U. S. Geological Survey

PURPOSE

Cooperative work between the United States Geological Survey, the Colorado Geological Survey Board, and the Colorado Metal Mining Fund, though mainly devoted to the study of mining districts has included studies pertaining to dam, reservoir, and tunnel sites for water supply in Colorado. One of the most recent water-supply projects in the State involved the driving of two tunnels in the Independence Pass district to divert water from Roaring Fork and Lincoln Gulch, on the west slope of the Sawatch Range, to the North Fork of Lake Creek, a tributary of the Arkansas River, on the east slope. The object of this diversion is to increase the water supply for irrigation in the Ordway district in the southeastern part of the State.

The writers were detailed to study the geologic conditions that might affect these tunnel sites and were in the field from the middle of August until the middle of October, 1932. During this time they profited by consultations with W. S. Burbank and T. S. Lovering, of the United States Geological Survey, and D. P. Rohlfing, a mining engineer well acquainted with the district. An excellent topographic map of the district, by M. J. Gleissner and T. T. Ranney, of the United States Geological Survey, was completed for use in mid-September and greatly expedited the geologic mapping. The writers conclude from the field study that the local geologic conditions are generally favorable for the driving of the tunnels but direct attention to a few, possibly minor difficulties.

LOCATION AND AREA

Independence Pass, in the central part of the Sawatch Range, is 20 miles east of Aspen and 18 miles west of Twin Lakes, the two nearest post offices, on State Highway 82. The pass is on the Continental Divide between Lake Creek, a tributary of the Arkansas River, on the east and Roaring Fork, a tributary of the Colorado River, on the west. The area described in this report covers about 25 square miles, and is shown on the accompanying geologica map. The part east of the Continental Divide has been briefly described by Howell[1] as a part of the Twin Lakes district, but the part west of the divide had not been previously studied in detail.

Of the proposed two tunnels, the longer, called for convenience the "long tunnel," is expected to extend from the junction of the North Fork of Lake Creek and Graham Gulch almost due west to Lincoln Gulch, as shown on the map. The other, or "short tunnel," is expected to extend southward from a point on Roaring Fork 1,700 feet southeast of Lost Man Creek to Lincoln Gulch.

RELIEF AND CLIMATE

The topography is rugged. The major streams are below 11,000 feet, but most of the divide is above 12,000 feet and some peaks along it exceed 13,000 feet in altitude. Many of the slopes are between 20° and 40° and are covered with loose slide rock or soil, but relatively few places are inaccessible. The timber line ranges from 11,600 to 11,800 feet in altitude, and some of the slopes below it, expecially east of the divide, have dense growths of spruce and pine.

1. Howell, J. V., Twin Lakes district of Colorado: Colorado Geol. Survey Bull. 17, 1919.

Frost or light snow may occur at any time throughout the year, and the heavy snows that close Independence Pass for the winter may fall at any time from early October to December.

GENERAL GEOLOGY

The formations of the district consist of pre-Cambrian gneiss and granite covered by Tertiary breccia and rhyolite flows into which a granite porphyry, also of Tertiary age, has been intruded.

Pre-Cambrian Rocks

Gneiss.--Gneiss, the oldest rock of the district, occurs extensively in the eastern, northern, and northwestern parts of the area, and small areas of it are present in the central and southern parts, where erosion has removed the relatively thin cover of Tertiary rocks. The relations between the gneiss and the Tertiary rocks, as shown in the accompanying geologic sections, imply that the gneiss will be the most common rock found in the tunnels.

The typical gneiss is a banded rock in which light-colored bands of quartz and feldspar alternate with dark bands of biotite and minor minerals. The arrangement of these minerals in bands permits the rock to break more readily parallel to the banding than across it. Throughout much of the area the gneiss is intimately injected along the banding with granitic material and in places grades into granite. The granitic injections range from bands a fraction of an inch thick up to sills 20 feet and more thick. The strike and dip of the gneiss, as a rule, are more or less uniform in a given area, but locally they vary considerably, owing to minor contortions in the rock. The regional strike is roughly northeast and the dip vertical or northwest, but in the southeast part of the area, as shown on the geologic map, easterly strikes with southerly dips and northwesterly strikes with southwesterly dips are prominent. Regional study has shown that the gneiss grades downward into more nearly granitoid rock, and the tunnels may therefore pass at their great depths into a rock approaching granite in composition and texture.

Granite.--Two large masses of granite are exposed in the area, one near the west end of Green Mountain and the other in the northeast part of the district. They are not near either of the proposed tunnel sites, and the only granite likely to be cut in the tunnel will be in the sills that cut the gneiss. The granite is pinkish gray, medium to coarse grained, and consists chiefly of quartz, pink feldspar, and black mica. Its texture and composition are uniform throughout the area.

Tertiary formations

The Tertiary formations consist of breccia, rhyolite flows, and an intrusive stock of granite porphyry. The breccia and rhyolite were deposited on an irregular, hilly surface, and it is therefore impossible to make close estimates of their thicknesses and of the depths to which they extend along the tunnel sites.

Breccia.--A breccia of pre-Cambrian debris is found in many places between the pre-Cambrian formations and the overlying rhyolite, and in the southern part of the district it is also found interbedded with rhyolite. It is on the whole coextensive with the rhyolite, along whose margins it is exposed, but it is absent for a considerable distance along the divide southwest of Independence Pass, where rhyolite rests directly on the pre-Cambrian gneiss. The thickness of the breccia is therefore variable, but in underground workings north of Independence it has an indicated thickness of about 300 feet and in upper Grizzly Gulch its thickness probably exceeds 500 feet.

The breccia is most commonly composed of subrounded to angular fragments, generally of one kind of rock, but in many places it contains fragments of gneiss, granite, pegmatite, quartz, quartz felsite porphyry, and less common rocks. The average diameter of the fragments is less than 6 inches, but fragments 5 to 6 feet are common and boulders 30 feet in diameter have been found.

The prevailing absence of the breccia at the surface near the tunnel sites prompts the suggestion that it may not be found during the driving of the tunnels, but its irregular distribution prevents a positive statement. This question will be considered more fully in the description of the geology of each tunnel.

Rhyolite.--Rhyolite, called the Grizzly Peak rhyolite by Howell,[2] occupies an elongate area that extends northwestward across the district. This rhyolite flowed over an irregualr and in many places rugged surface, and its thickness therefore ranges from a thin sheet in some places to more than 1,000 feet at Independence Mountain. In the vicinity of the tunnel sites it is of intermediate thickness, and its relations to the prevolcanic surface, as shown in the two geologic sections, imply that it will be cut for a distance of about 1,000 feet in the short tunnel but will not extend to the depth of the long tunnel.

The rhyolite is predominantly pinkish, but in the western part of Independence Mountain and farther west it is light gray. It consists of phenocrysts of quartz, feldspar, and biotite embedded in a dense groundmass, and contains numerous inclusions of pre-Cambrian rocks, expecially gneiss and granite, and fragments of chilled rhyolite. These inclusions are mostly an inch or less in size, but a few are 5 to 8 feet in diameter.

In many parts of the district and expecially near the base of the formation the rhyolite is vesicular. The vesicles may be 2 inches in length but most commonly are half an inch or less. Banding is present but is not common. A characteristic feature of the rock is its sheeted structure, which causes the rock to split into thin slabs 1 to 6 inches thick.

In many places throughout the area the basal member of the rhyolite is a dark-gray to black, more or less glassy rock, which attains a maximum thickness of about 50 feet and is best seen on the divide near the head of Mountain Boy Gulch. In several places this rock occurs in the form of dikes, and it may therefore be encountered locally in the tunnels. It contains numerous crystals of quartz, feldspar, and biotite embedded in a dense to glassy groundmass. It contains inclusions of pre-Cambrian gneiss and granite, most of which are less than 2 inches, though some are 5 feet in diameter. Just beneath the rhyolite a whitish porous tuff is found in places and may be 10 feet or more thick.

Granite porphyry.--The most recent rock formation in the district is a stock of granite porphyry that is intrusive into the breccia and rhyolite. It covers a wide area crossed by Lincoln Gulch in the southwest part of the district. Its western boundary, outside of the area mapped, has been followed in some detail and is everywhere in contact with rhyolite. Its contacts are steep except under Independence Mountain, where they dip 30° to 40° SW. The porphyry does not crop out on the north side of Independence Ridge except in one place near the top of Independence Mountain, where an offshoot extends for a little over half a mile beyond the main boundary of the porphyry.

The granite porphyry is gray and consists of phenocrysts of zoned fledspar, abundant quartz, and biotite in a light-gray fine-grained matrix. The chilled facies found near its margins contains a smaller percentage of phenocrysts and has a denser groundmass than the main mass. Both of the tunnels will cut this rock for considerable distances.

Surficial deposits

Surficial deposits in the district include glacial debris, talus, and alluvial fans. They are shown on the accompanying map only where they are sufficiently extensive and thick to obscure the character and relations of the bedrock. All the gulches in the district have been glaciated and are covered by glacial debris which ranges from a few feet to about 75 feet in thickness along the slopes but which may be much thicker along the bottoms. Most of the glacial covering found along the valley slopes is probably thin, but thicker accumulations are present at the junctions of the tributaries with the main gulches, including the junction of Grizzly Gulch and Lincoln Gulch and that of Graham Gulch and North Fork of Lake Creek, in which the two ends of the long tunnel are located.

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2. Howell, J. V., op. cit., p.l.

Talus fans and alluvial fans are common in the area. The talus fans are confined to the heads of cirques and in general have no bearing on the geology along the tunnel sites. The alluvial fans overlie glacial debris in the valley bottoms and thus have increased the thickness of the valley fill. They are mostly above the positions of the tunnel portals, and those at the west portal of the long tunnel may have materially increased the depth to bedrock.

Structure

The structural features most likely to affect the driving of the tunnels are shear or fault zones, the regional structure of the gneiss, the contacts between the pre-Cambrian formations and the Tertiary formations, and the contact between the rhyolite and the granite porphyry.

Shear or fault zones.--Surface indications of faults are few, but the few accessible underground workings north of the old town of Independence show two sets, one set with a N. 50° W. strike and the other with a northerly strike. The maximum displacement by these faults, shown by the offset of a gold-bearing quartz vein, is about 125 feet, but the average displacement is less than 10 feet. Brecciation along the faults is negligible, even close to the surface. Very little timbering was necessary in the mines and most of the underground workings, 30 to 50 years old, have slumped very little, showing the rock to be unusually firm.

About 7,000 feet east of the junction of Lincoln and Grizzly Gulches and on the north side of Grizzly Gulch two vertical fault zones, one striking northwest and the other northeast, cross the course of the long tunnel. The northwest fault zone is parallel to the contact between the granite porphyry and the rhyolite and a zone here about 200 to 300 feet wide shows fracturing of both the rhyolite and granite porphyry. Slickensided fractures are abundant in the local rhyolite and are somewhat less numerous in the granite porphyry. No displacement is evident and if present is probably small. The northeast fault forms a shear zone about 100 feet wide and has horizontally displaced the contact between the rhyolite and granite porphyry about 250 feet. Its probable continuation northeastward across the Continental Divide is indicated by the presence of slightly mineralized fractures in the rhyolite near the pre-Cambrian contact.

A third fault is suggested along the divide northeast of the two just described, and if present may continue southward across the course of the long tunnel. There the west slope of the divide is gentle, whereas the east slope is a bluff. The rock along the bluff is a much broken granite, but whether it represents a shattered granite sill in gneiss along a fault or is part of the breccia that commonly occurs at the base of the rhyolite has not been determined. Most of the steep slopes that commonly occur on the north and west sides of ridges throughout the district are due to the rapid erosion caused by temperature changes and frost action and are not to be ascribed to faulting.

The presence of swampy ground and several springs a mile east of Green Mountain and the apparent break in the ridge to the southeast suggest another fault zone, which has been indicated on the map; but since the north side of the ridge at this apparent break is clearly a cirque and the apparent break in the ridge is attributable to glaciation, and since the swampy condition may be due to obstruction of drainage by glacial debris, this suggestion of a fault has very little to support it. The absence of any apparent offset along the poorly exposed contact between the rhyolite and pre-Cambrian rocks casts further doubt on the existence of such a fault zone.

In the eastern part of the district few shear zones may be present, but no faults can be traced. At the junction of Graham Gulch and its northern tributary granite is found in contact with gneiss along a broken zone about 25 feet wide but without determinable displacement, which strikes northeast and crosses the tunnel site.

Reginal structure of the gneiss.--The gneiss along the northern part of the short tunnel site maintains its prevailing northeast strike and steep northwest to vertical dip, and its layers will therefore be crossed by the tunnel at moderate to high angles. Near the long tunnel site the strike of the gneiss is more irregular, and eastward and southward dips are common, but on the whole this tunnel, too, will cut the layers of gneiss at moderate angles, and any local shear zones or other sources of weakness along the layers will cause only local difficulties.

Contacts between pre-Cambrian and Tertiary formations.--The contacts between the pre-Cambrian formations and the Tertiary breccia and rhyolite appear, in some places at least, to be undergound watercourses along which some decomposition may have taken place. This statement applies expecially to the relatively porous breccia, which lies between the rhyolite and the pre-Cambrian rocks over much of the area. Small springs are found along the breccia at the head of Mountain Boy Gulch, but springs and a swampy zone from 25 to 50 feet wide are also present a short distance to the north along a poorly exposed contact between rhyolite and gneiss.

In the Brown tunnel, just east of the old town site of Independence, and in the Tillie tunnel the breccia is much decomposed. In these tunnels it is close to the surface and near a probable fault, which may account for its decomposition; but the springs and swamps in other places suggest it may also be decomposed at a considerable distance below the surface. In many places, however, the outcrops of breccia give no indications of decomposition, and it is not likely that serious difficulties will arise where the tunnels are to be driven through breccia; in fact, it is improbable that the long tunnel will cut either the breccia or the rhyolite, and the breccia may also be absent along the line of the short tunnel.

Contact between rhyolite and granite porphyry.--The contact between rhyolite and granite porphyry as a whole is not a marked zone of weakness, as it has had little influence on the localization of topographic features, and the rock exposed along it, with local exceptions, is firm. On the south side of Grizzly Peak the granite porphyry at the contact weathers to a brown-stained gravel along a zone from 10 to more than 400 feet wide. No springs or swampy places have been found along this contact, however, except at one place in Grizzly Gulch, where the swampy ground is more probably the result of glaciation than of circulation along a watercourse at the contact. The contact near both tunnel sites gives no indication of weakness except where it is closely paralleled by the fault zone, already described, over the course of the long tunnel.

CROSS SECTIONS AND RELATED GEOLOGIC FEATURES OF THE PROPOSED TUNNELS

Long Tunnel

(Cross section A-A')

The proposed east portal of the long tunnel is about 250 feet northwest of the junction of Graham Gulch and the North Fork of Lake Creek. The west portal is located about 1,200 feet northeast of the junction of Grizzly and Lincoln Gulches.

Formations along tunnel site.--The east portal is in an area of gneiss locally covered by glacial debris. The gneiss is exposed in the stream channel of Graham Gulch southwest of the portal, and outcrops of it are found along the stream to the west at close intervals for over 3,000 feet. Another outcrop of gneiss was found immediately above the course of the tunnel about 800 feet west of the portal. Solid rock may therefore be expected on the tunnel level within a few hundred feet of the portal. The glacial cover along the tunnel line is estimated to be from 25 to 50 feet thick in places, but the actual thickness at any given place can be determined accurately only by drilling or trenching.

Gneiss may be expected for 13,700 feet along the east part of the tunnel and granite porphyry for about 6,200 feet along the west part. The structure of the gneiss along the tunnel varies, but in general the strike was found to be 50° to 80° east of north. Observations in the surrounding area suggest sharp archlike or anticlinal form in the gneissic banding, the axis of which appears to be north of the tunnel line and to pitch westward. The strike and dip of the gneiss along the tunnel will therefore doubtless change from point to point, but in general the strike will be at an angle rather than parallel to the line of the tunnel, and any weak layers or partings along the gneissic banding therefore should not seriously affect the cost of tunneling. The granite porphyry is massive and apparently without fractures except for insignificant joints and should be a very satisfactory rock in which to drive the tunnel.

The rhyolite which overlies the gneiss along the tunnel line appears to be relatively thin in most places, since erosion has cut through it and exposed the underlying gneiss at altitudes between 11,800 and 12,600 feet on both sides of the divide. The base of the rhyolite near the granite porphyry can not be accurately projected because the exact form of the irregular surface on which it was deposited is not known. The maximum slope of this surface along the divide and to the west above the tunnel is about 35° SW. The projection of this slope on the cross section is about 25° to the horizontal and implies that the contact is nearly 750 feet above the tunnel level; it is therefore improbable that any considerable amount of rhyolite will be cut by the tunnel, although a few of the black rhyolite dikes previously mentioned may be found. These should not affect the tunneling appreciably.

The west portal of the long tunnel will be in unconsolidated material, comprising alluvial fans and glacial debris, which overlie granite porphyry. As the granite porphyry crops out in the stream channel of Lincoln Gulch west of the portal and also in the channel of Grizzly Gulch to the south, it may be inferred that the unconsolidated cover along the tunnel line may not be very thick; but owing to possible irregularities in the bedrock surface, its maximum thickness may exceed 200 feet. The depth to solid rock can be determined only by drilling or trenching.

Faults and possible weak zones.--The gneiss both north and south of the tunnel is cut by a few small shear or fracture zones that strike 35° to 40° west of north and dip vertically. Any displacement along them is probably small and the width of any one zone is limited to less than 10 feet. These zones pinch out along the strike and can not be traced continuously to the tunnel line, although similar minor zones are to be expected there.

The shear zone shown intersecting the tunnel line 2,000 feet west of the east portal is exposed in the stream channel of Graham Gulch. The rock along it is broken and iron stained for a width of nearly 25 feet, but the strike and dip of the zone are not well defined in its one outcrop, and the amount of displacement can not be determined. To the northeast and southwest along its strike this zone is covered by glacial drift.

Under the Continental Divide, about 12,000 feet west of the east portal, two faults are suggested on the cross section. The eastern one is inferred from a steep bluff of broken granite 1,500 feet northwest of the tunnel line, although the bluff may have resulted mainly from glacial erosion. The estimated width of broken granite along the bluff is 200 feet or less. The western one is indicated by an offset of the granite porphyry contact 1,000 feet south of the tunnel line. The width of this fault zone at the granite porphyry contact is estimated to be not more than 100 feet. The dips of these faults are steep or vertical but their strikes can not be definitely determined, although they appear to have the general trends shown on the geologic map. Since these two zones, if continuous, should intersect near the tunnel line, there may be a broken zone between the two, but there is no surface evidence to indicate that this is probable.

A little farther west a shear zone of northwest trend closely parallels the contact between granite porphyry and rhyolite above the line of the tunnel. Many slickensided surfaces parallel to and dipping into the essentially vertical contact are present in the rhyolite and to some extent in the porphyry, but the distribution of chilled marginal facies of the porphyry and of branches of it in the rhyolite indicate that any displacement along the shear zone is probably small. The width of the broken zone ranges from 100 to about 300 feet. The porphyry is iron stained and somewhat disintegrated, although relatively firm rock is found in a nearly continuous outcrop along the contact for a vertical distance of at least 700 feet. Outcrops of the adjacent rhyolite also are numerous, and the rhyolite breaks into sharp, angular fragments that give no evidence of decomposition. No clay mineral was found in either rock. This shear zone may be related to an old fault which guided the intrusion and along which later movement occurred, or is may represent a movement which was entirely post intrusive.

The shear zone at the surface is appreciably weaker than the rock on either side. Underground it will doubtless be relatively weak also and at the tunnel level it may prove to be a water channel in gneiss. The absence of clay minerals at the surface does not prove their absence at lower levels, but if the rocks cut in the tunnel are as firm as those found at the surface unduly heavy ground need not be anticipated.

Short tunnel

Formations along tunnel site.--The north portal of the short tunnel is in Roaring Fork about 1,700 feet upstream from the junction of Lost Man Creek. The south portal is in Lincoln Gulch.

The north portal is in an area of gneiss that crops out in the stream. Glacial drift covers bedrock for 400 to 500 feet south of the portal, but the steep slope is a fair indication that solid rock is near the surface. The gneiss will be encountered at least for 5,000 to 6,000 feet, to its inferred contact with the rhyolite and may extend to the contact with granite porphyry, which is about 7,000 feet from the portal. The position of the contact between the gneiss and the rhyolite along the tunnel line can not be determined because of the irregular surface on which the rhyolite was deposited. Locally the slope over which the rhyolite flowed along the tunnel line appears to strike northeast and to slope about 30° SE. In many other places it slopes 20° to 40° . If this degree of slope persists downward, rhyolite should be cut by the tunnel as suggested in cross section B-B'.

The contact between the gneiss and rhyolite in places is a favorable water-bearing zone but not noticeably weak. Outcrops of the contact commonly show firm rock without appreciable alteration on either side, and no extensive swampy areas are found along the contact, even where small springs are common.

It is also possible that breccia will be found between the rhyolite and gneiss, since it occurs locally on the surface. The breccia may be as much as 300 feet thick, and its inferred dip of 25° along the plane of section implies that it may be cut for a distance of as much as 700 feet along the tunnel. The breccia is a weaker rock than the rhyolite, gneiss, or granite porphyry and may require some timbering; however, as stated in a previous paragraph, the Brown tunnel, which is approximately 5 by 6 feet in cross section, is in breccia for 300 feet and has stood for over 40 years without caving. Similar ground in the proposed tunnel should therefore cause relatively little trouble.

The contact of the granite porphyry at the surface and east of the tunnel line dips about 70° NE., and above the tunnel line the dip of the contact is nearly vertical. From the contact practically to the south portal only granite porphyry will be encountered. Although the immediate vicinity of the south portal is covered with glacial drift, porphyry crops out along the tunnel line only 300 feet to the south, so that bedrock may be expected close to the tunnel level at the portal.

The intrusive contact of the granite porphyry along the tunnel line is well exposed east of the tunnel line high on the slope south of Independence Mountain, and wherever exposed the porphyry is "frozen" to the rhyolite, Indications of shearing, alteration, or other signs of weakness are entirely lacking, and the contact should not cause any difficulty underground.

Faults and possible weak zones.--A fault striking N. 80° E. and dipping vertically is found on the surface about 3,100 feet south of the north portal. In one place along this fault a small remnant of rhyolite is found on the south side of the fault in contact with gneiss on the north side, proving that the south side has moved down relatively, but the amount of displacement is not clear, This fault where exposed nearly 1,000 feet above the tunnel line is accompanied by a zone of broken ground less than 20 feet wide and does not seem likely to cause much trouble if cut in the tunnel.

The doubtful fault zone that has been mapped a mile east of Green Mountain does not appear to intersect the tunnel line, but since it so nearly parallels the tunnel line geophysical methods or drilling are recommended first to determine whether it is really present, and if so to determine its width and relation to the proposed tunnel line. Should it prove to be present and to threaten serious difficulties to tunnel operations, these difficulties may be avoided by shifting the course of the tunnel a little to the east.

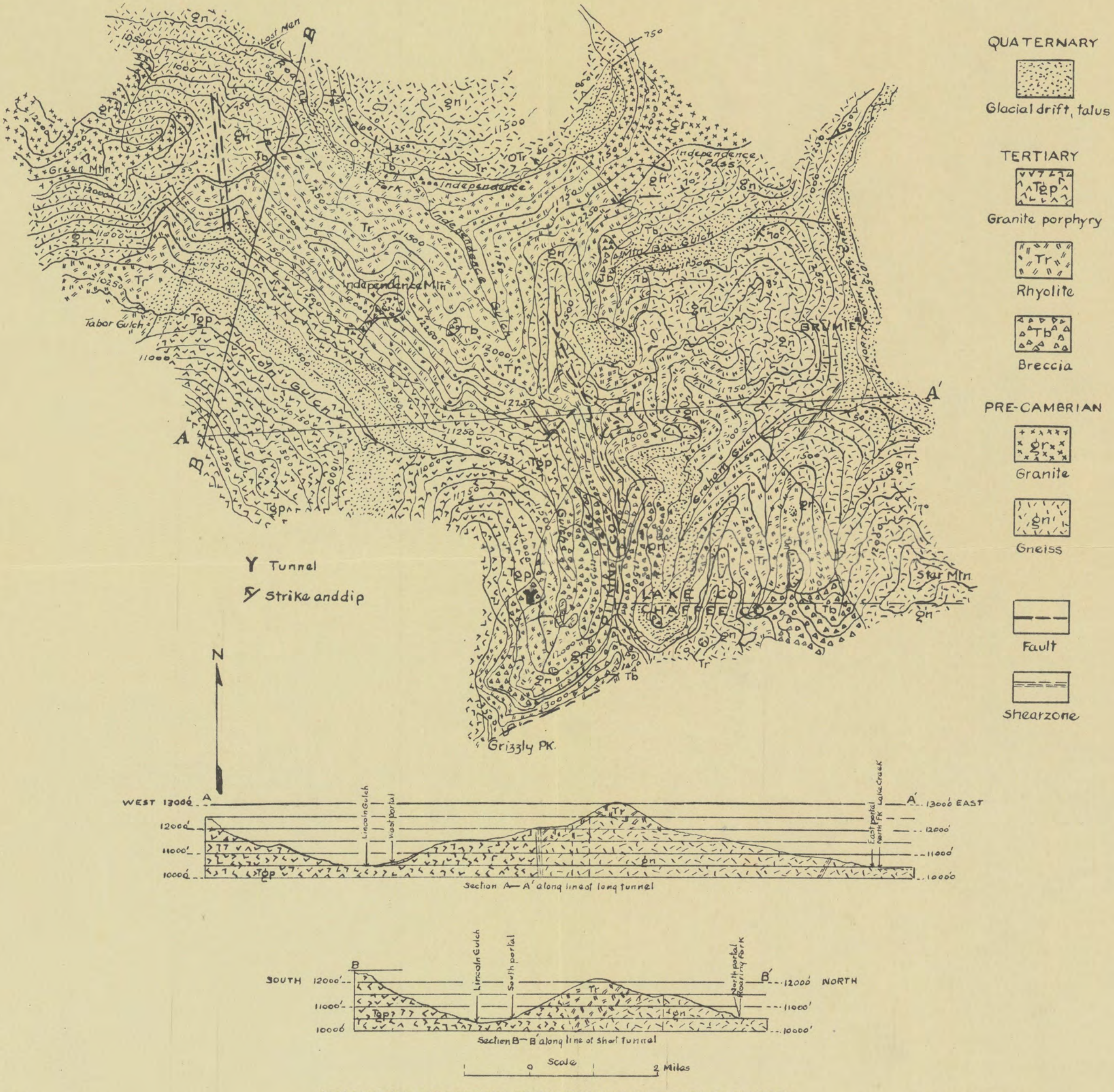
SUMMARY OF CONCLUSIONS

The study shows that there will be about 13,700 feet of gneiss and 6,200 feet of granite porphyry in the long tunnel. These formations will prove strong rock with the exceptions already noted. The total estimated width of possible broken zones which may require timbering is between 500 and 700 feet.

In the short tunnel about 5,600 feet of gneiss, 1,500 feet of rhyolite, and 2,400 feet of granite porphyry may be expected, As much as 700 feet of breccia may be encountered between the rhyolite and gneiss. The breccia is a rather weak formation as compared with gneiss and granite porphyry but is not expected to cause excessive cost in tunneling, since it si known to have stood for more than 40 years with little or no caving in old mine tunnels. A possible fault zone that nearly parallels the tunnel and may intersect it should be further studied by geophysical methods or by drilling.

SOURCE OF MATERIAL FOR CONCRETE

As the tunnel is to be lined with concrete, and as concrete may be used also for local dams, it is noteworthy that the large amounts of granite porphyry and gneiss, as well as the probable minor amount of rhyolite that will be taken from the tunnels, should provide an adequate supply of coarse and perhaps also fine aggregate. The gneiss and granite porphyry, and in most places the rhyolite, have strength, hardness, and resistance to weathering comparable to those of granite and should therefore be satisfactory for such use. In places in the gneiss there may be sufficient clay along joints to necessitate some sorting of the rock, but probably little more than would be necessary in a surface quarry. Laboratory tests should be made, however, to verify this opinion regarding the suitability of the different rocks for concrete aggregate.



GEOLOGIC MAP AND SECTIONS OF INDEPENDENCE PASS DISTRICT, COLORADO

Traced - S.H.Eisenberg
4-17-36