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REPORT ON THE

GEOLOGY AND ORE POSSIBILITIES OF THE PROPERTY OF THE

TONOPAH BELMONT DEVELOPMENT COMPANY

at

Tonopah, Nevada.

by

H. P. HENDERSON

Mining Engineer and Geologist.

June 27, 1924.

CONTENTS.

REFERENCES.

References to publications on the geology of Tonopah are referred to by letter, as follows:

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H. P. HENDERSON
MINING ENGINEER
522 FIFTH AVENUE
NEW YORK

PART I.

SUMMARY OF PRESENT SITUATION AND OF GEOLOGICAL CONCLUSIONS.

With the approach of the summer of 1923 and the expiration of the Pittman Act you were advised that no more profit could be expected from Company operation of the Belmont Mine at Tonopah, that the mine workings should be leased and that the mill should be shut down. Milling was terminated about the first of September, and the idea was considered of removing the mill from Tonopah to another property. Profit from Belmont ore dropped in August to $3,344.

About September 1st I made, at your request, a brief inspection of the mine and as a result, advised you under date of September 20th, that the evidence was not conclusive that the mine was substantially worked out. On the other hand there seemed to me to be considerable possibility that new blocks of ore could be opened up. I therefore suggested to you a detailed examination of the situation. I had previously advised strongly against leasing.

Since September, 1923, monthly profit from Belmont ore has compared very favorably with the first part of 1922. During the first three months of 1924, such profit amounted to $49,462, or 28 percent more than the $38,588. earned from Belmont ore during the first three months of 1923. This is in spite of higher expense and deductions for ore treatment, on account of the mill shut down, higher development expense per ton, and much lower price of silver. With the mill running, assuming ore is available, lower grade ore could probably be mined with larger tonnage and substantial reduction in costs.

A very important element in these improved results was the opening up by Mr.Robins, of the I.O.U. vein, which appears to be the continuation of the Rhyolite vein east of the Belmont fault. This can not be regarded as a last opportunity. There would appear to be quite abundant opportunities for opening up greater or less amounts of ore, though this was undoubtedly one of the most favorable places.

During the summer and early fall of 1923, Mr.Robins had no engineering assistance in connection with the operation of the mine. Such a condition prevents the keeping up of data necessary to finding ore. It is very unjust to the mine and should not be repeated.

The poor stage of operations last summer appears to have been the direct result of a spirit of pessimism rather than of actual conditions. It had been assumed that certain rock formations were entirely unfavorable, that the area of past and present stoping operations was entirely exhausted, and that it was impossible to project faults and interpret their effects in a quantitative way as assistance in pointing the way to faulted continuations. All these ideas are, I believe, in large part, erroneous. I believe there are good chances of ore in some of the deeper formations, and that by close study and systematic map records, with close attention to faulting, the continued discovery of ore is possible both in the areas of old stoping and in faulted continuations.

The record of annual earnings from the Belmont Mine shows a very consistent series of between one and two million dollars annually from 1910 to 1917 inclusive, and between $603,000. and $255,000. annually from 1918 to 1923. There have been produced 1,802,898 tons containing $37,673,771. or $20.89 per ton, from which about $15,000,000. or $8.30 per ton was profit and $10,793,063. have been paid in dividends. This is the record of an extremely good mine, the sort of mine that dies hard. There is nothing in the total or the recent productive record, in the results of inspection or in theoretical geological considerations that warrants pessimism or the expectation of immediate death. The fact that the present average grade of ore mined is somewhat higher than the average during the life of the mine, and that good profit is possible even with the present small scale operations, the mill shut down, higher development cost per ton, the present economic conditions, and the low price of silver, shows much vitality. There is every reason to expect that a systematic course of treatment will bring good results.

Although no definite statement can be made based on ore reserves, it would seem entirely reasonable to hope that $10,000. to $20,000. monthly profit can be continued for two years and perhaps considerably longer, from operations mostly within the present general limits of development work and with about the present monthly development expense. An optimistic point of view is required for such expectation, as it is based on general impressions, not on visible ore, but no more optimism than is justified in the case of a mine that has practically always, for a long period of years, done better than was expected of it. With such a mine reasonable optimism pays better than pessimism.

There are, however, additional possibilities in deeper rock formations beyond the present limits of development, which may readily prove of greater importance in extending the life of the mine. These should be well tried out. I believe that an expenditure around $12,000. monthly should be authorized in exploring for deeper ore, in addition to the present rate of expenditure which is all in connection with immediate probabilities. On account of the extensive faulting which brings much of the property on the 500 level to greater depth from the geological standpoint than the eastern 1500 workings, it would seem inadvisable to sink the Belmont shaft deeper for the present. It appears entirely reasonable to hope that funds for this work can be derived from current operations.

The geological ideas which have been most widely held regarding the relations of the ore and the various rock formations of Tonopah are the result of the work of Mr. J.E. Spurr, who came to very definite conclusions at an early stage in the development of the district. These conclusions were not greatly modified in his later work.

Spurr regards deposition of pay ore as of two periods: The principal large and rich veins which have "made" the mining camp of Tonopah are considered of first period deposition, and the importance of the second period of ore deposition is stated as insignificant compared with the first period.

To contain ore, a rock formation must have been in place before ore was deposited. The Mizpah trachyte and

Glassy trachyte are the only rock formations regarded by Spurr as older than the first period of vein deposition and these with Montana breccia and West End rhyolite are the only formations regarded as older than the second period of ore deposition. These conclusions have discouraged much exploration of the deeper rock formations in most of the mines of the district.

In the present investigation the greatest emphasis was placed on the bringing together of as much as possible of the aggregate experience of the district, rather than in the interpretation of individual exposures, most of which are open to more or less question and which have been variously interpreted. For this purpose a series of over one hundred level maps, north-south and east-west sections of the district and of the Belmont Mine were constructed. This method enables the consideration as units of the vein systems and of the total exposed masses of rock formations, and the cross examination of projections and of hypotheses from different aspects. Some new conclusions, important in connection with the possibility of deeper ores, have resulted from this work.

The productive veins that have been regarded as of two periods of deposition are indistinguishable in mineral contents and in the gold silver ratio which is characteristic of Tonopah but not characteristic elsewhere. I regard these veins as being deposited in one period but over a term of probably a few thousand years immediately following the intrusion of West End rhyolite. This conception is more favorable than the earlier conception to the presence of ore in the deeper rocks. The Murray vein is an example of a deep productive vein which could not be a "first period" vein but the ore from which is identical with "first period" ore.

Mizpah trachyte, Midway andesite and Calcitic andesite have been regarded as distinct formations, but they have not been distinguishable in a practicable way in many places. I regard them as phases of one andesite formation, which have been altered differently. The Mizpah type has been altered by solutions closely associated with ore fluids, while the other types were altered by solutions not intimately associated with ore. While experience in the district has shown the typical Midway and Calcitic phases as unfavorable for ore, veins in other districts similar to Tonopah have andesites of similar alteration as wall rocks and as in the case of the Favorite vein, ore bodies have been formed in Tonopah in rock previously classified as Midway andesite. These phases are certainly not unfavorable to the same degree that a later formation is unfavorable. It is possible that under changed conditions of deposition, as at greater depth, ore may have been deposited in the Midway and Calcitic phases.

Most of the formation heretofore clasified as Glassy trachyte, Montana and Extension breccias, which may probably be correlated, and West End rhyolite appear to be closely associated rhyolitic intrusions, of which the West End rhyolite was the latest and was closely followed by ore deposition, starting while the West End rhyolite was too hot for the precious metals to be deposited in it, but continuing with the ore fluids rising along somewhat changing courses while the rhyolite cooled to such temperature that ore could be deposited in it. Thus some veins penetrate West End rhyolite, others do not. There appears to be no known reason why ore should not extend into Extension or Montana breccias, and the Glassy trachyte is favorable in similar respects except that its physical character appears to tend to the formation of stringers and included fragments of rock rather than solid veins of clear ore.

Oddie rhyolite and the closely associated Tonopah rhyolite, where correctly classified, appear to be rocks younger than vein deposition and therefore not capable of containing the productive veins. There seems, however, slight justification for the correlation of the rhyolitic breccia cut by the deep drill holes at the Silver Top and Mizpah shafts with Tonopah rhyolite. More probably, it is older rock, which solidified before vein deposition, therefore capable of containing ore. This rock is here named Silver Top rhyolite.

In the vicinity of the West End and McNamara properties an anticlinal structure having east-west axis, formed by a somewhat flat intrusion of West End rhyolite is well exposed. This anticline extends east into the Tonopah mining property and, although conditions are much obscured by faulting, it appears to continue at least in rudimentary form into the Belmont property. As may be seen on the level map and sections, the principal veins follow this anticline rather closely through the district, on approximately the same course, lying in the Mizpah trachyte above it, in the West End rhyolite and on its contacts. In the deeper levels of the Victor mine the Murray vein appears to be leaving the lower contact of the West End rhyolite and passing into Extension breccia. Veins have been more abundantly developed above and on the north side of the anticline than above and on its south side, moreover the former, which characteristically dip north, are usually larger and richer than the latter, which frequently dip south.

In the western part of the district where faulting is less abundant ore shoots have a distinct westerly pitch. In the Belmont and Eastern Tonopah mining areas abundant easterly dipping faults give an impression of easterly pitch, but study of the unfaulted margins of ore bodies, as in the case of the eastern portion of the Belmont vein shows westerly pitch. It is believed that the deep source of the ore fluids was to the north and west of the developed veins.

In the Murray vein, in the lower levels of the Victor mine, the large ore body composed of interlaced veins and stringers with unreplaced or partially replaced rock between has somewhat a pipe like form as contrasted with the more nearly tabular form of most of the veins of Mizpah trachyte. It is believed that this represents a main channel of the ore fluids. The distribution of ore through the productive part of the district indicates strongly that other channels must exist further east. The Murray ore shoot extends to 2000 feet depth without displacement by any important fault. The more abundant faulting to the east may explain in large measure, the absence of similar discoveries.

Subsequent to ore deposition there was much faulting in the district, notably in the Belmont property and its vicinity. From the eastern part of the Tonopah Mining property to the eastern part of the Belmont property there has been vertical fault displacement of about one thousand feet, so that the Belmont vein workings on the 1500 level are no deeper from this geological aspect than the 400 or 500 Mizpah workings west of the Desert Queen fault. This total displacement is divided between a number of important faults, with 200 feet or more vertical displacement on each fault.

This faulting is of the greatest importance in exploration for downward continuations of the ore channels. As illustrated by the stope elevation and other maps, the Mizpah vein in the western Belmont area is almost certainly the downward continuation of the Belmont vein in the central and eastern areas, although the latter extends much deeper than the former.

For ore to exist in any portion of a rock mass, the rock must be older than the veins, the particular portion of the rock mass must lie on a course of the ore fluids and the physico-chemical conditions must have been right for ore deposition. The main andesite mass, including the Mizpah trachyte, the Midway and Calcitic phases, the Glassy (trachyte) rhyolite, the Montana and Extension breccias, the West End and Silver Top rhyolites, are all probably older than the veins; while the Oddie and Tonopah rhyolites, according to restricted classification, appear to be younger than the veins. The courses of the ore fluids appear in general to dip northerly and pitch westerly, and it is of course probable that the portions of the known veins where ore was most abundant and richest were most directly tributary to such courses. In much of the district the courses of ore fluids closely follow the West End rhyolite anticline more especially its northern limb and extend upward from it into the Mizpah trachyte. Where the veins encounter the rhyolite going down, they some times flatten to the north. There, seems to be no theoretical reason why ore courses should not leave the West End rhyolite and extend downward into the older rocks below. Quite possibly, pipes rather than tubular veins may be characteristic of deep portions of ore courses. The physico-chemical conditions appear to have been right for ore deposition in most of the typical Mizpah trachyte phase which seems to be the result of alterations by solutions closely associated with such fluids, while in the Midway andesite phase such solutions have not been active either because away from the courses or because chemical activity or penetrative power were lost through previous reactions, loss of pressure, etc. West End rhyolite, immediately after its intrusion is believed to have been too hot for ore deposition, but it cooled to a sufficiently low temperature for ore deposition while ore fluids continued to rise along somewhat changing courses. Thus some veins extend into it with value of ore not impaired while others terminate or become barren. In the deeper rocks exploration has hardly touched the courses of ore fluids. No reason has been demonstrated why ore should not occur in the older rocks. Typical Calcitic andesite appears to lie mostly below the West End rhyolite and not on the courses of the ore fluids.

In the Belmont mine, the effects of these various geological conditions may be seen by examination of the maps accompanying this report.

It appears that in a number of cases, veins that have been called by different names are faulted segments of ore veins and may be correlated. Thus, the so called Favorite and Shaft veins are almost certainly one vein faulted by the Belmont fault, the displacement having been about 300 feet vertically and about 450 feet horizontally in north-easterly direction, downward on the easterly side, while the Rhyolite and I.O.U. veins appear to be the same vein with similar displacement. The Mizpah and Belmont veins appear to be the same vein west of the south fault and east of the Mizpah faults, with displacement of about 500 feet vertically and about 1200 feet horizontally, the displacement being divided amoung the Mizpah, South and Belmont faults. As may be seen from the maps, there appears a possibility that the vein called the Mizpah vein between the South and Mizpah faults may be a segment of the North vein. If this is so, a segment of the Mizpah-Belmont vein lies to the south. A cross cut, previously recommended, is being driven to explore this area. Besides the chance of opening up ore, this work should assist greatly in clarifying the effects of faulting in a complicated area, and should greatly assist in attaining full knowledge of the structure of the property and therefore help all further exploration work.

Belmont fault

Such correlations are of the greatest importance in finding new ore, as special maps can be constructed on which the effect of faulting is mostly discounted, thereby making possible the correlation of all veins which are cut off by fault. Absolute accuracy is not possible in this work but it is not essential for valuable results. The work should be kept up systematically.

Stope elevations showing on one sheet, all mined and unmined blocks of ore in all fault segments that can be correlated as one vein, should be prepared for the whole length of the property. Such elevations for the Mizpah-Belmont and Favorite-Shaft veins compiled from the fragmentary records available on separate sheets, are included herewith. No attempt was made to bring these up to date. This is a function of the mine staff. Doubtless many areas are shown as unmined which have been mined, and in some areas shown as unmined, slabs of ore exist in the walls. Such elevations showing faults, changes of formation in the walls, where possible, and important data in connection with the value and width of ore will prove of great value in connection with future exploration; they are also necessary in accounting for ore. The Company and its general officers deputize to the mine staff, the mining of the ore shoots as they exist. It is the duty of the latter to account for all blocks as mined out, possible or probable ore reserves or temporarily or permanently unminable for some recorded reason.

In connection with exploration of the deeper portions of the ore courses from which the known veins were deposited the relative positions of the major fault blocks before faulting are of the greatest importance. Thus the course of ore fluids which fed the Belmont vein in the vicinity of the Belmont shaft would be expected to be something like 1200 feet further west and the 1000 level in this vicinity is considerably deeper from this geological aspect than the 1500 level in the vicinity of the Belmont vein. Exploration for deeper ore bodies on this ore course should consist in tracing the course where best developed from the 800 and 900 levels to the 1000 level, with due regard to the effects of other faults, then exploring on deeper levels, the areas indicated by the northerly dip and the probable westerly pitch.

In deep exploration along courses of ore fluids, the ability of each vein to penetrate and carry ore in West End rhyolite is important. The Mizpah vein has not been found to strongly penetrate West End rhyolite or carry ore in it in important degree. In view of the changes in ore courses during the cooling of the rhyolite and ore deposition, a vein may be found to penetrate this rhyolite in some places though not in others. The rhyolite veins indicate that the ore fluids continued into the Belmont property during a late stage of deposition, as they did in the western part of the district; and, aside from faulting, the ore courses feeding such veins may be found more continuously ore bearing.

As ore deposition depends on a delicate physico-chemical balance, ore courses which fed the veins which were most productive in the upper workings may not be most favorable at depth. For example, the Murray vein which is by far the largest and most productive vein in the deeper Tonopah Extension workings was not of similar actual or relative importance in the upper workings.

Systematic work and records of the sorts mentioned under the heading of General Recommendations with mapping regularly brought up to date are essential for efficiency not only in finding ore blocks remaining, faulted continuations and new ore at depth, but for efficiency in mining. Without them it is frequently necessary to resume mining in the same area several times, with duplication of a portion of the mining expense each time. Specific recommendations are given in Part IV.

PART II.

GENERAL GEOLOGY.

INTRODUCTION.

The outcropping veins of Tonopah were discovered in 1900 in an area of about seventy-five acres of highly altered bleached volcanic rock surrounded by other volcanic rocks of andesitic and rhyolitic nature, including tuffs and breccias. No veins were found to extend into these surrounding rocks.

Of this area, about half containing abundant vein exposures formed part of the ground soon acquired by the Tonopah Mining Company, while the remaining half containing few vein exposures, with other ground was acquired by companies which were later consolidated as the Jim Butler Tonopah Mining Co.

With the rapid development of rich ore in the Tonopah Mining Company's property, surrounding ground for many thousands of feet was taken by various companies and many shafts were started in barren formation in the hope of reaching ore at depth.

A geological investigation of the district was soon started for the United States Geological Survey by Mr. J.E. Spurr. By the time a preliminary report (A) was issued in 1903, several shafts had passed through "cap rock" into ore bearing formation and ore was exposed at several underground points. In the deeper workings of the Tonopah Mining Co. ore was becoming less abundantly encountered. At this time, the bleached ore-bearing formation was named by Spurr "earlier andesite", and the rather dark andesite rock that forms large areas to the west, north and east of the main area of outcropping veins was named "later andesite". The later andesite was interpreted as a lava flow later than the earlier amdesite and later also than ore deposition. This interpretation was natural and has been generally held.

Before the completion of Spurr's geological investigation and the publication of the final report (B) in 1905, both rhyolite and andesitic rock had been exposed in the lower workings of the Tonopah Mining Company and it had been determined that the original veins did not extend, directly at least, into these rocks. Other veins, sometimes wide, but largely low grade, had been found in workings of the West End, Tonopah Extension and other mines in association with rhyolite.

With the publication of the final report all the rocks exposed on the surface and underground were classified. The rhyolite exposed in underground workings was named Tonopah Rhyolite Dacite and was regarded by Spurr as later than the Earlier Andesite and intrusive into it. The veins associated with it were believed of later deposition than the original veins and there was not available to Spurr evidence of much productive importance. The lower andesite was believed to be a phase of the Earlier Andesite which had been subjected to different alteration and was called briefly "Calcitic Andesite". About this time the rock later named by Spurr "West End Rhyolite" was exposed abundantly in the workings of most of the mines and was distinguished by various mine operators as a separate formation from the Tonopah rhyolite encountered in a few of the deeper workings. In 1909, a paper was published by Burgess (C) interpreting the whole series of volcanic rocks at Tonopah as flows with the oldest rocks consequently at the bottom, with progressively younger rocks upward.

In 1910, Spurr made a new geological investigation of some of the important mines of the district, and thereafter he was in intimate touch with Tonopah for several years. His new data and conclusions were published in 1910, (D) and in 1915, (F). The results of a study of Tonopah ores by Bastin and Laney including some more general geologic notes,(G) were published in 1918.

As a result of the investigations of which the results were published on 1910 and 1915, Spurr substituted the name Mizpah trachyte for earlier andesite, and Midway Andesite for later andesite. His opinion as to the time relations of these two formatoons was not changed in greater part, but the lower andesite sheet of calcitic alteration which previously had been believed a phase of the earlier andesite was regarded as an intrusive phase of the Midway andesite and was called Sandgrass andesite. The upper rhyolite encountered underground in most of the mines, intimately associated with veins in the more westerly of the productive mines, but against which some of the main veins in the workings of the Tonopah Mining Company and elsewhere were found to terminate, was named West End rhyolite and regarded as intrusive, later than the Mizpah trachyte and earlier than the Midway or Sandgrass andesite. A rhyolitic breccia abundantly exposed in the Montana Tonopah workings was ent tled Montana breccia and considered an intrusive slightly later than the West End rhyolite and intimately associated with it. A glassy acid formation with characteristic flow structure frequently encountered in the lower mine workings was named Glasy trachyte and regarded as contemporaneous with and a basal phase of Mizpah Trachyte. Rhyolitic rocks, described as characterized by auto-brecciation encountered in shaft and diamond drill holes to a thickness up to 1800 feet, underlying all other rocks in the vicinity of the Mizpah and Silver Top shafts were distingoushed from West End rhyolite, named Tonopah Rhyolite and regarded as intrusive, later than Midway andesite and about contemporaneous with the rhyolite of Mount Oddie, Oddie rhyolite.

Spurr (F) regards the veins as deposited in three periods. The first period veins, described as closely following the Mizpah trachyte eruption and preceding the West End Rhyolite intrusion are considered of by far the greatest productive importance. The second period veins, younger than the West End rhyolite and older than the Midway andesite, are described as having great volumes of quartz, but with commercial value insignificant as compared with veins of the first period. The third period veins are described as younger that the Tonopah rhyolite. No production is attributed to them. Locke (E) and Bastin and Lacey (G p.9) find no mineralogical evidence that the principal productive veins are of more than one period.

In all of his reports and papers, Spurr describes the characteristic great faulting of the district. The most abundant faulting is regarded as following the Brougher Dacite eruption but pre-mineral faulting is recognized as well as fault movements during other later periods.

During the later years, the relative importance of production from veins associated with West End rhyolite as compared with production from veins in Mizpah trachyte has increased, and has coincided with greater average depth. The extension of ore discoveries to the westward is of great interest. An outstanding feature of recent years is the development in the Tonopah Extension mine, of a practically continuous ore body from the upper workings to 2000 feet depth with the ore associated for the lower part of this distance with West End rhyolite and Extension breccia and with the ore body of greatest size in the lower levels. In the Tonopah Mining and Belmont properties, ore has been found through a vertical range of not more than about 700 feet as measured from top to bottom on any particular ore shoot or portion of the vein. The question presents itself whether the much greater, more abundant and more complex faulting in these properties, especially in the Belmont mine, may not have concealed downward continuations of ore similar to the conditions developed to the west.

It has been the purpose of the present investigation to review the geological evidence to determine if earlier conclusions as to the relations among the various geological formations and the veins are now justified and whether there may not be areas, heretofore considered unfavorable, which under different interpretation of Geological evidence are worthy of prospecting.

In the early stages of the development of a mining district it is inevitable that important geological conclusions must be based in part on observations of a few scattered exposures of small size in mine workings. Such observations if conditions are complicated, are subject to a large chance of error. They may easily be distorted by small faults or small variations of many kinds from normal. As a result of twenty three years of operations there are now in the district well over one hundred miles of workings which penetrate more or less intimately a volume of one billion or more cubic yards of country rocks. In this volume several million tons of ore have been found and mined by the various mine operators in connections with investigations and maps of relations of veins to faults and various rocks. It is believed that this situation permits the segregation of a form of evidence superior to that based on observations of small exposures, in which human limitations have a more direct bearing.

THE ANDESITIC ROCKS.

Included in this group are the rock formations named by Spurr Mizpah Trachyte or previously Earlier Andesite, Midway Andesite or previously Later Andesite, and Calcitic or Sandgrass Andesite.

In view of the uncertainty which has always existed in many of the mines as to the proper correlation of various areas of andesitic rock, and the interpretation of doubtful exposures and also because conclusions quite different from those of Spurr have been reached which have important bearing on relations of other rocks among themselves and to the veins, it has been considered advisable to describe the important conditions with respect to the andesite rocks at considerable length and largely through quotations from Spurr.

In 1905, Spurr (B, p.35) summarized the relations of the main masses of Earlier andesite (Mizpah trachyte) and Later andesite (Midway andesite) as follows:

> "The later andesite directly overlies the earlier andesite, and though in many underground workings and probably at every outcrop the contact is a fault contact, caused by movements subsequent to eruption of the later andesite, yet in several shafts one andesite has been found apparently lying undisturbed in its normal position upon the other. Such was the case in the Midway, the West End, and the Tonopah Extension shafts. In these places the contact was marked by a band of decomposed breccia, or even clay, yet there was no good evidence of faulting. The quartz veins of the earlier andesite extend up to this contact in full strength and then abruptly disappear. Most likely the earlier andesite was deeply eroded and the veins were exposed before the later andesite was poured out, and possibly the decomposed clay or breccia zone represents the result of surface decomposition and disintegration before the later andesite period."

Original Mineral Composition and Petrographic Character.

In 1905, Spurr described the mineral composition of the Earlier and Later andesites after the microscopic study of several hundred specimens (B, p.31 & 33). The Earlier andesite is described as a hornblende-biotite andesite of medium composition. Hornblende and biotite were considered about equal in amount, sometimes one predominating, sometimes the other. Feldspars were identified as typically andesine-oligoclase, though some ranged from orthoclase to labradorite, the basic varieties being more abundant. The Later andesite as described typically contained biotite crystals and feldspars determined as predominantly between andesine and labrodorite although there are more calcic and more sodic varieties, varying between oligoclase and bytownite.

The characteristics by which the Earlier and Later andesites might be distinguished were summarized by Spurr in 1905, as follows (B, p.35):

> "The earlier andesite and the later andesite are usually sufficiently distinct in appearance to permit identification in the field. The later andesite is generally darker; on account of the greater amount of iron present it has the characteristic strong coloration mentioned above. The earlier andesite is characteristically finer grained than the later, and contains smaller and less abundant porphyritic crystals. The porphyritic feldspars in the earlier andesite are usually slim, of simple form, and almost rectangular, while those of the later amdesite are apt to be stout and complex as a result of twinning. In the later andesite crystals of fresh or bleached biotite can usually be seen; in the earlier andesite they occur more rarely."

> "Similar characteristics serve, as a rule, for the microscopic determination. The phenocrysts of ferro magnesian silicates - augite, biotite, and hornblende - and their pseudomorphs or decomposition products are usually more abundant in the later andesite. The typical alteration of the earlier andesite is to quartz, sericite and a little pyrite; that of the later andesite to chlorite, quartz, calcite, siderite and pyrite. While the character of the alteration is a valuable help in

> diagnosis, it is not by any means a sure test, for in some cases the process of alteration has been apparently almost exchanged."
>
> "On account of the similarity in the original composition of the earlier and later andesites it is frequently very difficult, either from field or from microscopic study, to refer a specimen to the proper age. Often the economically important question is decided by tracing the doubtful phase into some decided phase in the same rock body."

In 1910 and 1915, Spurr did not repeat a detailed description of these andesite rocks, but the Earlier Andesite was changed to Mizpah Trachyte and the Calcitic Andesite formerly considered a part of the Earlier Andesite formation was then regarded as an intrusive phase of the Later or Midway Andesite. Thus a rock formerly determined as andesite, which is a rock in which the feldspars are predominently plagioclase, on the basis of microscopic study of several hundred specimens, was changed in name to trachyte, a rock in which feldspars are predominantly orthoclase. Petrographic evidence is not given of sufficient importance to justify this change, which appears to have been made mostly on the basis of chemical composition.

In the years of experience of the various mine operators in Tonopah the distinctions suggested by Spurr have not been found to apply and no definite distinctions between Mizpah trachyte (earlier andesite) and the other andesites can be made on the basis of original characteristics. Rock of andesitic nature having pronounced quartz-sericite alteration and associated with veins is usually called "Mizpah Trachyte" and andesite rock having calcite-chlorite alteration is usually called "Calcitic Andesite". These conditions will be discussed in a later section devoted to alteration. They have no direct bearing on a classification based on original characteristics.

By inspection of surface exposures of Midway andesite a very great range in the size and shape of feldspar phenocrysts may be observed, fully covering the range in these features of rock attributed to Mizpah trachyte. The ferro-mangenesian minerals especially biotite are frequently more noticeable in exposures of the Midway than of the Mizpah phase but the quartz-sericite alteration of the latter phase has much more efficiently destroyed these minerals. The color of the two phases of the result of alteration. Microscopic study gives no definite evidence. In both phases most feldspars, where sufficiently fresh for determination are plagioclase of medium composition and a similar range of size and form. No distinction can be made from the ferro-magnesian minerals though it has been rather a convention to consider a rock Midway andesite if it originally contained abundant biotite and if there are no important features pointing to a contrary interpretation. The Earlier Andesite (Mizpah trachyte) is according to Spurr, a hornblende-biotite andesite with sometimes biotite predominating over hornblende.

The practical difficulty encountered by Spurr in distinguishing the Mizpah (Earlier Andesite) and Midway (Later Andesite) phase appears from the quotations below.

B, p.185-6.

"The earlier and the later andesites are so closely related that many times they have almost identical characteristics, and it is difficult or impossible to discriminate them in the hand specimen or under the microscope. A specimen taken in the (West End) shaft, at a depth of 116 feet, was judged to have the characteristics of the later andesite rather than of the earlier andesite. Another specimen taken in the shaft, at a depth of 196 feet was supposed to represent the same rock, for no sharp division had been noted, but was judged after microscopic study, to have rather the characteristics of the earlier andesite. This specimen was altered by quartz, sericite and pyrite".

B, p.186-187.

"After studying the delicate question as to whether the rock (from West End 220 level) is the earlier or later andesite, the writer has satisfied himself that the andesite of the south drift in the West End is identical with that shown in the long north drift from the 400 level of the Fraction No.2 shaft. The face of the two drifts are only about 250 feet apart in a straight line but there may be and very likely is intervening faulting. The writer was not able to distinguish between the general type of andesite in this north drift of the Fraction and the typical Fraction andesite, which is often relatively dark and chloritic. In the Fraction No.1 workings the andesite contains a large vein, carrying in places at least good values."

"It seems to the writer, moreover, that the andesite in the Fraction No.1 is identical with that in the Wandering Boy, which is more nearly the Mizpah Hill type of earlier andesite. On following the chain still farther, the andesite in the Fraction and that in the Wandering Boy seem to be identical and are probably in the same fault block as the Gold Hill andesite. The rock of the Gold Hill has certain peculiarities which at one time caused the writer to study for some time the question carefully as to whether or not it belonged to the earlier or later andesite, thus bringing up again the question of the exact age which has just been raised with respect to what is probably the corresponding rock in the West End. It was found however, that the peculiarities which suggested the correlation of the Gold Hill andesite with the later andesite, namely the frequently large sized feldspars and the presence of biotite could be paralleled in specimens found in Mizpah Hill, even in the workings of the Mizpah Mine, and again in the Montana Tonopah, where there was no question as to the andesite being other than the earlier andesite."

"Moreover, in Gold Hill this andesite encloses veins having all the characteristics of the veins found in Mizpah Hill, such as have not been found in the undoubted later andesite. Therefore the evidence decidedly favors the conclusion that the Gold Hill rock is the earlier andesite. If it is true, as has been concluded, that the veins of the Wandering Boy and the Fraction were originally a part of the Valley View system and that they were displaced by faulting, the evidence grows still stronger. The writer is forced to the conclusion that the andesite exposed on the 200 foot level of the West End belongs to the earlier andesite."

B, p.189.

"The (McNamara) shaft was first sunk to a depth of 200 feet, from which point drifts were run 50 feet to the north and about 300 feet to the south. The rock in which the shaft started and which outcrop in the vicinity is undoubted later andesite, such as covers the whole surface of this fault block. The rock encountered on the 200 level differs in character very slightly from that at the surface, except that the latter has the purplish color due to partial oxidation, while the former has a green color characteristic of andesite, containing a large proportion of chlorite as a result of subterranean alteration processes. Also the andesite at the surface is decidedly fresher than that on the 200 level, where it is always highly altered. There would, however, be hardly sufficient reason for dividing the upper and lower andesite were it not that study and comparison make it seem clear that the rock on the 200 level is practically identical in characteristics with that on the 220 level of the West End, which the writer, for reasons previously given, is obliged to believe to be a phase of the earlier andesite rather than of the later andesite. The MacNamara rock can be matched almost exactly with specimens of the West End rock."

The conditions described above show the failure in definite correlation based on original rock characteristics, and the necessity of relying on the presence of ore and the form of alteration which characteristically accompanies the deposition of veins, in such rock correlation.

Chemical Composition.

The available complete analyses in 1915 of the andesite phases are tabulated by Spurr (F, p.731). A number of averages are given below.

Average Anaÿyses of Andesites

	$S.O_2$	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	Na_2O	K_2O	Fe_2O_3 FeO CaO MgO
Average of Mizpah Trachyte; No. 2 & 4 excluded	70.31	15.92	1.53	0.65	0.47	0.67	1.38	5.25	3.30
Average of Mizpah Trachyte 3, 4 & 6, regarded by Spurr most representative of fresh rock	67.69	17.67	2.43	0.80	0.45	0.88	2.64	5.11	
Average of Sandgrass andesite analyses; No.1 excluded	56.94	18.72	2.19	3.71	3.23	2.56	3.59	3.59	11.68
Average of Midway andesite analyses; No.1 & 7 excluded	56.6	17.3	2.88	1.94	4.64	2.63	1.93	2.96	12.00

Comparison of the analyses quoted by Spurr might lead to the conclusion that there is a rather sharp line between rocks classed as Mizpah Trachyte and rock classed as Midway, Calcitic or Sandgrass andesite with respect to silica, the alkalis and the bases. Silica, for example, is above 65% in all the Mizpah Trachyte analyses and below 60% in most of the Midway and Sandgrass andesite analyses. Spurr has advised the use of rock analyses in rock classification as an assistance to exploration work in the various mines, and many partial rock analyses have been made for this purpose. The results, however, have been of slight significance, since all sorts of gradations and intermediate stages have been found. For example, out of

199 partial rock analyses of the andesites on file in the Tonopah Belmont office, 91 ranged between 60 and 65 per cent silica. Nine partial analyses were selected from this list as showing results quite different from those listed. The average and range of these nine analyses in silica lime and potash is shown below:

	SiO_2	CaO	K_2O
Range	55.0 - 59.6%	0.8 to 2.3%	4.27 to 6.57%
Average	58.0%	1.48%	5.27%

In these analyses as compared with analyses tabulated by Spurr, average silica is 7.5% lower than in any analyses of Mizpah trachyte and higher than all but four out of eighteen of other andesite analyses. The lowest lime is higher than in any but one analysis of Mizpah trachyte and the highest lime is lower than in all but one of the other andesite analyses; average potash is within 0.1% of the Mizpah trachyte analyses, and the lowest potash is higher than in all but one of the analyses of the other andesites. Analyses naturally reflect the extent of silicification, sericitigation and probably to some extent propylitic alteration. They are apparently not of assistance in an attempt at separating the andesite rocks into an earlier trachyte and a later andesite on the basis of the original rock characteristics.

In explanation of the differences among these two sets of analyses, it appears probable that the analyses quoted by Spurr were made on rock samples selected as typical of the rock formations and of their characteristic alterations. Since the andesites at an early stage in the development of Tonopah were divided into two formations, one earlier and more acid, the other later and more basic, examples of unusual phases or doubtful conditions could not be regarded as typical of either formation. The analyses made by mining companies were on the other hand, largely made on samples from doubtful areas with the object of determining whether the rock was a pre-mineral or post-mineral formation. It seems evident that analyses for such purposes would show too much distinction between the phases in the first case, too little in the second.

The fact is that the rock called Mizpah trachyte, that is, the rock which forms the wall rock of the veins in extensive udderground areas, is usually quite distinctive in appearance and probably is in such phases usually distinctive chemically from the Midway, Dandgrass or Calcitic andesite, that is, the andesite rocks which are typically not closely associated with ore. There are, however, phases intermediate in appearance and it is believed that these are usually intermediate also in chemical composition. It will be considered later whether these represent real, or only apparent, transitional phases. In their present altered condition, with the respective types of alteration characteristic of each phase, the impression is made on an observer that the Mizpah phase is usually a more acid rock than the Midway and Calcitic phases. Yhis is largely or wholly explainable by alteration. In any event amount and variety of alteration and complexity of geological conditions are such that results of analysis give little evidence on original differences in composition that may have existed between the different units that made up the andesite rock masses of Tonopah.

Alterations.

Alterations of the rocks of Tonopah may be summarized as od four different types all of which are well developed in the andesite.

1. Calcite-Chlorite (Propylitic) Type
2. Quartz-Sericite Type
3. Oxidation
4. Transitional and Intermediate Types.

Calcite-Chlorite Type. Alterations of the andesites to chlorite, calcite, quartz, pyrite and siderite is widespread in the Tonopah district, much of the andesite not otherwise altered showing alteration of this type, which is well described by Spurr. It results from the action of hot water frequently carrying carbon dioxide, and although andesites altered in this manner form the wall rocks of ore bodies similar to those of Tonopah, the process may result by hot volcanic or other water and is not necessarily associated with ore deposition. The process may result in decrease in silica and potash and increase in lime, magnesia and iron, but little change in composition is necessary.

The Calcitic andesite takes its name from this alteration, but those portions of the Midway andesites and Mizpah trachyte which have well-marked greenish color have more or less alteration of this nature. Oxidation superimposed on propylitic alteration produces a purplish color, but those surface exposures of purplish andesites showing fresh biotite crystals are probably nearly free from such alteration.

Quartz-Sericite Type. Alteration of the Mizpah trachyte phase to quartz, sericite, adularia, pyrite and siderite is typical in proximity to the productive veins, and indeed there is little of the rock which has been definitely classified as Mizpah trachyte which has so little alteration that it can be regarded as approximately fresh rock. In the practice of the Tonopah district the alteration is typical of the name. The facts that this form of alteration is usually most complete in immediate proximity to veins and that a large part of the vein matter consists of the minerals developed in the andesite by alteration leads definitely to the conclusion that the waters causing the alteration were closely associated with those from which the veins were deposited. It is quite evident that the respective amounts of silicification and sericitigation vary from point to point, as shown by the varying contents in silica and potash, and the varying hardness of the altered rocks. The form of alteration is common but not universal in the wall rocks of ore bodies similar to those of Tonopah. It seems, however, to be more widespread at Tonopah than in most mineral districts of similar type.

Oxidation. In the areas of outcropping Mizpah trachyte, oxidation has been active usually penetrating this rock mass to depths of several hundred feet. The deepest oxidation usually occurs in the vicinity of veins on account of the greater brittleness and near important faults where the rock is more shattered. The outcropping veins are oxidized in greater or less degree for usually four to seven hundred feet from the surface. Where the Mizpah trachyte phase and the veins are capped, neither the rock nor the vein matter is characteristically oxidized although streaks and bunches of oxidized ore and rock are frequently found in association with faults and fracture zones even to depths of twelve hundred feet or more. The results of oxidation are entirely normal. Sulphides and carbonates have been decomposed yielding reddish brown and black oxides of iron and manganese, sericite and other early minerals have been kaolinized in the acid environment caused by oxidation of pyrite and other sulphides.

Bastin and Laney describe (G,p.31) a case in the West End mine of oxidation of the Mizpah trachyte phase and of vein matter from the surface which existed during Tertiary time just prior to the deposition of the Fraction dacite breccia formation. At this point, fragments of oxidized ore and rock are mentioned in the oxidized breccia.

Under the Midway andesite capping no general oxidation has been observed. Although there are small areas of partial oxidation of both rock and vein matter in connection with faults and shattered zones immediately below this capping, this horizon does not seem to have favored oxidation to a more general extent than other area showing faulting and shattering in similar degree. Spurr (B, p.91) describes but comparatively little oxidation under capping of either Midway andesite or Fraction breccia.

Transitional and Intermediate Types of Alteration. The three types of alteration described above may be present in any proportion. In general it is believed that the propylytic type of alteration affected a larger proportion of the total andesite rock mass than the quartz sericite type of alteration, and, in part, was imposed on the rocks before alteration of the latter type. Rather extensive areas of rock in different parts of the district, from the Belmont to the Tonopah Extension properties show partial alteration of both types in the same exposures. In such cases the identification of the rock as Mizpah trachyte or Midway and Calcitic andesites have been doubtful, and rock analyses have shown intermediate or transitional composition.

Oxidation is found to be superimposed on either of the two other types of alteration and usually seems to be much more complete in such cases than where the rock exposed to oxidation was comparatively unaltered. The surface exposures of andesites are greenish from propylitic alteration usually showing also some oxidation effects, light colored with reddish brown iron oxide stains as a result of quartz sericite alteration and oxidation, or rather dark purplish as a result of oxidation alone. Many exposures of the last type are rather hard rock showing quite fresh shining feldspar and biotite phenocrysts. The other types ofalteration characteristically destroy the freshness of feldspar and biotite. Andesite rock with fresh feldspars and brotites has been seen on the surface in apparently greater realtive abundance than underground where shining phenocrysts are rare, and considerable alteration of the other types is quite general.

Alteration of the propylitic type is well developed in the lowest body of andesitic rock, ~~the calcitic~~ andesite, which takes its name from this form of alteration. Proceeding upward in the andesitic rock bodies this type of alteration is widespread outside of the limits of the quartz sericite alteration, but in the upper andesites it seems less complete and abundant than at lower horizons. There is considerable probability that this alteration is the result of hot ascending water, and it is quite possible that the apparently less amount of such alteration in the upper than in the lower parts of the andesite rocks is due to decreased penetrative power or decreased chemical efficiency of such water upward.

The quartz sericite type of alteration of the andesite is not usual in marked degree below the bodies of West End rhyolite and Montana breccia, where the Calcitic phase is typically found. In the deeper Belmont workings, however, the andesite rocks below the glassy trachyte, and, so far as known below West End rhyolite and in the general horizon where Calcitic andesite is usually found, while of somewhat intermediate type, resembles the Mizpah more than the Calcitic phase. Immediately above these rhyolite and breccia masses, the typical Mizpah trachyte phase of quartz sericite alteration begins with quartz sericite alteration in the rhyolite as well. At these point also, the downward limit of pay ore in some of the largest veins of the district is found. Going upward this type of alteration accompanies the veins and is usually most complete in immediate proximity to them. In the upper ore bearing levels however there is distinct decrease of the completeness of this type of alteration, and rock away from the vein becomes frequently more nearly of the Midway type, while sometimes this or a doubtful or intermediate type forms the wall rocks of the veins. Such is the case in the 800 and 900 levels on the Belmont vein.

In most cases a short distance higher up, the veins terminate either sharply against faults or gradually "feather out" sometimes by fingering into several stringers. A short distance above the upward termination of the main veins, andesite rock conforms in type to the "Midway" phase and has been so classed throughout the district. It is believed that the quartz- sericite type of alteration results from the action of hot ascending water closely related to the solutions responsible for vein depbsition. Such conclusion appears inevitable both from the relation of the zones of alteration to the veins, and absence of any exact line of demarcation between altered rock and vein material.

It appears probable, therefore, that the solutions which caused the quartz sericite alteration reached the andesitic rocks now found altered in this manner (the Mizpah trachyte phase) at the horizon marked by the West End rhyolite and penetrated the andesitic rock from such level upward in rather intimate association with the channels of vein deposition. Beyond a certain distance from the rhyolite, quite variable in different parts of the district, the penetrative power or efficiency in alteration of the solutions seems to have decreased, and from such levels upward the rocks show less alteration of this sort.

Contacts and Faults.

The Belmont Shaft was sunk in Oddie rhyolite to 700 feet depth where andesitic rock was encountered, thence downward was entirely in andesite to nearly its bottom. The andesite rock close to the rhyolite contact is difficult of determination but above the vicinity of the 800 level it may be considered of intermediate or transitional phase, and from the 800 level downward of the Mizpah trachyte phase.

In the Desert Queen, North Star and Montana Shafts, the important Mizpah fault forms the contact between the Mizpah trachyte and Midway andesite phases.

The conditions at the contacts of the Mizpah trachyte (earlier andesite) and Midway andesite (later andesite) phases in the West End, MacNamara, Midway and Tonopah Extension Shafts may be illustrated by the words of Spurr.

B, p.187.

"The conclusion that the rock on the 220 foot level (of the West End) is the earlier andesite having been reached, the question comes up as to the line of demarcation between the earlier andesite below and the later andesite above. Since the West Edd fault probably dips south westward and is normal, the shaft after passing through the fault and leaving the rhyolite is in the block lying north east of the fault, which may be called the Midway block. This block is characterized at the surface everywhere by undoubted later andesite. It is then likely that the contact between the later andesite and the earlier andesite occurs in the West End shaft somewhere above 196 feet, and from considerations given, it may be assumed, temporarily at least, that it lies between 116 and 196 feet. This assumption is rendered somewhat doubtful by the fact that no contact was observed, but, on the other hand, the rock is thoroughly decomposed and much disturbed by faulting, so that the presence of a contact would be obscured."

"At another point where the writer has seen the contact between the overlying later andesite and the underlying earlier andesite, in the same fault block, at the Tonopah Extension, the contact is by no means striking, and could not be distinguished if the rock was much decomposed of faulted. In the Tonopah Extension, this contact is at a depth of about 184 feet from the surface and is nearly flat. Similarly in the Midway Mine, which is very likely in the same block, the contact between the overlying later andesite and the underlying earlier andesite could not be definitely located, probably on account of the great decomposition of the rocks at this place. The earlier andesite in the Tonopah Extension, moreover, partakes very largely of the characteristics of the Fraction andesite, and in many cases resembles somewhat the later andesite, but elsewhere is quite typical, and contains strong veins, which show in places high values and evidently belong to the earlier andesite series of veins, so there can be no doubt as to its identity."

B, p.190.

"Since it therefore seems unnecessary to distinguish between the andesite near the surface and that on the (MacNamara) 200 foot level, the question as to the line of contact comes up. According to the conclusions arrived at, this must exist, although it is very difficult to distinguish it. From the study of the rock in the shaft and from specimens taken there, the approximate boundary line has been placed at a point 125 feet from the surface, where a change in formation was recognized by the miners in sinking. This would also correspond fairly well with the conclusions in respect to the West End where the contact was placed between 116 and 196 feet from the surface and with that in the Tonopah Extension, where it has been placed at 184 feet from the surface."

B, p.181.
"The Tonopah Extension shaft starts in the later andesite and extends down about 183 feet to the contact of the earlier andesite. Below it the earlier andesite is very full of quartz veinlets. This phase of the earlier andesite resembles in many plases some of the phases of the later andesite, although just below the contact referred to above, it is fairly typical. The contact is probably not due to faulting, but is normal and indicates that the vein in the earlier andesite outcropped at the surface at the time of the later andesite extension".

Similar conditions are shown at other points. In 1915, Spurr (F, p.744) summarized the contact conditions as follows:

"The contact of the Midway andesite with the underlying rocks is frequently a fault contact. Where this is not the case, as in certain portions of the West End and Belmont areas, the actual contact with the underlying trachyte is in many places obscure. In the Tonopah Extension Sandgrass area, however, basal phases of the Midway andesite, overlying the trachyte, are found which are unusually fine grained on account of rapid marginal cooling and contain inclusions of trachyte, evidently pebbles picked up from the surface over which the andesite flowed. This shows in the 660 level of the Tonopah Extension and the 700 level Sandgrass but best in the 270 level Tonopah Extension where it was observed by J.W.Finch, H.W.Stotesbury and the writer. Here along a flat contact zone several feet thick, the andesite contains rounded and sub angular (apparently water worn)pebbles of trachyte, up to several inches in diameter. Some of the pebbles contain quartz stringers, which do not pass into the andesite".

This exposure is not now accessible. There may be some question if such apparent conditions might not result from the surface of a flow not separated by the period of vein deposition from those above. Mr.John G.Kirchen, manager of the Tonopah Extension and his geological and engineering staff have not made any note of contact showing plain features of this kind in the portion of the mine near the Sandgrass claim. Some distance to the west however, Mr. Volney Averill has found a contact at which West End rhyolite, softened and oxidized, and apparently forming an old surface os overlain first by fragments of rock resembling Mizpah trachyte with several hundred feet of quite fresh andesite above.

Throughout the district the regions of contact between the Mizpah and Midway phases are characteristically ummarked by faults rather than by the sort of contacts normal with two formations separated by an erosion interval. Where faults are not present, there is almost always a doubtful or transitional zone. Since these contact areas have been most frequently reached and the conditions best shown in connection with development and stoping on veins the relations at contacts will be considered later in connection with veins.

The typical Calcitic phase is usually below West End rhyolite which separates it from andesites of Mizpah or Midway phase.

Thickness of Formations.

The andesitic rocks classified as Midway andesite, Mizpah trachyte and Calcitic andesite are found to vary much in thickness throughout the district, but it is quite noticeable that the total aggregate thickness of andesite rocks is less variable than that of the members. There is a distinct tendency toward thickness of Midway andesite where Mizpah trachyte is thin, and thinness of Midway andesite where Mizpah trachyte is thick. The Calcitic phase is evidently variable in thickness, but its total thickness is not well exposed. There is much doubt as to the position of the upper Midway andesite contact under Oddie rhyolite in the Belmont area. Erosion to the present surface has of course in some sections reduced the total thickness of andesitic rocks. Doutful and transitional phases also introduce difficulties. In the aggregate, however, the more regular thickness of total andesite rocks than of the members, is apparent.

To the east of the Belmont property, the Mizpah trachyte phase has been mapped in places as but 100 or 200 feet thick and flat lying, overlain by 500 or 600 feet of Midway phase. In the Belmont property the Mizpah phase becomes suddenly 600 or 700 feet thick, in places, with little or none of the Midway phase above. Alittle further west the Mizpah phase is only about 200 or 300 feet thick overlain by 250 feet and perhaps much more of rock closely resembling the Midway phase and heretofore classified as such, In the western part of the Belmont property, the situation is much complicated by the Mizpah and other faults, but very variable thicknesses of the two phases are apparent. In the Tonopah Mining property and in part of the Jim Butler property to the south, the Mizpah phase is 600 to 800 thick with no other andesite overlying. Immediately west of the Burro fault, which displaces the West End rhyolite only about 100 to 200 feet vertially, the Mizpah phase suddenly thins to 100 or 200 feet with 400 or 500 feet of Midway phase above to the surface. Other similar changes occur further west. The thickness of the underlying Calcitic phase has rarely been demonstrated.

This condition is very doubtfully explainable by the extrusion of the Midway phase on a very irregulat erosion surface with subsequent faulting. It appears much more readily and simply explainable by the alteration of different portions of the aggregate andesitic mass by hot assending solutions of two different types, which varied in their courses, penetration and chemical e ficiency in different areas.

The variable thickness of these phases may be seen on the series of sections through the district.

Relation to Veins.

The original distinction between earlier andesite as a pre-mineral formation and later andesite as a post-mineral formation resulted naturally from the fact that veins were found not to continue from the former into the latter either horizontally or vertically, and no productive veins or important evidence of vein deposition was found anywhere in the latter formation.

The conditions found where veins approach the contact or transition of the Mizpah and Midway phases is of interest.

Going upward in the upper Belmont workings the andesite rock becomes gradually transitional in appearance but a more marked change appears on faults with abundant gouge above which the rock has been classed as Midway andesite, though still somewhat transitional in appearance. About fifty feet below the 800 level the veins start narrowing with massive mixed carbonates appearing. The decrease in width and increase in proportion of carbonates increases upward. Very little ore extended up as far as the 800 level, where the veins are in contact with the fault, and about 25 feet above the level, according to Mr. L.R.Robins, the veins feathered out.

On the 900 Belmont level, the Favorite vein was discovered in a area previously classified as Midway andesite, but which may be considered a transitional phase. The vein at this level was wide and rich, while upward from this point the vein narrowed and became lower grade. About 60 feet above the level, the vein is said to have pinched out, against a rather flat impermeable layer; a cross cut above on the 800 level is in rock classified as Midway andesite, showing no sign of vein deposition.

The vein first encountered in the Montana Tonopah mine in Mizpah trachyte terminates sharply against the Mizpah fault. In the Midway andesite beyond the fault are stringers of calcite and quartz but no important vein and no ore has been found.

In the North Star Mine, on the 950 and 1050 levels veins had been found below and southwest of the Mizpah fault in rock classified as Mizpah trachyte. The rock northeast of the fault was classified as Midway andesite, a somewhat transitional phase. A good vein was discovered later northeast of the fault, from which much ore was mined. The rock beyond the fault was thereafter regarded as Mizpah trachyte.

In the Midway Mine, the Midway vein some twenty years ago was seen to extend upward against a rather flat soft "contact", above which the rock had been regarded as Midway andesite. Above the "contact" was a small "spur" of similar vein material which rapidly pinched out.

The Burro fault striking about N.30 E. and dipping westerly, crosses the course of the Mizpah vein on the surface about 500 feet west of the Mizpah shaft. On its eastern side Mizpah trachyte extends to 600 feet depth, below which is West End rhyolite about 100 feet thick, then calcitic andesite. On its western side Mizpah andesite extends to about 400 feet depth, following by about 150 feet of Mizpah trachyte, a thin layer of West End rhyolite glassy trachyte and then Calcitic andesite, The vertical displacement, estimated from the West End rhyolite is not over one or two hundred feet. If the

Midway andesite is later than West End rhyolite it must have flowed into a depression of which so called Burro fault formed one slope. The Mizpah vein, which is a wide rich vein for most of two or three thousand feet or more east of the Burro fault, narrows one or two hundred feet east of the fault and pinches out before reaching the fault. West of the Burro fault where it is in a small thickness of Mizpah trachyte, the Mizpah vein is much narrower and poorer than to the east.

As shown in a section of part of the West End mine, from Bastin and Laney, a vein of good ore, the Fraction vein, leaves the main vein of low grade quartz passing upward through Mizpah trachyte to the contact of Midway andesite and then extends along the contact. The explanation of this occurrence is difficult if the Midway andesite were not in place when ore was deposited.

In the vicinity of the intersections of veins with several important faults on which movement is interpreted as having taken place both before and after ore deposition, vein matter and sometimes ore occurs along the faults for limited distances from the veins, as in the case of part of the Mizpah fault, where the rock beyond the fault has been classified as Mizpah andesite. Later fault movement has prevented definite interpretation, but a possible explanation is in deposition for a limited distance along a less perfect channel tributary to a main channel of ore deposition. The lower value may perhaps be explained by "screening" action, enabling quartz to pass more readily than metallic compounds. In such cases the fault slips and gouges now soft and unsilicified probably represent later movement.

The normal conditions which should be expected when veins in a pre-mineral formation are followed upward to the contact with a post-mineral formation may be considered by comparison with the outcropping veins on Mizpah Hill if these had been covered by later volcanic rocks with subsequent faulting. The veins should continue strongly to the contact. The contact should be definite and abundantly exposed through mining out ore to it. There seems no reason that later faults should be characteristic in the immediate vicinity of this contact; even if they should be, the upper terminus of upper fault blocks would be the contact, not a fault of any other sort than one which followed the present surface in its irregularities. Oxidation of vein matter, and wall rocks, if the erosion period were considerable would be encountered, as is now characteristic of Mizpah Hill, and as Bastin and Laney describe from the surface before deposition of the Fraction Breccia in the West End. Climatic and topographic conditions different from recent conditions in Nevada might have resulted in greater or less oxidation and leaching than is the case with the present vein matter and wall rock near their surface exposures. If oxidation had been more intense values might have been greatly decreased by leaching but the result of oxidation in vein and wall rocks would have been great. If oxidation had not penetrated much below the surface, there would be no reason for veins to become poorer. In any event there would seem no reason for a feathering out of veins with a gradual transition, real or apparent, between the characteristics of the overlying and underlying formations.

Probable Relations of the Andesitic Rocks.

The most reasonable interpretations of the conditions recited above appears to lie in considering the andesitic rocks as exposed in the main developed part of the Tonopah district as a geological unit not separated by any period of erosion or other form of geological activity but composed of flows of varying thickness resulting from normally intermittent volcanic eruptions. The slightly differing original chemical, and mineralogical character of the rocks may be considered a normal result of slight variations in magma, temperature, thickness of flows and other such conditions.

The lower part of the andesite formation was later intruded by West End rhyolite and Montana breccia in close association. With this intrusion, probably also before it, toward the close of the andesite eruptions, there was considerable faulting along general planes many of which have remained planes of weakness or of movement to the present.

Closely following the West End rhyolite intrusion, ore fluids arose along paths which closely followed the rhyolite from or beyond the deepest limits reached by mining to or beyond the points at which the rhyolite reached the andesitic rocks. On reaching the andesitic rocks the ore fluids, in important parts of the district, left the rhyolite and penetrated upward more steeply through fracture zones in the andesitic rocks. Ore was deposited in the fracture zones, not characteristically in open fissures, replacing the rocks between fractures. The thinner solutions containing silica, potash and other earthy compounds penetrated the andesites from both fractures and from the rhyolite contact, resulting in silicification and sericitization of the rock.

The ore fluids penetrated the fissures and the altering solutions penetrated the rocks through pressure. With distance from the source, and after the elapse of time the pressure decreased. Since both ore deposition and rock alteration were from below upward decrease in pressure would result beyond certain points in a gradual pinching or feathering out of vein upward, and in gradual decrease in the quartz-sericite alteration of the rocks upward and outward from the veins. Since fluids cannot carry ore minerals against as much resistence as earthy minerals under the conditions of ore deposition and rock alteration, ore should be expected to decrease in value before the veins entirely pinch out. Such gradual pinching out with loss in value, with gradual decreased alteration of wall rocks is the normal result with uniform fractures and uniform rock. If however, an imperamable layer, such as fault gouge or perhaps a layer of clay on a former flow surface, not necessarily a surface of much erosion, should be encountered when pressure was sufficiently low, the path of both vein deposition and rock alteration would be blocked, and as a result the vein would terminate more suddenly with value continuing to its termination, while in the wall rocks the quartz-sericite type of alteration would also terminate suddenly. Where faults were abundant this would be a quite probable result. Fluids would penetrate until they were stopped by a fault. If they passed through one they might readily be able to penetrate to the next.

The andesitic rocks were also permeated, perhaps in somewhat indirect association with vein deposition, perhaps in association only with volcanic activity, by hot ascending water carrying small amounts of carbon dioxide, sulphur, and perhaps lime, iron, etc. These solutions resulted in the propylytic (chlorite-calcite) type of alteration. The main deep mass which has been classified as calcitic andesite below West End rhyolite appears to lie below and to the south of the course of solutions which resulted in quartz-sericite alteration.

It is believed that this explanation summarizes the conditions which are found in the andesitic rocks, including Midway andesite, Sandgrass and Calcitic andesite and Mizpah trachyte, in their relation among themselves and with the important veins of the district. It is entirely possible however that other andesite eruptions have occurred in the immediate vicinity of Tonopah, separated by appreciable geological intervals from the period described. Indeed, the andesitic fragments found in breccias which seem to have come from considerable depth, point to earlier andesite eruptions, while some observations of contacts in the western part of the district which could not be inspected in the present investigations, may be later than the period described, as also may be the case with some particularly fresh rock exposed on the surface without either propylytic or sericite alteration.

Evidence regarding the andesites have been presented at length because the conclusions are radically different from those of other observers and because important conclusions regarding the relative ages of the other rocks and of the veins have been based on the supposed more recent age of the Calcitic and Midway andesite. The other rock formations can be discussed more briefly.

THE RHYOLITIC ROCKS.

The rhyolitic rocks exposed in the Tonopah district have been previously classified as West End rhyolite, Montana and Extension breccias, Glassy trachyte, Tonopah rhyolite, Fraction breccia, Siebert tuff, Oddie rhyolite, Heller dacite, Brougher dacite, and some small late rhyolite flows. A new name, Silver Top rhyolite is presented here for rhyolite cut in the deep Silver Top and Mizpah drill holes.

West End Rhyolite.

West End rhyolite is usually easily recognized on account of its characteristic greenish color. Included whitish fragments are common. It is composed of devitrified glassy ground mass with small, scanty, quartz phenocrysts visible under the microscope but usually not visible with a hand lens. The best known mass of this rock froms an anticlinal structure of east-west axis which is best exposed in the vicinity of the West End and McNamara mines. The course of this mass can be best seen in the level maps and sections of the Tonopah district presented herewith. The anticlinal structure is believed to extend eastward into the Tonopah Mining property and, in at least rudimentary form, probably with some splitting, into the Belmont property. The association of the vein systems with this anticline, more especially with its northern limb is characteristic. Other thicker and more nearly equidimensional masses of the rock are exposed to the north of the anticline in the Belmont, Montana, Midway and Extension mines. Some of these large masses appear to strike nearly north and south. The shape of the bodies of rock, its contact phenomina, the association with it of veins and the distribution of the alteration types in the andesites all indicate that this rhyolite is intrusive into the andesites. The glassy character of the rock is less typical of intrusives, but the other evidence is sufficient. I believe it is now quite universally regarded as intrusive.

Some veins penetrate West End rhyolite with their strength and value unimpaired, others become weak and poor or split to stringer zones or areas of silicified rock on reaching it. Spurr regarded the West End rhyolite as an intrusive younger than his first period veins, such as the Mizpah vein, and older than his second period veins. Burgess, who was very familiar with the abundant mining of the Mizpah vein at that time, stated in 1909 that he had "not seen a single instance of a vein having been cut off at an intrusive contact" of West End rhyolite. This was also my opinion from experience with the mining of the Mizpah and other veins in the Tonopah Mining and Belmont properties up to the end of 1907. The evidence indicates that all the productive veins are younger that the West End rhyolite, that conditions were not right for the deposition of important value in it at the time some veins were deposited, but were right later when other veins were deposited. As the rock is mainly a devitrified glass, the very characteristic green color by which the rock is identified is an alteration color, not an original color. This is interesting in view of its close association with the different alteration phases of the andesites.

Montana and Extension Breccias.

These breccias have received the two names in different parts of the district. They occur under the same conditions and there seems no reason why they should not be considered as one formation, although no bodies have been traced from the eastern part of the district to the western part. The matrix of light greenish or brownish glass is apparently rhyolitic. The included fragments are usually very abundant, variable in character and are frequently altered to such an extent that their deterioration is impossible. In some large masses, however, the fragments are mostly glassy trachyte. Fragments apparently of Mizpah trachyte and of rhyolite have also been observed. Spurr notes inclusions of shale and of Sandgrass andesite. In the Victor Mine near its contact with Calcitic andesite, Extension breccia contains and surrounds large blocks of the andesite. Spurr notes penetration of glassy trachyte by dikes of the breccia. In the western part of the district there seem to be two or three varieties of breccia of different appearance but closely associated. There is no evidence of any important difference in their time of intrusion.

The penetration of Montana or Extension breccia by dikes or tongues of West End rhyolite has been seen in many places. In the Tonopah Extension workings, fragments of breccia were seen included in West End rhyolite. Breccia is frequently found on the contacts of West End rhyolite. In many such places it is difficult to decide whether such breccia should be correlated with Montana breccia or should be considered a contact phase of the rhyolite.

It seems clear that the Montana and Extension breccias are intrusions which penetrate the andesites and glassy trachyte, in general at least, slightly before intrusion of West End rhyolite, but closely associated with the latter rock in time and position. The Extension breccia contains ore near the contact with West End rhyolite in the Victor Mine.

Glassy (Trachyte) Rhyolite.

The rock formation known as Glassy trachyte is a grayish or cream colored devitrified glass with characteristically no phenocrysts visible either in the hand specimen or under the microscope, but with characteristic flow structure. The rock as a rule does not seem to be very greatly altered aside from devitrification.

The average of three complete analyses each of Glassy trachyte and West End rhyolite given by Spurr shows these rocks to be substantially identical in composition.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	Na_2O	K_2O
Glassy Trachyte	73.17	15.13	1.59	0.11	Tr.	0.19	0.57	5.20
West End Rhyolite	75.87	14.06	0.92	0.72	0.19	0.48	0.22	4.55

The only recognizable differences between these rocks are in color, the presence of few very small phenocrysts in the West End rhyolite and the less characteristic flow structure, though it is sometimes noticeable, in the latter rock. The association of these two rocks with also the Montana or Extension breccias is very noticeable and shows clearly in the sections through the district. As previously mentioned, Glassy trachyte forms the most abundant fragments in the breccia. In places it appears that this whole formation has been converted to breccia.

The characteristic color of the West End rhyolite is evidently due to alteration, and from its position with respect to the intensely altered andesites may be attributed to the solutions which caused that alteration. The slight differences in scanty presence or absence of phenocrysts and in abundance of flow structure are easily explainable by slight differences in time and temperature of intrusion.

Comparison of the course of the lower surface of the Fraction breccia, probably a pyroclastic formation, with the course of the lower surface of the glassy trachyte shows no parallelism, suggesting that the latter rock was not poured out on the surface. The brittle nature of this rock also suggests that if calcitic andesite were intruded into glassy trachyte, the former should be found to contain abundant fragments of the latter.

It seems extremely probable that Glassy (trachyte) rhyolite, Extension and Montana braccia and West End rhyolite all were intruded from the same magma along about the same courses within a comparatively short range of time.

Glassy trachyte has been regarded by Spurr as a basal phase of Mizpah trachyte and therefore contemporaneous with it. In support of this idea, attention was called to transitional phases. There are a number of objections to this classification. With regard to transitional phases it may be said that exposures that appear transitional between almost any pair of the rocks of the district are common. This is one of the important difficulties in attaining results. Apparent transitions between Mizpah trachyte and Glassy trachyte are not more abundantly encountered than other apparent transitions,

Study of the general structure of the district does not point to this as an actual transition as is the case with the Mizpah andesite and Mizpah trachyte.

Moreover, in chemical composition, the glassy rock appears to be a rhyolite, while the Mizpah is less acid by analysis and much less acid in its least altered phases. The process by which its bottom portion would have remained glassy while its upper portion became porphyritic is difficult to understand, as is also why there should be a brittle parting between the two phases which became a favorable phase for intrusion of rocks of different sorts which must have come from somewhat different sources. The association in time, position and origin of glassy trachyte with West End rhyolite and Extension breccia seems very simple, more logical, and more probably correct.

Oddie and Tonopah Rhyolites.

The rhyolite of Mount Oddie and Rushton Hill forms a neck, pitching eastward from the eastern part of the Belmont property into the Halifax property, as may be seen in the sections of the property and the district. In the present condition of the mine workings, exposures of the contact are not abundant but a number of general considerations as well as the fact of extensive mining to the contact in the Belmont and in the Halifax without any ore indications being followed into the rhyolite suggest strongly that the rhyolite is later than deposition of the productive veins. This has been the opinion of Spurr and other geologists, but under the interpretation of the age of Midway andesite in the report, a considerable part of the evidence of the post mineral age of the Oddie rhyolite is removed. Rhyolite of similar character is exposed in the Desert Queen workings but in a fault block not in direct association with ore, and although its post mineral character would seem reasonable, it does not appear demonstrated as a fact. In the Tonopah Extension workings a dike of similar rhyolite was seen to end across a vein in a way which fully demonstrated its later intrusion.

The central rhyolite of Mount Oddie and Mount Ararat appear to represent the lava which solidified in the craters and volcanic pipes represented by these hills and therefore was, aside from the few small dikes and thin flows, the result of the last volcanic activity from these sources. Some rather extensive surface areas of rhyolite and rhyolite breccia to the northeast of the Belmont area, well exposed around Mt.Ararat probably are the product of previous eruptions from these volcanoes.

Spurr calls these rocks Tonopah rhyolite and correlates them with other exposures to the southwest and with rhyolite exposed in the deeper Desert Queen and Tonopah Mining workings. To some of the latter rock I have given the name of Silver Top rhyolite.

Silver Top Rhyolite.

Much of the rhyolite rock, mostly breccia, cut by the deep vertical drill holes from the Mizpah and Silver Top shafts - the greater part of a total thickness of rhyolitic rocks of at least 1800 feet - varies quite widely in appearance from the rhyolite of Mt.Oddie and Mt.Ararat, the rhyolite in the deeper Desert Queen workings and that in the post-mineral dike in the Tonopah Extension referred to above. While the opportunity for study was limited to diamond drill cores and microscopic slides made from them without observation of the rock in place, the distinct impression was gained that the rock was a different formation and probably older than the Oddie and Tonopah rhyolites.

In looking through the published data there seems no justification for definite correlation with the Tonopah rhyolite which is nearly equivalent in age to Oddie rhyolite.

From general structural considerations also there would seem much doubt if this deep rhyolite is more recent than the overlying rocks. The Glassy trachyte is the oldest rock exposed according to Spurr; aside from this rhyolite, the Calcitic alteration phase of the andesites is oldest according to the conclusions in this report. This lower rhyolite if younger must have intruded to a thickness of 1500 feet or more without apparently breaking through to the surface in this immediate area although the erosion seems to have been very moderate, and without leaving any identified fragments of the rock mass on which the other rocks originally rested. If this rock mass were intruded as a unit in this great thickness it would seem that crystallization should be coarser in its interior. If it intruded as two or more units it means that two or more units must be correlated with the Tonopah rhyolite, there were two or more opportunities to break through to the surface, etc. In the absence of strong evidence favoring correlation with the Tonopah rhyolite, it would seem more probable that this deep rhyolite represents an older rock on which the exposed andesites were extruded. Such older rhyolites are indicated by occasional fragments in breccias which are not readily explainable otherwise.

If the Silver Top rhyolite is an older rock it is capable of containing ore where on the course of the ore fluids under suitable physico-chemical conditions. A part of this and other rock masses previously classified as Tonopah rhyolite may be correlatable with Montana breccias.

Fraction Dacite Breccia and SiebertTuff.

As these formations were not of direct bearing in connection with the Belmont Mine they were not investigated in connection with this report. A few general remarks may, however, be of interest. Spurr places the Fraction braccia in age between the Tonopah rhyolite and Midway andesite. The Tonopah Extension geologists have not found it possible to follow Spurr's surface mapping or distinguish between Tonopah rhyolite and Fraction breccia. The breccia is almost certainly a pyroclastic formation deposited on the surface, and later than Midway andesite but, according to the conclusions of this report, this would not necessarily make it later than ore deposition.

The Montana breccia appears to be the results of very violent intrusion, and it is exposed underground in large volume, but no surface formation has been identified, as resulting from this intrusion although volcanic activity might be expected in connection with such violent intrusion. It would seem that the Fraction breccia might have resulted from such eruption. If this should prove to be the case it would be older than the veins.

Bastin and Laney mention the oxidation of the veins and enclosing rocks in the West End mine from an erosion surface on which the Fraction breccia was deposited. If this is correct the Fraction breccia is younger than the veins. On the other hand some question may remain after one observation. Different interpretations are possible in many such instances.

The Devide ore is in breccia which, it would appear, may probably be approximately correlated with Fraction breccia. This ore is, of course, not necessarily of the same age as Tonopah ore, but it would not be surprising if ore were found of about the same age in two such closely adjacent camps. No definite conclusion is possible from the evidence at hand. The point is of some interest to the district though not of direct bearing in connection with the Belmont mine. It does not seem to have been demonstrated whether the Fraction breccia is rhyolite or of less acid nature.

The Siebert Tuffs are regarded by Spurr as somewhat younger than Fraction breccia and as having been deposited in a large lake occupying a large area in Nevada. The relations between these two formations are not clear from the district mapping by the U.S.Geological Survey. The presence of a large lake extending to this immediate locality would seem to require a flatter general topography than might be expected in view of the large amount of volcanic activity earlier than deposition of Siebert Tuffs and the apparently much smaller amount of more recent age. An explanation might lie in the deposition of the tuffs, not in a large continuous lake but in ponds formed in depressed fault blocks.

Brougher Dacite and Heller Dacite.

As these rocks do not appear in the Belmont Mine no detailed investigation of them was made. Of the two Heller dacite is regarded by Spurr asthe older, and Spurr's interpretation of these rocks as the last rock which solidified in the respective volcanic craters and pipes would seem correct.

It may be noted that a line joining the Brougher dacite masses of Mt.Brougher and Mt.Golden and a line along the long axis of Mt.Butler are about parallel, and about parallel to and opposite the general course of the veins and the West End rhyolite anticline through the district. This rather suggests that the lavas of these former volcanoes may have come from the same general source at depth as the rhyolite rocks which have solidified as Glassy trachyte, Extension breccia and West End rhyolite, and also the ore fluids from which the productive veins were deposited, and that these molten rocks and fluids rose along similar courses.

VEINS AND ORE.

The veins of Tonopah are mainly replacements of the wall rocks, the filling of open spaces being of minor importance. The bulk of the vein matter in all but the richest spots is formed by the gangue of quartz, mixed carbonates of lime, mangenese, magnesium and iron, with unreplaced or partially replaced wall rock. The original metallic minerals include polybasite, argentite, pyrargyrite, sulphides and sulphantimonides of silver, with pyrite, sphalerite, galena and chalcopyrite usually not in abundance. In oxidized ore, horn silver and silver iodide are found. Silver and gold are present in the ratio of ninety or one hundred ounces of silver to the ounce of gold. This ratio is very characteristic of the district and few of the productive stopes throughout the extent of the district, so far as can be learned, have varied much from it. Similar mineral composition is also characteristic.

According to Bastin and Laney, the minerals first deposited from the primary ore fluids through replacement of the rocks, were later replaced to a moderate extent by the same series of minerals. This replacement was by the primary ore fluids under somewhat changed physico-chemical conditions. Secondary deposition was also imposed on the ore but is not, in general, considered of great importance in affecting its final value.

The first veins were found in rock which during recent years, has been called Mizpah trachyte, and the largest part of the production and profit of the district has come from veins in this rock. The veins were found not to extend into

Midway andesite. Evidence is given, in the section of this report devoted to the andesites, that these so called formations are alteration phases of ore andesite formation, that the Mizpah phase is due to rock alteration by solutions associted with the fluids that resulted in ore deposition, and that both vein deposition and rock alteration weakened beyond and above certain horizons through lessened pressure and chemical efficiency, resulting in termination of the veins and transition of the Mizpah phase to the Midway andesitic phase. The Midway phase has heretofore been regarded as a separate formation later than ore deposition.

In following down in the veins in the Mizpah trachyte phase, West End rhyolite usually appears, frequently on one wall first. The Mizpah vein and other important veins have not been found to penetrate West End rhyolite on their regular courses with size and value comparable to that above, though small and irregular penetrations of pay ore occur. At this horizon there is frequently a change in course, with pinching, splitting or "frazzling" into a mass of partially or irregularly silicified rock with great decrease in value. Spurr interpreted the conditions as the vein being cut off by an intrusive contact. According to Burgess and the results of observations which have entered directly into this report, the conditions cannot be thus interpreted.

Other important veins continue from the Mizpah trachyte phase on West End rhyolite contacts or into the rhyolite with their strength and value unimpaired. Such is the case with the rhyolite veins in the Belmont mine and many veins in the western part of the district.

Spurr was therefore led to the conclusion that the productive veins of the district were of two periods of deposition, one before, one after the intrusion of West End rhyolite. The observations entering into this report, on the other hand, indicate that all productive veins were later than the West End rhyolite intrusion. Moreover, the silver gold ratio and mineral composition which is very characteristic of Tonopah but not characteristic elsewhere is very strong evidence that all of these characteristic veins result from one lot of ore matter which came together at depth at one time under one set of conditions. Both silver and gold are indeed characteristic of Nevada but not in this fixed ratio and not necessarily together. For example, value in Devide ore is almost all silver, in Goldfield ore almost all gold, in many small prospects in the general vicinity silver and lead, etc. Any substantial repetition of the same ratio, mineral composition and other characteristics at two times would be an extraordinary coincidence.

It is concluded that the productive veins of the characteristic type were deposited at one time, considered geologically, immediately after the intrusion of West End rhyolite. As mentioned previously, it is believed that vein deposition started immediately after intrusion of the rhyolite while it was still too hot for gold silver minerals to be deposited in it or on its contacts, therefore the metals continued in the ore fluids until they had passed from the rhyolite into colder rocks above where deposition of gold-silver minerals began. During a term of perhaps a few thousand years, the ore fluids continued to rise along somewhat changing courses while the rhyolite cooled to a temperature at which ore of the same character could be deposited on its contact and in it. The evidence with regard to the deposition of barren veins and veins of different gold silver ratio and mineral contents is less strong. In the case of veins like the Gold vein in the Belmont mine similar age is perhaps most probable with other evidence lacking. Profitable ore is somewhat rare at best, and variations from characteristic ore might be expected more commonly than they have been found. Barren veins are more common and their deposition might be associated with some other period of volcanic activity in the district. On the other hand, barren veins are frequently deposited at some general period as productive veins, at an earlier or later stage and under conditions of higher or lower temperature.

The Murray vein in the Tonopah Extension property extends for a long distance on the contact formed by West End rhyolite above and to the north, Extension breccia below and to the south. Both rocks are replaced. In the lower levels, the ore body is large and of good grade and ore is mainly in Extension breccia. The vein is of normal type in gold-silver ratio and mineral contents. It would appear that Extension breccia must be considered a favorable formation for ore at depth.

Glassy trachyte is a formation older than vein deposition and ore can extend into it. Its brittle character seems to cause a tendency for veins to split into stringers on entering it causing ore to be diluted with unreplaced or partly replaced rock. Possibly it was not as readily replaceable as some other rocks, and possibly also it was in places too hot.

on account of close association with West End rhyolite, for some of the veins to penetrate it. In parts of the district the course of the ore fluids appears to have passed above the Glassy trachyte horizon.

Calcitic andesite is believed to be older than vein deposition, but it is an alteration phase which has been found to be characteristically not associated with ore deposition in the Tonopah district, being in its most characteristic development below the course of ore fluids. Andesitic rock of similar alteration forms the wall rocks of veins in other districts of similar type to Tonopah. It may be possible that this sort of rock will prove ore bearing under different conditions from those in the area now developed, as at greater depth. It may also be found that a more favorable form of alteration will extend into a general mass of calcitic andesite where on the course of ore fluids.

It is believed that Silver Top rhyolite is older than the veins and may prove to be ore bearing where on the course of ore fluids. All such rock now known isapparently to the south of and below such courses.

The main veins of Tonopah occur in an east west zone from the Belmont to the Tonopah Extension and West End mines, most of the veins striking in approximately east west direction along the general course of the zone. Most of the veins dip northerly, a few, mostly along the southern border of the zone, dip southerly.

An anticline in the West End rhyolite previously described occurs in close association with the zone of veins and this structure is believed to have been important in connection with vein deposition. The greatest depth reached by mining is on the northern limit of this anticline where a good orebody has been followed to 2000 feet. The dip of this ore shoot is north, the pitch westerly. It is believed probable that the north dip and westerly pitch are representative of the main courses of ore fluids in the district. As the northerly dip characteristic of the veins seem to have causal connection with the northern dip of the West End rhyolite which forms the northern limit of the anticline, the westward dip of the ore bodies may be connected with the westward dip of north south striking masses of rhyolite.

In the upper levels ore characteristically occurs above West End rhyolite in Mizpah trachyte. At greater depth in the western part of the district ore occurs in the West End rhyolite and on its contacts. There is an apparent tendency at least, for veins and ore to occur on the upper contact at shallower levels and on the lower contact at deeper levels. In the deepest levels on the Murray vein there seems to be a tendency for the orebody to leave the lower contact of the rhyolite and extend into the Extension breccia below. The possibility is suggested that the deeper rock formations may be increasingly favorable for ore with increased depth. Such possibility is not out of line with the probable geological history of the district.

The actual depth to which ore may extent cannot be predicted. The ultimate course of the ore fluids was, according to the best geological theory applying in such cases, in the chamber of magnetic differentiation at probably several miles depth, in which the associated volcanic rocks also had their source. Deposition of ore at any point depends on the physico-chemical conditions that existed at that point at the time ore fluids arose. If the ore fluids started below the West End rhyolite, rose through the deeper rocks until they joined it, followed along the rhyolite, and finally left it passing by fissures into the higher rocks, as seems possible, it would seem possible that ore might be deposited in deeper rocks even along courses which were not ore bearing in the West End rhyolite.

There seems somewhat of a tendency for ore bodies at depth to form pipes rather than the tabular veins characteristic of veins in Mizpah trachyte. The amount and character of exploration work sufficient for tabular veins might prove inadequate for pipes.

The general distribution and relations of the veins may be seen on the level maps and sections of the district.

FAULTS.

The general tendency of faulting is downward to the east in the eastern part of the district and downward to the west in the western part. Some of the important faults are shown on the maps and sections. It was not considered justifiable to take time to work out fault conditions at a distance from the Belmont property.

There seems to have been quite abundant faulting before and at the time of West End rhyolite intrusion. Intrusion of Glassy trachyte, Extension breccia and West End rhyolite might naturally be expected to result in fault movements. Vein deposition took place to a moderate extent in some of these faults, as the Stone Cabin fault and a part of the Mizpah fault. Much more faulting has occurred since vein deposition in part along the course of the old planes of weakness, in part on new planes.

Summary of Geological Theory and History of District.

To an increasing extent of recent years, geologists have become of the opinon that the different varieties of igneous rocks resulting from volcanic activity in any region, and also the fluids from which most types of ore bodies are deposited, are the result of magnetic differentiation in large chambers of molten intrusive rock which have penetrated the earth's crust from the little known deeper zones. Assimilation or solution of the pre-existing rocks of the crust is believed to be of greater or less importance in connection with differentiation.

The older igneous rocks of the earth's crust which occupy large portions, at least, of the continental areas, are known to be more siliceous than the average of more recent igneous rocks. The interior of the earth, from its much higher specific gravity of the whole than of the exposed rocks, is known to be more basic. It is believed that the great intrusions from the deeper zones into the crust are more basic rocks, which on penetration assimilate portions of the old igneous crust and of the older sedimentary rocks, which are also on the average siliceous, though variable in composition. Through this process, different portions of the magma become of different composition. On cooling, there is a tendency for fractions of different acidity to separate from the other fractions, somewhat as different furnace products separate in a pot. In general, the more siliceous fractions in such differentiated magma are above the less siliceous fractions, although variations may occur through special causes. The gaseous elements that enter into the compisition of water, carbon dioxide, etc. have an important part in these processes as they tend strongly to keep silica and silicates in fluid form, and also furnish a reserve of pressure. There is a tendency for such gases to accumulate in the region of the top of the magnetic chamber, with other less abundant elements such as sulphur, chlorine, fluorine, etc., which have affinity for the metals and are important in connection with ore deposits.

As a result of these processes there is commonly believed to exist, in regions of volcanic activity, a large mass of molten rock divided into fractions of varying composition with the more siliceous fractions generally above the more basic fractions, containing gases and under elastic pressure tending to disrupt the enclosing rocks and to drive any portion of the liquid mass that may encounter fractures into such fractures. In short, the conditions are such as to permit the intrusion and eruption of different sorts of igneous rock according to what part of the magnetic chamber is tapped; and the composition of the rock tapped may vary from time to time. The accumulation of vein matter is part of the same process, and no sharp line of demarkation can be drawn between some particularly siliceous phases of dike rock and quartz veins. The conditions in upper part of magnetic chamber favor the concentration of the metallic elements in connection with silica and gaseous elements. Since this mixture remains fluid at lower temperature than is the case with the rocks, the accumulation seems to be favored in the later stages where the rocks of the magma have largely solidified or volcanic activity from that particular source is dying out. The type of ore body depends on the metals contained, or the distance traveled from the source, on gradual or rapid change in temperature and pressure, on the composition of the rocks traversed, on the courses of travel, whether other solutions are encountered, etc. Gold and silver are more characteristic of most of Nevada, as is copper of Arizona, and mixed metals in Colorado, probably mostly because those metals are more abundant in the depths of those localities. The minerals of different metals tend to deposition at different temperatures. Thus silver sulphide and sulphantimonides appear to be deposited at lower temperature than lead and zinc sulphides, while copper sulphides are deposited at still higher temperature. Gold can apparently be deposited at various temperatures, possibly because the actual amount for good value is so small. Where several metals are present, they tend to be deposited together with rapid temperature change and separately with more gradual temperature change.

This summary, necessarily brief and inadequate, will give some idea of the conditions under which the rocks and ores of the Tonopah district were derived and brought into their existing positions.

During Paleozoic time, limestone and shale were deposited in the region where Tonopah is now situated. These rocks were later intruded by granites.

Volcanic acticity started during the Tertiary era and became widespread through Nevada. In the Tonopah region, there appear to have been both andesitic and rhyolitic eruptions, as suggested by fragments in breccias, before any of the formations now well exposed came into place. The Silver Top rhyolite, of at least 1500 feet thickness was erupted. The initiation of volcanic activity as outlined above, presupposes the intrusion of the region by a large mass of igneous rock at considerable, probably several miles, depth. The different varieties of rock are probably the result of magnetic differentiation accompanied or preceded by more or less assimilation of the pre-existing rocks. It is probable, in general, that large volumes of rhyolite came to upper horizons through passages that tapped the upper part of the magnetic chamber, and large volumes of andesite came t rough passages that tapped a deeper part.

The main andesite formation of Tonopah was then built up of lava flows to a thickness of 1500 or 2000 feet, probably as a result of normally intermittent eruptions of the more quiet type, similar to those which may now be observed, though the evidence points to more abundant volcanic activity in Nevada during the Tertiary era than is now in progress in any of the present volcanic areas of the world.

The vents from which the andesitic rocks were erupted probably then became closed and pressure, which had found relief in the andesitic eruptions, accumulated. New passages, from an upper part of the magnetic chamber to a horizon within one or two thousand feet of the surface appear to then have been opened, along which the rhyolitic rock which has generally been called Glassy trachyte was intruded. These passages appear to have been along a east west course and to have tapped the magnetic chamber at depth to the north and west of the productive mines. This intrusion appears not to have been of great explosive violence. This may perhaps be explainable by the passages tapping the magnetic chamber somewhat below the area of gaseous accumulation, and the fluid lava being powerfully forced into the passages, but without much admixture of gases.

A little later, but after the Glassy (trachyte) rhyolite had mostly or wholly solidified, the matrix of Extension or Montana breccia was forced with explosive violence through approximately the same passages to approximately the same horizons. Glassy trachyte was very greatly shattered and cemented to breccia, which contains also, varying amounts of fragments of other rocks. There were probably several different intrusions of this nature as indicated by slightly differing varieties of breccia differing somewhat in age. The greater violence of the Extension breccia intrusives may be attributed to the passages tapping areas of more abundant gases or to the intrusions breaking through to the surface. Under the latter alternative, there should be a surface pyroclastic deposit of equivalent age. The Fraction breccia is here suggested as this possible surface equivalent. The age of the Fraction breccia has been previously interpreted as more recent. Although it was not investigated in connection with this report, there may perhaps be some question as to the correctness of earlier conclusions. There appears to have been faulting in the older rocks, as would be natural, in connection with Glassy trachyte and Extension breccia intrusions.

Soon after, when the breccias had solidified, West End rhyolite was intruded from the same general cource along approximately the same passages to similar positions. It would seem that the West End rhyolite intruded along some of the then recent faults and lifted different fault blocks different amounts with additional faulting. While an important mass of this rock has east west trend and moderate thickness, there are thicker less tubular masses to the north with apparently a north south trend. This intrusion seems to have been less violent than that of the breccias, perhaps on account of the exhaustion of accumulated gas pressure in the magma, the lack of connection with surface eruptivity and a general dying of volcanism. These three intrusives formed the anticline described elsewhere.

Immediately after the West End rhyolite intrusion while it was still hot, ore fluids arose from the same general source at depth to the north and west, the extreme volatile and siliceous result of differentiation in the magnetic chamber. These ore fluids followed part of the course of the West End rhyolite, then, in large part, entered fissures penetrating the andesitic rocks above. Possibly lower portions of the courses of ore fluids were below the rhyolite. At first the rhyolite was too hot for deposition of gold silver value and productive veins were only formed above it. As explained elsewhere, the ore fluids probably continued rising along somewhat changing courses for perhaps a few thousand years, while the rhyolite cooled to or below the temperature of deposition of the valuable minerals. Ore deposition then took place in the rhyolite.

Solutions containing silica and potash penetrated the andesitic rock above the West End rhyolite upward from its contact and outward from the fractures of ore deposition, causing quartz sericite alteration and resulting in the andesitic alteration phase known as Mizpah trachyte. With distance from the rhyolite, the ore fluids in the fissures and the altering solutions in the andesitic rock lost penetrative power and chemical activity through decreased pressure, and temperature and previous reactions, resulting in gradual decrease in vein deposition and rock alteration.

More rapid decrease occurred in places on impervious layers. The andesitic rock beyond these limits is known as Midway andesite. Other solutions penetrated part of the andesitic rock mass causing propylitic or calcite-chloride alteration. This is typically best developed in the Calcitic andesite below the West End rhyolite, but part of the other phases have partial alteration of this sort.

Later andesitic eruptions probably occurred in the region about Tonopah and may have extended into the district.

Extensive faulting of the district occurred after ore deposition. Probably considerably later than ore deposition, the district was intruded by rhyolite, in part, at least, rising from the east. Early eruptions resulted in surface deposits called Tonopah rhyolite, and the last lava solidified in the craters and pipes of Mount Offie and Mount Ararat, is known as Oddie rhyolite.

About the same time a rhyolitic rock known as Brougher dacite was probably erupted and solidified in the craters and vents of Mt.Butler, Mt.Brougher and Mt.Golden. This may have come from the magnetic chamber in the north and west.

This brief summary must necessarily be imperfect in many details; it does not pretend to cover the rocks that are not of great importance in connection with the Belmont mine, especially the more recent rocks.

PART III.

GEOLOGY OF THE BELMONT MINE.

In considering the geological features of the Belmont Mine, it is importamt to keep constantly in mind the different depths and relative positions reached in different parts of the workings, from geological aspects, as contrasted with actual depths and positions. This difference is the result of extensive faulting.

The more important faults within the limit of mine workings are the following:

The Stone Cabin fault, as it has been designated, is a compound fault or composite of intersecting faults, dipping easterly rather flatly, but striking irregularly, different members at different points striking both east and west of north. On the 700 level, this fault occupies a general north-south position a short distance west of the western boundary of the Belmont property, the nearest point being at the Desert Queen shaft. On progressively lower levels its dip carries it further east until at the 1500 level it may reach a position only about 125 feet west of the Belmont shaft. The fault or fault complex is very slightly exposed below the 1000 level and exposures above are not sufficient for analysis of its members and its effects, which may be expected, on account of its complexity to vary much along its course. It evidently has, however, a considerable downward displacement to the east. In part this fault complex has been the site of quartz deposition, nearly barren so far as is known.

Where the rocks west of the Stone Cabin fault have been penetrated in the Belmont Mine, glassy trachyte has been abundantly found with also some Tonopah rhyolite. On the 1500 level, however, andesite rock resembling the Mizpah trachyte phase more than the other phases though somewhat transitional, has been encountered in position which, provisionally, appears to be west of the fault. No ore has been found west of the Stone Cabin fault in the Belmont Mine, but almost all of the ore in the property of the Tonopah Mining Company was on its western side. There is, therefore, nothing inherently unfavorable in the western side of this fault except as may result from the character of rocks and the relative positions with respect to ore courses brought opposite ore-bearing horizons on its eastern side.

In the eastern Tonopah Mining workings near the Mizpah vein, there is displacement of about 300 feet vertically and 200 feet south going east, on about this line, but additional displacement of perhaps half this amount occurs a little further west and these displacements may perhaps join on the general downward course.

The South fault is found to the east of the Stone Cabin fault, striking about North 30 West and dipping about 50 degrees easterly. This course brings it to junction with the Mizpah fault upward and to the north on its strike, and with the Stone Cabin downward. From several aspects, notably the displacement of the South and Occidental veins, the displacement would appear to be about 200 feet vertically, downward to the east, and about 300 feet horizontally to the southeast on its eastern side. This, however, is very far from the displacement of the Mizpah vein according to previous correlation, but would be about correct if the block of the vein east of the south fault mined as the Mizpah vein were in reality a block of the North vein. If such is the case an unmined block of the Mizpah vein should lie further south. A cross cut to explore this situation has been recommended for some months and, I believe, has recently been started. Until the results of this work are available, any estimate of the displacement on the South fault must be considered as tentative. On the 1000 and 1100 levels, the rock exposed west of the South fault is largely glassy trachyte, while on higher levels it is mostly Mizpah trachyte with West End rhyolite. East of the fault on the 1100 level, although the rock is still largely Mizpah trachyte, Montana breccia appears.

The Mizpah fault, of north-west strike and rather flat north-easterly dip, is at the surface in the eastern part of the Tonopah Mining property, enters the Belmont property near the Desert Queen shaft a short distance above the 600 level and extends downward through the workings crossing the Belmont shaft just above the 1400 level. This fault is complex, variable both in dip and strike and appears to be composed of a considerable number of smaller faults along which movement occurred at different times, the planes of later movement faulting the earlier planes, thus introducing irregularities into the general course. Some faulting had probably occurred on this general course before vein deposition and quartz with moderate values was deposited in places on some of the earlier planes. The later and most of the more prominent planes* are, however, definitely later than ore. The Mizpah fault shows a distinct tendency to split into components. In the Belmont area this tendency is probably greater to the southeast of the vicinity of the Mizpah and Belmont veins. This may be seen from the faulting of the South vein on the 1000 level. From some aspects, the South fault may be considered as a split from the Mizpah fault.

All ore in the Tonapah Mining property is west of the Mizpah fault, the rock to the east being the Midway andesite phase, which extends in the Belmont property down to about the 800 level. On account of the various planes of movement in the Mizpah fault zone, the splitting and the intersections of other faults, the movement on the Mizpah fault zone varies greatly from place to place. The total vertical displacement is probably 700 feet with horizontal component of 1100 feet or more in a nearly easterly direction. Part of the total displacement below the junction in the South fault is on the latter. Thus the Mizpah and Belmont veins, which are correlated as one vein, are not greatly faulted out of line, although the originally adjacent parts of the ore shoot have been separated by long distances both vertically and in east-west direction. The Mizpah fault displacement can be more definitely ascertained after the exploration recommended in the block between the South and Mizpah faults.

There is little direct evidence as to the movement on the portion of the Mizpah fault in the more northwesterly workings. Several hundred feet vertical displacement appears probable from some aspects, less from others. This is important from the standpoint of future ore discoveries, and evidence should be accumulated toward more specific information,

On the Belmont fault displacement appears to be about 300 feet vertically and about 400 feet horizontally in direction about North 70 degrees East. The amount and direction of movement has probably varied somewhat on different parts of the fault. In general the displacement of the block of ground east of the Belmont and Mizpah faults seemsto have been governed by the pitch of the trough formed by the intersection of these faults. It is very probable that the Flat Favorite and the Shaft veins are one vein; also the 953 and Lillie Belle veins and the Rhyolite and I.O.U. veins as shown by special maps. The positions of the continuations of other minor veins, as the smaller rhyolite veins, would seem rather definitely predictable, subject to their continuing reasonable distances.

Still further east veins and stopes have terminated against Oddie rhyolite pitching eastward. There is considerable reason to believe that the contact is largely formed by two faults both dipping easterly, but one striking northeasterly the other northwesterly, or perhaps by different steps on these two courses. Exploration workings have not penetrated beyond this contact to any considerable extent.

These conditions can be most readily understood from the maps. As the movement on fault planes probably varied in character and was modified by splitting and intersections, the evidence and deductions which have been made do not apply accurately to the whole extent of the faults named and the presence of many minor faults modify the relations of different parts of blocks separated by one or more of the larger faults. The conditions are favorable to more accurate interpretation through the accumulation of evidence yielded by operations, and is necessarily more susceptible to both exposition and use by mapping than by verbal description. The constant accumulation and mapping of new evidence is strongly recommended. It should prove very valuable.

The Belmont Mine may, therefore, be divided into major fault blocks as follows:

- A - West of Stone Cabin fault.
- B - East of Stone Cabin; west of South fault.
- C - East of South fault; west of Mizpah fault.
- D - East of Mizpah fault; west of Belmont fault.
- E - East of Mizpah and Belmont faults; west of Oddie contact faults.
- F - East of Oddie contact faults.

If veins, igneous contacts and other features are considered according to the levels shown in the following tabulation on each horizontal line for the various major fault blocks, much of effect of faulting will be discounted. This is frankly a tentative arrangement subject to correction by further data. Some aspects of present data also point to other levels as closer the truth than those selected. This is a start on a method that should prove valuable.

Tentative Approximation at Equivalence of Levels in Major Fault Blocks, Belmont Mine.

A	B	C	D	E	F
(1)	(4)	6	7-8	10	
(2)	(5)	7	8-9	11	
(3)	6	8	9-10	12	Uncertain
(4)	7	9	10-11	13	or
(5)	8	10	11-12	14	Variable
6	9	11	12-13	15	
7	10	12	13-14	(16)	
8	11	13	14-15	(17)	
9	12	14	15-16	(18)	
10	13	15	(16-17)	(19)	
11	14	(16)	(17-18)	(20)	
12	15	(17)	(18-19)	(21)	
13	(16)	(18)	(19-20)	(22)	
14	(17)	(19)	(20-21)	(23)	
15	(18)	(20)	(21-22)	(24)	

An accompanying map shows geological mapping according to this scheme, starting with the 600 level in Block A and extending to the 1500 level in Block F. The method of connection of the various blocks is shows by arrows. This map illustrates the possibility that the Mizpah vein may have been displaced by the South fault to a position south of the present openings in the vicinity.

A series of maps also illustrate the approximate conditions of probable displacement of the Belmont fault. In this case, the coordinate system is displaced on the two sides of the fault so as to show no vacant area between the two blocks, thus, theoretically bringing into conjunction points that were together before faulting. There are minor discrepancies due to causes previously mentioned as well as to inexactness or variation from point to point between the actual and assumed fault displacement, but the fit seems good enough to warrant belief that it is a fair approximation to correctness for at least part of the area.

Longitudinal sections of the Mizpah-Belmont and Flat Favorite-Dhaft veins, also compiled for this report, show the effects of major faulting from a different aspect.

It is believed that the West End rhyolite shown on the 600 level west of the Belmont property in fault Block A, on the 900 in fault block B and on the 1100 in fault block C, with the glassy trachyte below are on abat the crest of the continuation of the anticline previously described as extending east from the vicinity of the West End mine. In the Belmont, in addition to being much cut up by faulting, the rhyolite is split and the anticlinal form is less perfect. The mass of rhyolite to the north in the vicinity of the Rhyolite vein system is of massive form and occupies relative position to the anticline similar to other rhyolite bodies father west. In a broad way aside from faulting, the geological relations in the Belmont area appear to be similar to those for several thousand feet west along the productive extent of the district.

The various veins in the mine in their relations to rock formations and faults can best be seen on the maps and sections. Their productive importance is illustrated in the following table giving tons produced from 1913 to 1923:

Table Showing Tons Mined from Various Veins in Belmont Mine.
March 1st, 1913 to June 1st, 1923.

Belmont Vein	389,827
Shaft Vein	166,402
Mizpah Fault Vein	47,726
Mizpah Fault Vein Branch A (Flat)	27,090
Mizpah Fault Vein Branch B	18,009
Mizpah Fault Vein Branch C	16,388
Mizpah Fault Vein Branch M	1,303
Mizpah Fault Vein Steep Branch	7,226
Mizpah Fault Vein H.W. Branch	236
Mizpah Fault Vein Miscellaneous	123
Total, Mizpah Fault Vein System	118,101

Table (Contd.)

Favorite Vein (Flat, Steep & 1087 Branches)	168,528
Lille Belle Vein	31,368
Occidental Vein (Includes 11008 vein)	44,088
Thanksgiving Vein	22,831
Middle Vein (Includes H.W.Branch)	25,438
Western Vein	53,086
North Vein	27,427
Mizpah Vein	106,780
South Vein (Includes 10004 Vein)	118,540
Nevada Vein	316
Shoestring Vein	32,194
Rescue Vein	41,560
Rhyolite Vein	177,686
No. 711 Vein	14,388
No. 729 Vein	4,000
No. 725 Vein	929
No.1173 Vein	2,187
New Rhyolite Vein	124
Total Rhyolite Vein System	199,314
No.1220 Vein	20,450
No. 953 Vein	3,733
No.1083 Vein	2,874
No.1320 Vein	7,978
No. 850 Vein	3,966
No.1406 Vein (Gold Vein)	357
Miscellaneous veins not segregated	15,074
Total	1,580,232 Tons.

Large production was made from the Mizpah, Belmont and other veins before 1913.

It should be noted that the following pairs of veins may be correlated with reasonable approach to certainty.

The Mizpah and Belmont veins.
The Flat-Favorite and Shaft veins.
The Lillie Belle and 953 veins.
The Rhyolite and I.O.U. veins.

From inspection of the Special Belmont fault maps, other correlation of minor veins are apparent, as well as probable opportunities to open continuation of the minor rhyolite veins east of the Belmont fault. Still more correlations can probably be made following work recommended, as the exploration south in the South-Mizpah fault block.

The practical effect of such correlations may be seen from the Mizpah-Belmont stope elevation. There is a very great probability that the Belmont ore shoot, on which stopes come down to the Mizpah fault between coordinates 250 and 1200 east and reach the fault from the 1000 to nearly the 1500 level, were before faulting immediately over the Mizpah stopes which come up to the Mizpah fault between coordinates zero and 1000 west and between the vicinity of the 600 and the 1000 levels. Under such correlation it is useless to look for the ore channel which fed the Belmont vein below the Belmont stopes. The channel which fed both the Belmont and Mizpah stopes must be looked for a thousand or more feet west.

It has been stated in a preceding section of this report that the conditions necessary for ore are rocks older than ore deposition, position along the courses of ore fluids and physico-chemical conditions at the time of injection of ore fluids permitting deposition in the particular places.

It is concluded in this report that, in the Belmont as elsewhere in the district, the rocks probably older than ore deposition include the main mass of andesite rocks including the Mizpah (trachyte) phase, the Midway and Calcitic phases, the closely associated rhyolitic rocks which are regarded as shortly preceding ore deposition including glassy "trachyte"

Montana or Extension breccia and West End rhyolite, and the formation here called Silver Top rhyolite. These rocks are regarded as potentially ore bearing where on courses of ore fluids. Oddie rhyolite and the associated Tonopah rhyolite would seen to be probably later than ore deposition. Attempt should be made to distinguish between the rocks called Silver Top rhyolite and Tonopah rhyolite. The former has heretofore been included in the latter classification, but it does not closely resemble Oddie rhyolite. In those rocks especially, from which commercial ore has not been produced, exploration should be restricted to the probable vicinity of ore courses.

Calcitic andesite is regarded as an andesitic alteration phase probably not actually on the courses of ore fluids, from which typically it seems to be separated by West End rhyolite and associated rhyolitic rocks, though it has frequently been found in line with the course of ore fluids in the upper levels, projected downward. Possibly, however, under somewhat different conditions of deposition at greater depths, it may be found associated with ore. In the Belmont mine, very little or no typical calcitic andesite has been found. Apparently below the horizon of West End rhyolite and glassy trachyte in the 1400 and 1500 Belmont levels below the Mizpah fault, the andesitic rock in geological position where the calcitic phase might be expected is more nearly of the Mizpah phase. The alteration appears nearer to that accompanying ore and may be construed as more favorable than the calcitic phase.

In the upper workings, as in the vicinity of the Belmont vein around the 800 level, the Midway phase or rock intermediate between the Midway and Mizpah phases appears. This rock though on the projection of the general course of ore fluids is believed to be beyond the limits of effective penetration or activity of the ore fluids or altering solutions affiliated with them. Similar conditions appear in the vicinity of the upper parts of the South, Favorite and Rhyolite veins. These veins where unfaulted appear to terminate gradually more or less coincidently with the change in alteration of wall rock from the more favorable to the less favorable type. It appears therefore that the physico-chemical conditions gradually become less favorable, and finally unfavorable for deposition. The so-called Mizpah vein comes up against the Mizpah fault in full strength. The so-called Belmont vein as previously noted is its upward continuation.

Going downward, most of the veins are found to encounter West End rhyolite, though the so-called Belmont vein ends against the Mizpah fault, the Mizpah vein as noted being its downward continuation. In the case of the Mizpah vein, both in the Belmont property and farther west, ore typically continues while, as is commonly found first, the rhyolite appears on but one wall, but profitable ore is not found to extend any considerable distance into the rhyolite. The vein appears usually to flatten from its well defined course displayed above and becomes less well defined, splitting into stringers and "frazzling" into zones of silicified rock. It is believed that these areas were on the courses of ore fluids but that the temperature was too hot for ore deposition. The situation has been somewhat complicated by faulting along the veins in places.

In the case of the Shaft vein, value appeared to penetrate the West End rhyolite more definitely at one point than at any point observed in connection with the Mizpah vein. The Rhyolite vein system in general penetrates the West End rhyolite without characteristic change in strength or value of ore. This condition is regarded as resulting from cooler temperature at the time of deposition. There are some indications that more northerly veins may be found to penetrate the rhyolite more frequently than more southerly veins.

The tendency shown strongly in the western part of the district for veins to join the West End rhyolite on the north limb of the anticline and extend downward in it or on its contacts for long distances may also prove to be characteristic of the Belmont mine, though here, the anticline, even aside from faulting, appears to be less perfectly developed. The flattening dip to the north, mentioned above, suggests the continuation of this tendency.

In the western part of the district, westerly pitch is characteristically displayed. In the Belmont mine, the abundant easterly dipping faults give the appearance of easterly pitch. This is merely an appearance due to a cause later than ore deposition. The Belmont ore shoot quite definitely pitches westerly, and this is believed probably characteristic of the ore shoots in general. It seems probable, therefore, that, in general, the downward courses of ore fluids from which the veins in the Belmont mine were derived, should be looked for to the north on the dip, perhaps usually a flatter dip, and along a generally westerly pitch from the lower portions of the veins as developed. In the search for such ore courses the effect major faulting is of the greatest importance and should be allowed for as much as possible. The more abundant faults in the Belmont mine which dip easterly and displace to the right would have the effect of causing downward continuations to lie still farther to the north and west.

It would seem entirely probable that the veins that penetrate the West End rhyolite with good strength and value can also penetrate the Montana breccia and other older rocks with continued value. The tendency for an increasing amount of ore to lie in the Extension breccia at depth is shown by the Murray vein, suggesting that the ore fluids may have been injected on a course steeper than the rhyolite contact and joined the rhyolite at about the depth now reached. In the case of veins which do not penetrate the rhyolite in good strength and value, the failure in deposition would seem more definitely due to the high temperature of the recently intruded rhyolite than to an assumed general high temperature of other rocks at the same horizon. It would seem theoretically possible in such cases that ore might be deposited both above and below the rhyolite but not in it. There is no definite evidence on this point but it is of interest as a possibility of deeper ore in the ore courses that fed the Mizpah vein. It cannot be assumed, however, that if ore does exist in the deeper rocks in the general Belmont area, it will probably be found most abundantly in the courses that have fed the most productive veins above. It would be entirely reasonable to expect that the relative importance of deposition from different ore courses would vary much at different horizons.

PART IV.

RECOMMENDATIONS.

General Recommendations:

Value in veins and stringers is important geological evidence and records of assays of ore in place and production records of veins should be kept in such form as to be readily compared with other geological data. Assays should be entered on geological maps where they have important bearing, as in isolated places. Continuous veins may be shown by color without detailed assays but any sudden change of value with change of formation, fault or otherwise, should be indicated. Abnormal gold-silver ratio and unusually large base metal contents should be noted.

All accessible workings on veins, including stopes and development places, of which there is not any assay record now available should be systematically sampled and mapped. This applies both to unmined pillars and blocks of vein matter, and to unmined portions of the total width of the vein including stringers that may exist in the walls of the main vein. Additional slabs of ore in the walls are likely to have escaped notice more frequently than blocks of full width. In connection with this work the diluting effects of faults, by mixing waste with ore, should be taken into consideration and a few shifts work should be done where such dilution is indicated, to expose solid vein matter. Where workings terminate against faults, knowledge of what exists beyond should always be obtained. Stope sections should be made at regular intervals where possible and important.

Stope elevations should be made for all of the important veins for the length of the property. Fault blocks of veins that can be correlated should be included on the same sheet, even if they have formerly been called by different names. Such stope elevations should show faults, vein intersections, change of formation and similar important information. They should be made for -

The Mizpah - Belmont vein
The Shaft - Flat Favorite vein
The South vein
The Occidental vein
The Lillie Bell - 953 vein
The Rhyolite - I.O.U. vein
The other rhyolite veins with their continuations east of the Belmont fault as they may be developed and identified. Other minor veins as they may be correlated beyond the Belmont and other faults.

The stope elevations are not now up to date, and some places are shown unmined which have been mined. The Company's operating staff have the ore shoots as they remain on the property to mine. The staff should account for each block of the oreshoots either as mined out, ore reserves or possible ore, or unminable for some specific reason which should be kept conveniently available.

The course of past operations should be reviewed through consideration of development and production reports to ascertain if working places may not have been temporarily abandoned on account of some immediate causes and work not since resumed. The work that was going on just before strikes and not resumed afterward deserves special consideration, also the changes in working places before and after mill shutdowns and at times when new rich orebodies were opened after periods when the desired grade of mill heads had been unobtainable or obtainable with difficulty.

In carrying out future development work, the relative geological elevation of workings in the various major fault blocks, as distinguished from the actual elevation, should be constantly considered. Thus, workings west of the Belmont fault appear to be about 300 ft. deeper geologically than workings east of the fault; the eastern Belmont 1500 workings appear to be no deeper geologically than the eastern Mizpah (T.M.Co.) 500 workings.

The interest of foremen and bosses in new ore should be encouraged.

Geological, assaying and engineering records should be kept up to date and conveniently available until the mine proves by its record that it is coming to its end.

The mine assay records show ore in a few places not being worked and scattered assays of interest in several places. Lists of places where work can be started on ore or indications, when conveneint in connection with other operations, would be a valuable addition to mine records. Such places would be indicated by symbols on the mine maps.

Special Recommendations:

The best way of finding ore blocks remaining in the known veins is by systematic work of the sort recommended under General Recommendations. This applies especially to the larger and more extensively mined veins. Included herewith are prints of longitudinal elevations of the Mizpah-Belmont and Flat Favorite-Shaft veins, compiled from partial elevations at the mine office. The blocks shown as unmined should be accounted for. Some blocks are undoubtedly mined; some ore undoubtedly remains in blocks shown as mined. There should be similar accounting for blocks shown as unmined on similar elevations of other veins, which should be prepared. Any block which cannot be accounted for should be investigated. Such systematic work will not only result in efficiency in finding ore, but will save mining expense by preventing the necessity of mining several times in one area. With the results of such systematic work available, the best points for exploration and the amounts of exploration work advisable at each point can be more accurately estimated, enabling saving in development cost. Such systematic work would probably point directly to faulted continuations of some of the minor veins.

In the case of a mine such as the Belmont, it is impracticable in most cases to lay out in advance specific courses and amounts of exploration work which are not subject to change as changing conditions are encountered. On the other hand, when the exploration of large new areas is undertaken work should be planned to reach the areas of the greatest interest rapidly and conveniently.

For purposes of general exploration at depth, the 1500 West crosscut should be continued westerly from its face at about 2180 south, 250 west. Cross cutting should follow according to conditions encountered. These workings will penetrate an area that has not been explored for several hundred feet above, and the workings to the north from the main west cross cut, will penetrate the rocks on the probable downward course of the channel of ore fluids which fed the Mizpah-Belmont vein. Detailed exploration should be indicated in the light of the new conditions exposed and the conditions around the lower portions of the Mizpah vein on the levels above, and west of the Stone Cabin fault. In this connection, an area of 100 feet radius about 2000 south, 400 west on the 1000 level is of interest. In this vicinity there are a number of quartz exposures, most of which are evidently of low value, with their courses not clearly exposed, but as a whole lying on, or somewhat to the north of, the general downward course of the Mizpah vein. Sampling and assaying with a moderate amount of exploratory work to clarify the situation, would seem advisable. The continuations of this area on the 1100 and 1200 levels could then be explored if it proved desirable.

The possibilities in connection with the downward continuations of the Rhyolite veins between the Mizpah and Belmont faults are not well explored below the 1100 level. It would seem advisable to continue the cross cut north of the 1200 level at about 630 east.

For general exploration, the furthest north-west cross cut on either the 1200 or 1300 level should be extended. The former has the advantage of being out further; the latter, the possible advantages of greater depth and of probably being (according to the possibly incorrect information available to me) at about the same elevation as the deepest level of the Gypsy Queen, with which a future connection for good ventilation might be practicable under possible circumstances.

A considerable mass of Mizpah trachyte occurs on the 1000 and adjacent levels, between the South and Mizpah faults, which has not been adequately cross cut. The mine staff have considered that the Mizpah vein has been mined in this block but the effect of the same faults or other veins is such that there remains a possibility that the vein mined was the North vein, not the Mizpah vein, and that a large unmined block of the Mizpah vein may exist to the south. "A cross cut on the 1000 level about parallel with the South fault, starting at 30 east - £390 south, has been strongly recommended to extend 200 feet if nothing is previously encountered." 2

The opening of the I.O.U. vein last December was the first work to discover the continuation of the Rhyolite veins east of the Belmont fault. Work to open the I.O.U. vein on other levels is well planned, progressing well and is approved. Cross cutting north of the same levels for continuations of the other rhyolite veins east of the Belmont fault should be undertaken at propitions time. The most favorable levels would seem to be about 300 ft. deeper east of the fault than those shown as favorable by records of production west of the fault. There may be good reason for some delay in this work.

When the I.O.U. vein is well opened up on several levels near the Belmont fault, the record of the Rhyolite vein should be scrutinized to ascertain if it was mined for similar vertical limits to those shown by assays on the I.O.U. vein with regard to fault displacement. Such investigation may indicate the possibility of more mineable ore in the Rhyolite vein at some particular elevation and will serve as a correction of the estimated displacement on the Belmont fault.

The unexplored area north of the Shaft vein and east of the Belmont fault on the 1300 level deserves exploration. The 1300 level is the deepest regular level on the Shaft vein though there are two intermediates between the 1300 and 1400, connected by a raise from a 1400 cross cut, which does not extend sufficiently far north to reach the Shaft vein if its dip continued normal. Although some apparently adverse conditions were disclosed, more explorarion on the 1400 level is advisable.

On the 1500 level a cross cut should be driven northeasterly from a convenient point near the foot of the raise to the Gold vein to explore for the Gold vein on the 1500 level and extend to the Mizpah fault in this vicinity. This work has recently been started. The barren quartz north and northwest of the foot of the raise should be investigated further. A northwest drift on this quartz would seem a favorable means of exploration of the large area of deep rocks to the northwest. It is regarded as possible that such a large quartz vein, largely barren, may occur on a main course of mineralization and may contain ore in more or less pipe form.

Attempt should be made to extend the limits of pay ore in the Gold vein on the 1400 level. The cross cut to the southwest from the Gold vein should be extended 100 feet or more to explore underneath the exposure of the Mizpah fault Vein B on the 1300 level, where it contains good ore, and also to explore for the upward continuation of the barren quartz vein at the foot of the raise on the 1500 level, which is trending in this direction. The continuation of the Western vein on the 1400 level may be cut from the face 120 ft. northwesterly from the Gold vein or by exploring northwesterly on the general course of the Gold vein.

Work up on the Shaft vein from the 1300 level is attractive not only because of the ore found to be remaining, but because ore exists in the Lillie Belle vein between the 1300 and 1200 levels.

7 The continuation of the east drift, Belmont vein, 1400 level, for a distance of 300 ft. along the line of the vein would be good prospecting and would lead to a ventilation connection with the Halifax on about the same level near a connection of the latter mine with the Mizpah Extension. It would seem that ventilation could thus be led to the 1500 level.

The southeast crosscut, 1500 level, was driven largely on account of an option on the Buckeye property. By continuation for 1300 feet a connection could be made with the Buckeye Shaft. This would be expensive and I do not regard it as very attractive exploration, as I think that this area is south of the main course of mineralization.

The east drift, 1500 level, should be re-opened beyond the cave. Glassy trachyte to the east is said to contain a few dollars per ton for a considerable area. As this is the lowest part of the main Belmont vein, it is important.

The following additional notes are offered for consideration. In some cases the advisability and character of work would depend on results elsewhere and in many cases the amount of work would depend on results of the first few shifts.-

<u>900 Level</u>. There would seem a possibility of additional ore above the 900 level in the south vein.

<u>1000 Level</u>. (270 East, 2360 S.) The Belmont vein here has not been followed west to the Mizpah or Belmont fault.

It would seem advisable to continue the drift to see if some ore may remain.

1000 Level(280 W., 2355 S.) A bunch of stringers striking easterly in glassy trachyte at this point shows considerable zinc with low sulphur values. As this is about on line with the Mizpah vein a few shifts drifting may be advisable.

1000 Level (320 W., 2060 S.) Cross cutting northwesterly about 40 feet from this point would expose the G.T., M.T. contact carrying a quartz vein exposed elsewhere in the vicinity and carrying some values not far distant. This may be the main channel of ore solutions feeding the Mizpah vein on levels above most of the south faults.

1000 Level (400 W., 2000 S.) The area of about 100 feet radius around this point contains a number of quartz exposures which would seem to justify a moderate amount of exploratory work with assays of fresh exposures.

1000 Level (450 to 430 W., 1560 to 1610 S.) One to three feet of quartz, considerably split and broken, is exposed showing silver minerals. Work on this is advisable at a convenient time.

1000 Level (600 W., 2110 S.) Cross cutting westerly from about this point would show amount of quartz on the New and Stone Cabin faults at about this junction. Five or six feet of quartz is now exposed but there is apparently more to the west. A few feet of work only if there are no encouraging results would seem desirable.

1000 Level (1175 E., 2260 S.) Some fairly good looking vein matter is exposed in the Belmont vein at this point. It should be investigated.

1000 Level (about 895 E., 1510 S.) Good looking stringer should be sampled and followed if assay encouraging.

1100 Level (About 150 E., 2320 S.) If work on the 1000 Level in the same vicinity, cross cutting south, shows encouraging results, work here would be advisable for the same reasons.

1200 Level. (1100 to 1200 E., 1700 S.) Good values are shown on the Lille Belle vein which will be stoped when convenient.

1200 Level (500 E., 2400 S.) The Silver State vein on this level is on the contact of the M.T. and the North and W.E.R. to the south. Although this vein has not been productive in an important way on this level or above in M.T., the possibility should be kept in mind that it may be better in W.E.R.

1200 Level. The area to the north of Lillie Belle vein deserves exploration according to results above and below.

1200 Level. This level west of and below the Mizpah fault is but very slightly explored. Further work may well be desirable after other work recommended. There are apparently large areas of Mizpah trachyte. In this direction on this level about half the total Belmont property is penetrated by no openings.

1300 Level (750 E., 2100 S.). Assays on quartz streaks here and southwest toward face. Exploratory work if encouraging results of assays.

1300 Level (300-400 E., 1770 South). There is a good string of assays on Mizpah Fault Vein B.

<u>1300 Level</u>. Exploration to north for downward continuation of rhyolite veins if results on 1200 level are encouraging.

<u>1400 Level</u>.(795 E., 2005 S.). A quartz stringer striking east-west about 1 foot wide showing slight mineralization is exposed in Mizpah trachyte at this point which is about on line for the downward continuation of the Mizpah vein below the Mizpah and Belmont faults. On account of this position a west drift should be run on this stringer with some cross cutting further west before the place is abandoned.

<u>1400 Level</u> (1200 E., 2010 S.). West End rhyolite is exposed about 35 feet in the foot wall of the Belmont vein at this point with steep contact carrying quartz. In view of the fact that veins in M.T. in the Tonopah Mining and other properties to the west extend downward in M.T. to W.E.R. and then end or flatten to the north on a W.E.R. contact, the Belmont vein between the 1400 and 1500 levels in this vicinity should be examined to see if similar conditions, not exposed in the present condition of the workings may exist there.

<u>1400 Level</u> (690 E., 1640 S.). The 2-foot quartz vein averaging abundant pyrite but not much value should be remembered in connection with other work in the general vicinity on this level above and below.

Drifting on the narrow vein about 375 feet southwest of the Belmont shaft on the 1500 level in the glassy trachyte area is advisable. This work is under way. It should be continued for a moderate time according to results. From general considerations, as much work of unprofitable character is not regarded as justified in this direction as more to the north, nearer the probable main course of ore fluids, but the erratic high assays justify development in moderation for possible immediate results.

Conclusions:

At the close of 1907 the situation in the Belmont property was somewhat analagous to the present situation. Exposed ore was inadequate to supply the mill for ahead and continuations of ore were restricted by geological conditions. There appeared, however, very good reasons to hope that a strong continuation of the vein system might be found east of and above the Mizpah fault but not reaching to the surface, as similar capped continuations of the vein system had been found in the western part of the district. The 1000 easterly crosscut was being driven to reach that portion of the main area of the property east of the Mizpah fault that was considered in favorable position for the eastward continuation of the Mizpah vein, where north-south cross cuts were to be driven in further search of ore. This work was terminated. Events have shown that if it had been continued the main Belmont vein would have been reached more than a year earlier than was the case.

At present, the large ore bodies from which fifteen million dollars profit have been earned are restricted by changed conditions in connection with the deeper rock formations, but of recent years, ore in the western part if the district has been found more abundantly below the original ore-bearing formation than in it. The mine that has been most successful in finding such deeper ore has done so by acquiring contiguous property.

The chances of similar conditions will warrant exploration of the Tonopah Belmont Company and the acquisition of new property or mining rights on favorable terms is desirable in order that operations on any ore bodies found shall not be hampered by the present property boundaries.

A good mine that has been extensively worked at large profit does not usually come to its end suddenly. In the later stages of operations one of the most successful ways of finding ore within the limits of old mining operations is by continued mining. Stoping operations on ore not good enough to repay its share of overhead expense frequently leads to the opening of ore bodies of good grade. With operations of this nature, it is difficult to expose a reserve of measurable tonnage and the results of operations in profit or loss must become variable from month to month. The end of the mine is not indicated until the absence of profit is demonstrated over a period of months.

The search for ore in the deeper rocks might logically have been carried out earlier when operations were more profitable. Current monthly profit is now sufficient to more than pay the expense of the monthly exploration proposed. There is reason for strong hope that this condition can be continued, but it cannot be stated definitely that it will continue.

The Belmont mine must now be regarded as a prospect which is now self supporting and may be hoped to continue self-supporting; which has a good number of chances for increased profit for longer or shorter limited periods and a tangible chance for becoming again a very profitable mine; and which is equipped for operations on any scale than can be anticipated. Under these conditions a program of exploration is justifiable and attractive. Systematic records by the mine staff of the kinds recommended will assist greatly toward successful results, and are desirable from all standpoints.

Respectfully submitted,

H. P. Henderson

Mining Engineer and Geologist.

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