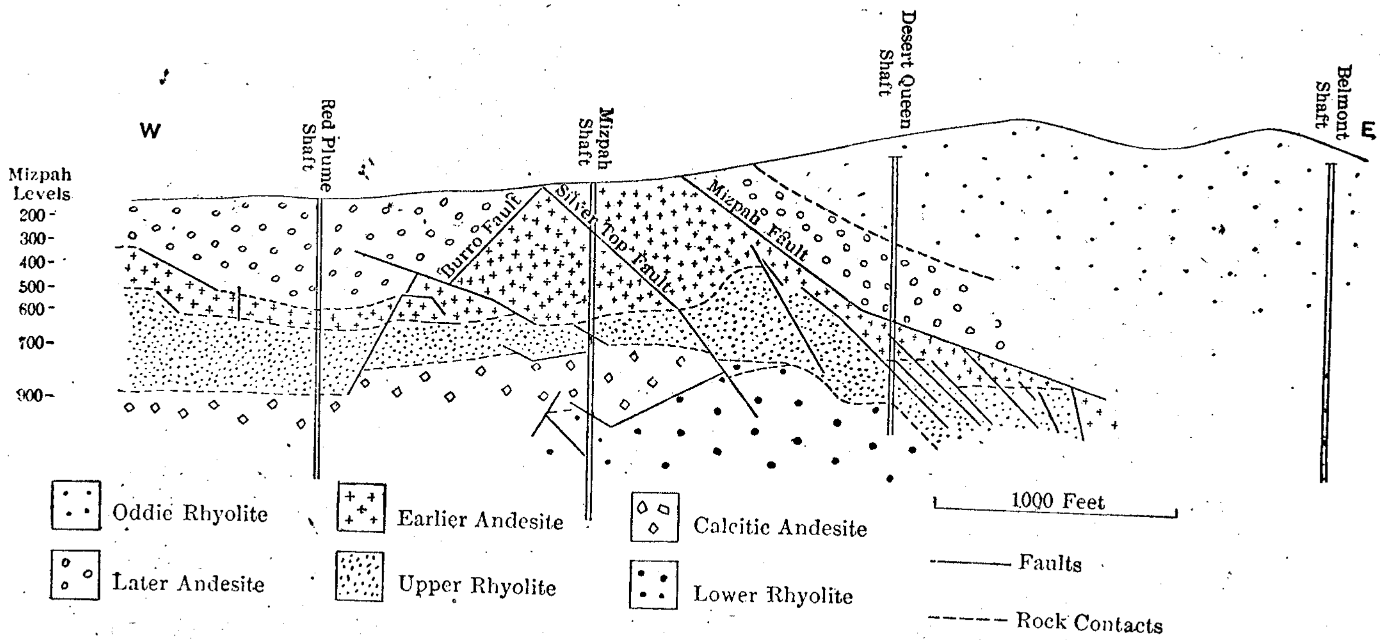
Geology of the Tonopah Mining District, Nevada

By Augustus Locke.*



Geologic column of rocks shown in section (youngest at top).

Spurr (1910).

Oddie rhyolite (partly intrusive).
Lower rhyolite.
Later andesite. } probably identical.
Calcitic andesite (intrusive). } probably identical.
Upper rhyolite (intrusive).
Earlier andesite.

Burgess.

Oddie rhyolite.
Later andesite.
Earlier andesite.
Upper rhyolite.
Calcitic andesite.
Lower rhyolite.

Fig. 1. East-West Section Through Mizpah Shaft.

The important geological publications concerning the Tonopah mining district are those of Spurr and of Burgess. In these publications are presented fundamental differences of interpretation, which are the more interesting because both authorities have had ample opportunity for observation, and because both are geologists of proved ability.

The general geological features of Tonopah are shown in Fig. 1, and the differences of interpretation referred to are outlined in the accompanying notes. Briefly, Burgess regards the various rocks as flows, lying in the order of their deposition. Spurr regards them in part as flows, and in part as flat-lying intrusives. The disagreement, then, concerns the rocks regarded on the one hand as intrusives, and, on the other hand, as flows. These rocks are chiefly the socalled calcitic andesite, the upper rhyolite, and the lower rhyolite.

Economic Importance of the Question of Interpretation.—The economic importance of the question of interpretation is, of course, limited to its bearing on the probable distribution of undiscovered ore. The later andesite is generally conceded to be barren—a "cap rock," at whose lower contact the productive veins apex. The earlier andesite has so far yielded the bulk of the production. As has been already suggested, both Spurr and Burgess regard it as a flow, and both have essentially the same conception of its distribution. Above the bottom of the earlier andesite, therefore, the conception of the ore-distribution is the same, whichever interpretation be adopted.

Below the bottom of the earlier andesite, however, the matter of interpretation assumes supreme economic importance; for, while Burgess regards all the underlying rocks as older than the earlier andesite, and older than the chief ore mineralization, Spurr regards them as younger than both. Under Spurr's hypothesis, exploration in these rocks is emphatically discouraged; under Burgess', it is to a certain extent encouraged.

Outline of the Evidence.—The important evidence appearing to favor the hypothesis that all the rocks occur in flows is as follows:

1. The locus of each rock is horizonlike. For example, the lower rhyolite is encountered at depths averaging about 1000 ft., over an area of at least a square mile. Its surface, except where it is faulted, is seldom steeper than hill slopes, and is chiefly flat or horizontal.

2. Materials closely resembling stratified volcanic tuffs occur abundantly on the upper contact of the lower rhyolite, and less abundantly on the upper contact of the upper rhyolite.

3. The contact between the supposedly intrusive and intruded rocks are, when unfaulted, most often notably straight and regular. Nowhere have the socalled intrusives been conclusively proved to invade by means of offshoots the rocks which they have supposedly intruded. The interpretation of irregularities of contact as proof of intrusion is made difficult by the abundant faulting, and by the possibility of interflow erosion.

4. The andesitic cover has, over a large area, rigidly confined the rocks which underlie it. The lower rhyolite, a rock having a very characteristic and unmistakable appearance, has been proved to occur on the surface only in the territory considerably north of the producing mines, and there in very small and scattered bodies which may be inclusions.

5. The productive veins in certain places pass without diminution either in size of richness from the earlier andesite down into the upper rhyolite.

6. In many places near the top and near the bottom of the upper rhyolite, there occurs an extraordinary igneous breccia, often many feet thick and crowded with foreign inclusions; the matrix is rhyolitic, and the rock looks exceedingly like a flow breccia. The upper portion of the lower rhyolite has numerous but less abundant inclusions.

7. The rhyolites, though containing abundant inclusions, and, among them some which are andesitic, have never

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yielded inclusions which can be positively identified as belonging to the earlier or later andesites.

8. The andesites are free from inclusions of all sorts; therefore their freedom from inclusions of rhyolite is no indication that they are older than the rhyolites.

The evidence supposedly favoring the hypothesis that some of the rocks are intrusive is as follows:

1. In the rhyolites, a banding resembling flow structure sometimes follows irregularities in the contact:

2. The rhyolites occasionally have on their contacts with the andesites knoblike and wedgelike projections, looking like intrusive shapes.

3. In certain places, the calcitic andesite is separated by rhyolite from the later andesite with which it is supposed by Spurr to be identical. In certain places, the earlier andesite is separated by upper rhyolite from a rock called glassy trachyte, with which Spurr supposes it to be identical.

4. The profitable veins often disappear or weaken when they reach down to the lower contact of the earlier andesite.

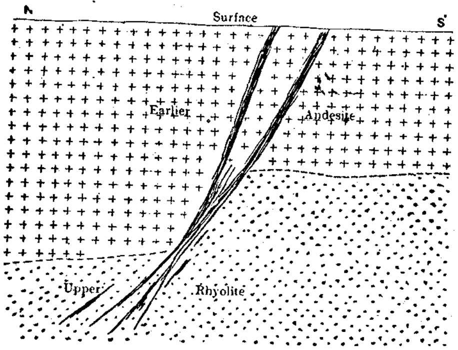


Fig. 2. Downward Extension of Typical Vein Into Rhyolite.

The Evidence Afforded by the General Distribution of the Rocks.—It must be granted at the outset that the disposition of the rocks in horizons creates the presumption that they are flows. Most of the shafts penetrate similar rocks in similar succession. Thus, the lower rhyolite, so far as is known, underlies the whole district; the calcite andesite almost everywhere covers the lower rhyolite; and above these rocks come, in order, the upper rhyolite, the earlier andesite, and the later andesite. The individual sheets of rock have many irregularities in thickness; these, however, are satisfactorily attributable to inter-flow erosion and to faulting.

Again, if we conclude that the earlier andesite is the oldest rock in the district, we must conclude also that it has been floated up by the intrusive underlying rocks to a height of at least 1000 ft., and possibly to a much greater height. (The lower contact of the lower rhyolite is not known.) During the process of floating up, the andesite has retained over an area of at least a square mile, its integrity and approximate horizontality.

A general view, then, of the large features of rock-distribution affords strong evidence in favor of the theory of extrusion. Nevertheless, it is conceivable that pseudo-flows might result from intrusion, and this evidence is therefore, by itself, inconclusive.

The Evidence Afforded by the Supposed Tuffs.—If the large facts of rock-distribution fail to furnish conclusive evidence of the origin of the rocks, this evidence must be sought in the details of the rock contacts.

In general, there are certain details of rock contacts whose testimony must be accepted as unimpeachable. One such detail is the existence at contacts of volcanic tuffs; genuine tuffs being proved to exist between layers of volcanic rocks, it is difficult to conceive of evidence, however abundant, which would prove that the layers are not flows.

It becomes, therefore, a matter of extreme importance to determine whether or not in Tonopah the supposed tuffs are genuine. Burgess, who discovered them, believes that they are. Spurr believes that they are not.

That they are tuff-like, is beyond doubt. They are somewhat soft; they possess stratificatioin, marked by alternating bands of coarse and fine fragmental material; they cleave easily along the junctions of these bands; they lie with their structure parallel with the rock contacts.

If they are not true tuffs, resulting from surface deposition, then they are conceivably attributable to one or both of two processes—flow banding (the arrangement of inclusions along flow-lines) and movement-banding. Spurr's conception of their origin is expressed in the following: ". . . brecciated and granulated rock is often layered by the fault-movement and fault-pressure, so that it assumes all the appearance of certain varieties of surface-formed detrital tuffs."

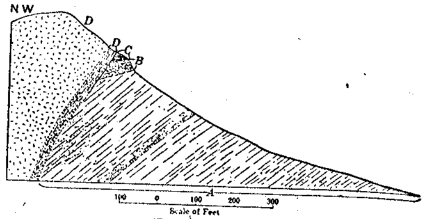
Microscopic examination of thin sections of specimens from the Mizpah 700-ft. level yields conclusive evidence against the possibility of the production of the supposed tuffs either by flow-banding or movement-banding. (1) The tuffs are made up of sharp-cornered fragments, often crowded closely together, and are typically elastic. (2) They are distinctly layered; layers of coarse material alternate with layers of fine material, with no gradation from coarse to fine. (3) The abundant quartz phenocrysts, with one or two exceptions, when revolved in polarized light, extinguish with much suddenness. The wavy extinction, which is the invariable characteristic of strained quartz, is strikingly absent.

That a sorting out and sharp separation of coarse from fine should result from flow or movement-banding, is, of course, incredible. And the significance of the unstrained quartz phenocrysts cannot be questioned. Indeed, the tuffs are so life-like and their detrital origin so obvious that their import would be ordinarily accepted as a matter of fact.

The Supposedly Intrusive Contacts.—The supposedly intrusive contacts of rhyolite with other rocks at no place seen by me offer incontestable evidence of intrusion. Before such proof can be accomplished, it is necessary to prove that the irregularities were not caused by faulting, or by inter-flow erosion, or by both. Now, in localities of extensive rock alteration and abundant faulting, such proof is impossible; indeed, here the proof that the irregularities were actually caused by faulting is frequently possible.

The rhyolite at certain places possesses a banding which follows to some extent irregularities of the contact, and which sometimes looks like flow banding, and might suggest intrusion. I have failed, however, to find any such place where the evidence of intrusion was unequivocal. Usually, the banding is irregular and very discontinuous. It is quite as often oblique to the contact as parallel with it. Moreover, if contact-movement, as Spurr believes, can produce tuffs, it is very easy to conclude that it can produce apparent flow structures.

Evidence Afforded by the Localization of the Profitable Ore-Deposits.—The usual localization of the profitable ore deposits to the earlier andesite is one of the most interesting facts of ore occurrence with which I am familiar. In certain cases, the ore ends abruptly when it comes down to the lower contact of the andesite. In other cases, it extends down into the underlying rhyolite, ultimately, however, weakening and dying out. Occasionally (Fig. 2) it survives for a time with a hanging wall of andesite and a foot wall of rhyolite, ceasing shortly after it passes entirely into the rhyolite. Lastly, it passes from andesite to rhyolite without change.



(From *Professional Paper No. 42, U. S. Geological Survey*)

A. Finely stratified Siebert tuffs (lake-beds) with occasional layers of rounded pumice fragments or water-worn lava.
B. Basaltic agglomerate with bombs, capped by solid basalt.
C. Basalt.
D. Brougher dacite, introsive neck.
D. Glassy marginal facies of dacite.

Fig. 3. Vertical Cross-Section of S. E. Side of Siebert Mountain.

To explain the superior productivity of the andesite, many hypotheses are possible: (1) The andesite is the earliest rock; the chief ore mineralization followed it and preceded the other rocks (Spurr's hypothesis.) (2) The source of the ore minerals may have been the andesite itself or the upper rhyolite (Suggested by Burgess.) (3) The ore was deposited largely by metasomatism. The various rocks, particularly the upper rhyolite and the earlier andesite, present great contrasts in texture. Certain textural and chemical properties possessed by the andesite caused it to be more favorable to the precipitation of the ore minerals than the other rocks. Or the andesite was more favorable to the formation of initial channels than the other rocks. (4) The path of travel of transporting agents was mainly along the andesite-rhyolite contact and upward into