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Outlook for Further Ore Discoveries in the Little Hatchet Mountains, New Mexico

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PREFACE

In 1934 the New Mexico Bureau of Mines and Mineral Resources and the U. S. Geological Survey began a joint investigation of the geology and ore deposits of the Little Hatchet Mountains in Grant and Hidalgo Counties, New Mexico. This investigation was done by S. G. Lasky of the U. S. Geological Survey, and Mr. Lasky's detailed report will be published by the Federal Geological Survey.

Inasmuch as it is now nearly six years since the investigation was started, and it may be two or three years more before the report is published, it appears advisable to release to the prospectors, mining men and citizens of the State all available information on the district.

Through the courtesy of Economic Geology and Mr. Lasky, the New Mexico Bureau of Mines and Mineral Resources is able to publish this paper as Circular 7. Grateful acknowledgment is also given Economic Geology for the use of the cuts in reproducing the maps and figures.

C. E. NEEDHAM, Director

OUTLOOK FOR FURTHER ORE DISCOVERIES IN THE LITTLE HATCHET MOUNTALNS, NEW MEXICO.[1]

SAMUEL G. LASKY.

ABSTRACT

The Little Hatchet Mountains contain two mining districts, the Eureka silver-lead-zinc district and the Sylvanite gold district, the deposits of each being associated with a mass of monzonite that intrudes Lower Cretaceous sediments. The same formations crop out in both districts, having been duplicated by a large post-ore fault, and the two monzonite masses and their accompanying mineralized zones lie at essentially the same stratigraphic position in the two fault blocks. The deposits of the Eureka district are mesothermal whereas those of the Sylvanite district are hypothermal, but the two groups are mineralogically similar in many respects.

As the two monzonite exposures are several miles apart, the natural inference is that there are two separate intrusions. Contrary to this inference, the evidence of structure, mineralogy, and petrology indicates that the two monzonite masses are faulted parts of the same body and that the mineralized areas of the Eureka and sylvanite districts were originally continuous and zonally related, the original igneous mass having been a flat-lying sill-like streamer, 7 miles or more long, that was bordered by a contact-metamorphic halo and that formed the core of a zone of mineralization.

The economic implications of this interpretation are three-fold: (1) the mineralized zone is limited in thickness and is restricted, like a bedded deposit, to a particular sedimentary horizon; (2) the area between the Eureka and Sylvanite districts, hitherto considered barren, should contain mineralized ground at variable depths below the surface; and (3) the deposits change along the trend of the zone from the gold deposits of the one district to the silver-bearing base-metal deposits of the other. In structure and size the deposits in the hidden parts of the mineralized zone probably are similar to those already known.

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[1] Published by permission of the Director of the Federal Geological Survey. Presented before Society of Economic Geologists, Washington Meeting, Dec. 29, 1937

Under the alternative interpretation that the two districts are separate centers of activity, the outlook for future successful pro petting depends upon the depths at which the underlying Paleozoic limestones lie and the possibility of large deposits having be formed in them.

FOREWORD

The Little Hatchet Mountains constitute an isolated desert range covering an area of about 75 square miles in the extreme southwest corner of New Mexico, lying partly within Grant and partly within Hidalgo Counties (Fig. 1). Prospecting and mining in this part of the State began about 1870, but, leaving aside the large-scale opera- tons in the Lordsburg district,[2] the aggregate value of the metals recovered from the ores mined from eight districts has been only about $2,000,000. 'The Little Hatchet Mountains area is credited with an output of about 60,000 tons of ore whose gross value is estimated at not more than $1,250,000.

In 1934 a survey was started by the Federal Geological Survey, cooperation with the State Bureau of Mines and Mineral Resources of the New Mexico School of Mines, with the aim of investigating the low mineral productivity of Hidalgo County, and field work was begun in the Little Hatchet Mountains. A detailed report on the geology and ore deposits of the Little Hatchet Mountains is being prepared for publication by the Geological Survey.

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2 Lasky, S. G.: Geology and ore deposits of the Lordsburg mining district, Hidalgo County- New Mexico. U. S. Geol. Sun·. Bull. 885, 1937.

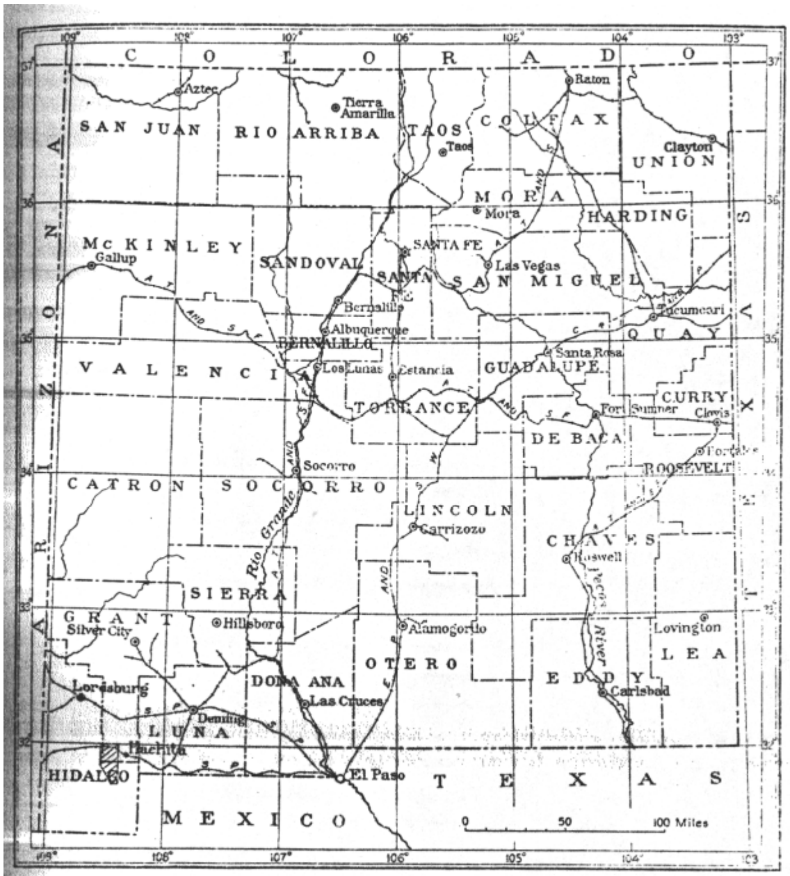

FIG. 1. Map of New Mexico showing location of the Little Hatchet Mountains (shaded area).

Acknowledgements.—I am indebted to a large number of friends and colleagues for informal discussions of different phases of the general problem covered in this paper. Particular mention should be made of the help obtained from a field conference with James Gilluly of the Geological Survey and from early discussions with

S. B. Talmage of the New Mexico Bureau of Mines and Mineral sources.

STATEMENT OF THE PROBLEM

The Little Hatchet Mountains contain two mining district Eureka district in the north half of the range and the Sylvanite district in the south half (Fig. 2). The deposits of the Eureka d trict are mesothermal and contain argentiferous ores of lead and zinc in a gangue predominantly of manganosiderite; those of Sylvanite districts are hypothermal and contain native gold, to ideas, and minor sulphides, principally arsenopyrite and chalcopyrite in a gangue of vein silicates, quartz and calcite.

In both districts the deposits are associated with monzonite intrusions. As the exposed areas of monzonite are several miles apart and as the mineralized areas around them are separated by a barren stretch 1 to 4 miles or more wide, the natural inference is that there are two separate intrusions. Contrary to this inference, however, variety of other evidence indicates that the two monzonite mass are in reality faulted parts of a single intrusive body and that mineralized areas of the Eureka and Sylvanite districts were o many continuous and zonally related. The two interpretations lead to far different conclusions regarding future prospecting in t range. The evidence for and against the two alternatives is assembled and balanced in the following pages, and the economic implications of each alternative are discussed. A brief description of t geology and ore deposits is included prior to a discussion of the problem itself.

GENERAL GEOLOCY

The rocks exposed in the Little Hatchet Mountains include chiefly sediments of Lower Cretaceous age; intrusive rocks of late Cretaceous or early Tertiary age; and Miocene (?) tuffs, breed and flows, which locally overlie the eroded and beveled outcrops of the other formations. The entire bedrock assemblage is surrounded by valley fill (Fig 2). Paleozoic rocks crop out in the nearby ran and desert hills and doubtless underlie the Little Hatchet Mountains.

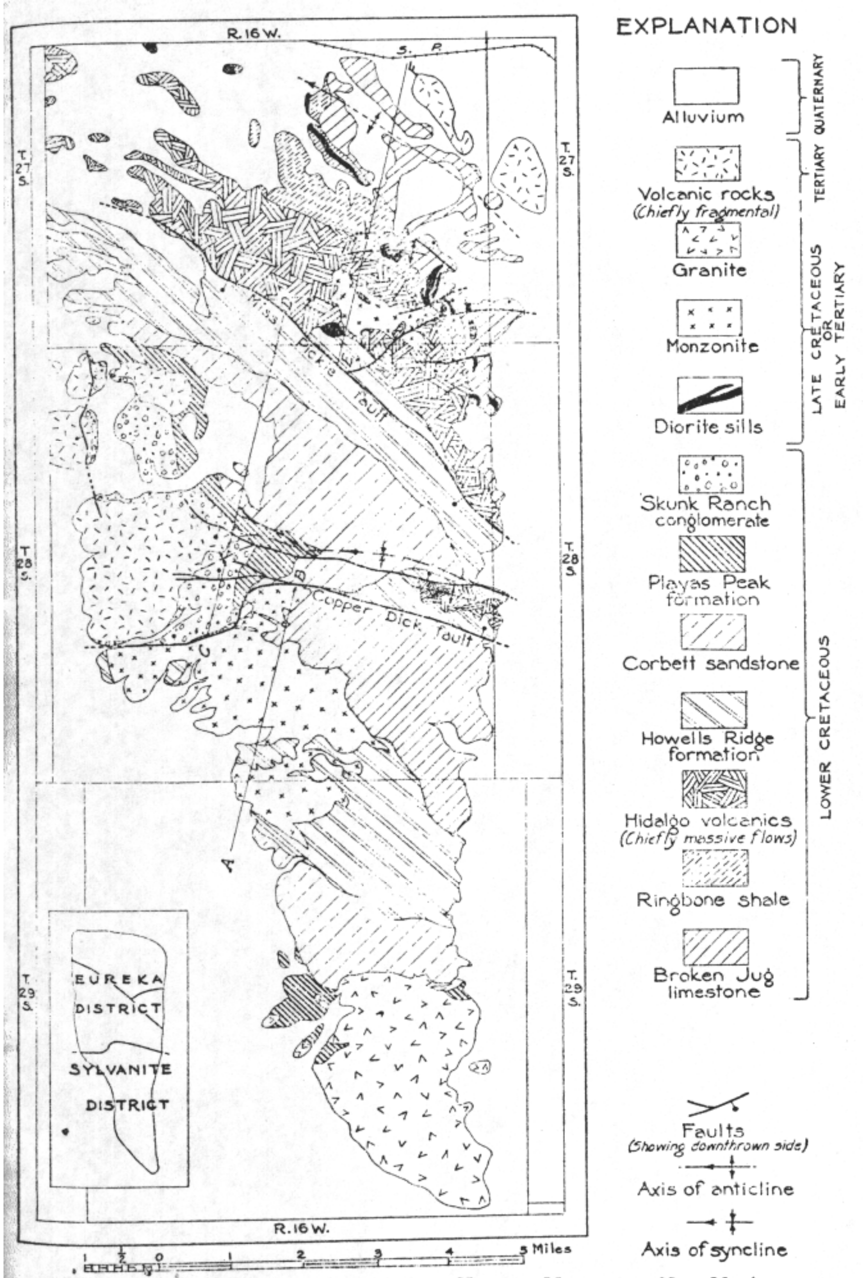

FIG. 2. Geologic map of the Little Hatchet Mountains, New Mexico, simplified from the larger scale field map.

The Lower Cretaceous rocks have been divided into seven formational units that have been named, in ascending order, the Broken Jug limestone, the Ringbone shale, the Hidalgo volcanics, the Howells Ridge formation, the Corbett sandstone, the Playas Peak formation, and the Skunk Ranch conglomerate [3] (Fig. 3a). The aggregate exposed thickness averages about 19,000 feet. They are composed in general of thin-bedded beach and near-shore marine deposits of shale, sandstone, limestone, and conglomerate and include several thousand feet of contemporaneous volcanic rocks. The volcanic rocks consist largely of andesitic and basaltic flows and are confined chiefly to the Hidalgo volcanics.

These formations are intruded by a number of relatively small diorite sills (Fig. 2) and by later masses of monzonite and granite of stock-like dimensions. Three such masses, to ignore the various outliers, are exposed:—one of granite occupying the south tip of the range, one of monzonite somewhat to the north in the Sylvanite district, and a smaller monzonite mass farther north in the Eureka district. All three lie sill-like, with concordant floors and roofs, within the sediments. They are not, however, extended sheets, but are more nearly nail-shaped masses that parallel the dip of the invaded sediments; they are like gigantic examples of what Daly [4] calls "ribbon injections." Neither the granite nor the diorite sills are directly pertinent to this paper and no further mention of them need be made other than to add that they emphasize the susceptibility of the formations to injections along the bedding.

The monzonite of the Sylvanite district has a sub-rectangular exposure of about 6 square miles whose northwest part is cut off by a fault and whose southwest part extends under the valley fill. In general attitude the mass parallels the strike and dip of the enclosing formations but has a blunt and almost square-cornered southeastern end composed of four principal sill members. Count-

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[3] Lasky- S. A newly discovered section of Trinity age in southwestern New Mexico, Am. Assoc, Pet. Geol. Bull., May- 19384

[4] H. A.: Igneous rocks and the depths of the earth, pp. 89-90, McGraw-Hill Co., 19n.

less sills and dikes too thin to be shown on the map extend out into the enclosing rocks. The part of the southwest boundary that is exposed *is* concordant with the beds of the Howells Ridge formation, and most of the northeast boundary is concordant with beds of the "Broken Jug limestone crosscutting contacts being local features only. The eastern of the two northward bulges along the northeast contact, as seen in plan, *is* not a crosscutting part but only a skin of monzonite that forms a dip slope on a high peak. The Howells Ridge formation thus forms the roof of the mass and the Broken Jug limestone the floor (Fig. 3). The thickness from floor to roof normal to the bedding *is* about 7,000 feet. An almost continuous tongue of the Howells Ridge formation, split longitudinally by thin sills of monzonite, extends westward through the monzonite with generally concordant contacts, and a similar but less continuous tongue of the Broken Jug limestone penetrates the northern corner of the mass.

The monzonite of the Eureka district has two major outcrops-one about 3,000 feet long and 500 feet wide that lies at and near the top of the Broken Jug limestone parallel to the bedding, and the other about 1$^3/_4$ miles long and 1/2 mile wide that lies within the Hidalgo volcanics parallel to the general trend of the formation. The several outliers also conform to the sedimentary structure.

Both the Eureka and Sylvanite bodies are bordered by a contact-metamorphic halo whose width ranges from 600 feet or less at the floor and roof of the intrusions, as measured normal to the bedding, to over 2 miles along some beds at the ends of the intrusions, where the width is measured parallel to the bedding. Within the sedimentary rocks the metamorphic halo consists chiefly of interbedded hornstones, garnetites, scapolite-diopside beds, and albite-diopside beds in the inner zone, and of marble-amphibole beds in the outer zones. In the Hidalgo volcanics the metamorphic minerals are epidote, pale-colored amphibole, and, locally, albite and sphene.

The outstanding structural feature of the range is that the same formations crop out in the north part of the range as in the south part, having been duplicated by the Copper Dick fault (Figs. 2 and 3). The formations in the block north of the fault are bent into two principal folds: one a broad anticline whose axis trends northwest through the northeastern foothills, and the other a syncline whose axis trends north of west through the center of the range and pitches westward at an average of 18 or 20 degrees. The common flank between the two folds is broken by an extensive strike fault (the Miss Pickle fault), and the south limb of the syncline is sharply cut off near the trough by the Copper Dick fault, which roughly parallels the syncline axis. The beds south of the Copper Dick fault form a southwestward dipping monocline.

The Copper Dick fault dips northward between 50 and 63 degrees. Its total displacement is estimated at about 15,000 feet, and the strike-slip component of movement appears to range roughly from 5.000 to 8,000 feet. The hangingwall has moved westward with respect to the footwall. The Miss Pickle fault seems to be a branch of the Copper Dick such as is commonly found in the hangingwall of most strong and relatively low-angle normal faults. Its dip is 60° to 70° SW., and its total displacement is estimated at about 6,000 or 7,000 feet; the direction of movement was nearly parallel to the strike, the hangingwall having moved westward relative to the footwall. Movement along both faults has been distributed over a long period of time, but the greatest displacement is post ore. Is now observable the Copper Dick fault brings the monzonite of the Sylvanite district and its metamorphic halo against unmetamorphosed sediments to the north, and more important still, forms a sharp north limit to the mineralized area of the Sylvanite district, the rocks north of the fault being entirely barren up to the fringe of the mineralized area around the Eureka monzonite.

ORE DEPOSITS.

Only five ore shoots of stoping size have thus far been found in the Little Hatchet Mountains. Two of them are in the Sylvanite district and three are in the Eureka district. Essentially the entire production of the range, about 60,000 tons, has come from these five shoots and the greater part of it has been from the Eureka district. None of these mines extends much below water level, which ranges from 10 to 225 feet below the surface, and those that do were flooded at the time of my visits.

Sylvanite District.

The deposits of the Sylvanite district are so few that it is difficult to generalize as to their distribution, but all those mapped lie within the monzonite or its metamorphic halo. The most distant is about a mile from the contact. All except two are vein deposits; of these two, one, including a few outlying pods, is a replacement deposit of chalcopyrite in garnetite and one is a replacement deposit of pyrrhotite in quartzite. One of the vein deposits has been prospected for copper and one for lead, but all others have been prospected for native gold. The two productive shoots were the chalcopyrite replacement deposit, which yielded about 4,000 tons of ore, and an oxidized copper-rich shoot in one of the gold veins that yielded about 1,300 tons of ore.

The veins are commonly short and tight. The maximum length is about 1,500 feet, though at one place a number of linked or overlapping fissures form a vein zone a little longer. Some are stringer lodes and some are better defined fissures. They pinch and swell abruptly, the width ranging from that of a mere joint to a rare maximum of 15 feet; the average width is probably less than 1 foot.

The usual ore minerals of the Sylvanite deposits are arsenopyrite, chalcopyrite, pyrite, tetradymite, and hypogene native gold. Two generations of pyrite are present, one a pale cubic variety barren of gold and silver that belongs to the early sulphide stage of deposition and the other a yellow pyritohedral variety that contains appreciable gold and silver and belongs to the late sulphide stage. Magnetite, specularite, pyrrhotite, molybdenite, and traces of sphalerite and galena have been found here and there; and one small prospect on the Bader property, at the bend of the Copper Dick fault (Figs. 2 and 3), contains sufficient galena to be explored for that mineral. Hessite has been identified in one vein. Here and there the ore minerals seem predominant, but on the whole they constitute a relatively small part of the total vein filling. The usual gangue minerals include quartz—massive coarse-grained, and generally white, but tending in one direction toward a glassy variety and in the other direction toward dull-white "bull quartz"—and tourmaline, chlorite, actinolite, muscovite, and iron- and manganese-bearing calcite. The calcite belongs to two generations, the first accompanying the silicates and the second characteristically associated with the second generation of pyrite, though only minor amounts of the second generation of calcite and pyrite seem to be present. Minute threads of a second generation of chlorite locally cut the sulphides and other vein minerals. Epidote (pistacite), biotite, and orthoclase have been found locally and coarsely crystalline vein scapolite (Ma_{65} in composition) has been recognized in two veins, one cutting a lamprophyre dike in the heart of the stock and the other cutting a sill-prong of monzonite. Coarse-grained barite *is* abundant in a chalcopyrite prospect on the Bader property.

Most veins have a white albitized border about 2 feet or less wide, but other effects of wallrock alteration are vague. Where the veins lie in the metamorphic halo, the garnet and diopside beyond the albite border are weakly replaced by actinolite and the rock in general is somewhat mote strongly replaced by calcite and *is* variably pyritized. Where the veins cut the igneous rocks the alteration minerals beyond the albite border consist primarily of pyrite and a little calcite. A little jasperoidal wallrock was observed in the Bader area.

The mineralogy of the Sylvanite deposits indicates a hypothermal environment, and the vein scapolite, whose composition *is* identical with that of the scapolite in the metamorphic halo, suggests that the upper limit of the temperature range was near the temperature boundary between the hypothermal and pyrometasomatic types, pled by Lindgren [5] at about 600° C. The lowest temperature may have been as low as 150° C., as suggested by the tellurides, one of

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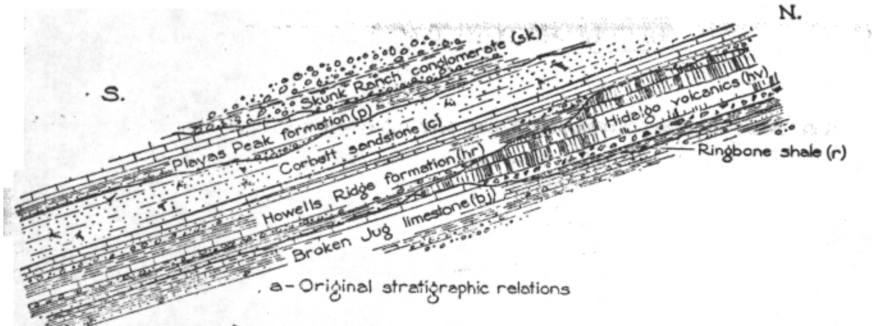
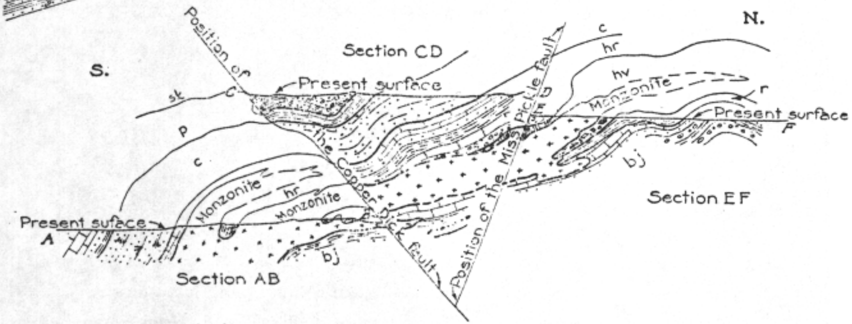
[5] Lindgren, Waldemar: Succession of minerals and temperatures of formation in ore deposits of magmatic affiliations, A. I. M. E. Tech. Publ. 713, pp. 10-11, 1936.

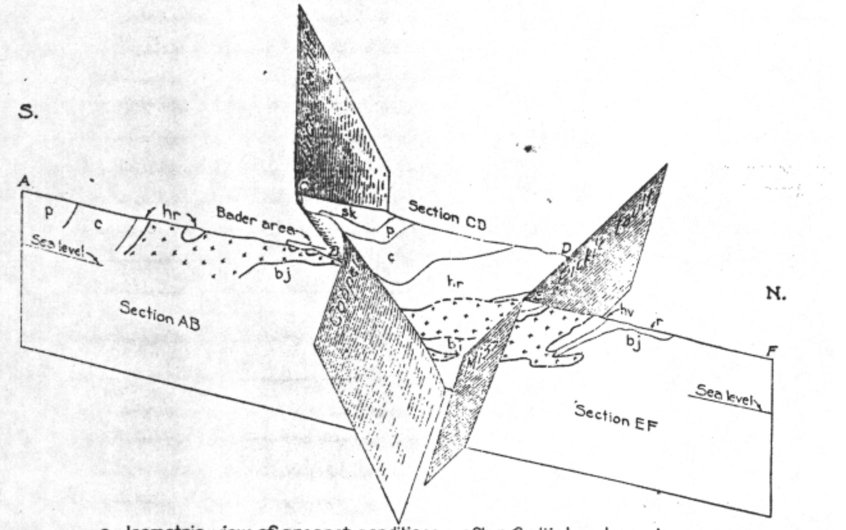
FIG. 3. Sequence of events in the development of the major igneous and structural relations in the Little Hatchet Mountains, New Mexico. Minor faults, Miocene (?) volcanic rocks, and alluvium not shown.



a – Original stratigraphic relations



b – After intrusion and before faulting



c – Isometric view of present conditions — after faulting and erosion

1 ½ 0 1 2 3 4 5 6 7 8 9 10 Miles

Horizontal and vertical scale for all parts which, hessite, Borchert [6] claims forms only between 150° and 184° C., though Borchert's figures remain to be verified. The minerals seem to form an orderly sequence, without any crowding of the different stages of deposition, and thus those veins that contain all minerals of the sequence presumably passed through almost the entire hydrothermal range of temperatures.

The general order of deposition is summarized in the left half of Fig. 4, the succession having been largely determined by field observations. The full succession, mineral by mineral, cannot be determined because there are too few places where the sequence can be studied adequately, but the diagram helps to present the general picture. It is strictly qualitative, the lines representing the different minerals being drawn long or short as may be necessary to show the known detail. Minerals whose position in the sequence is un-

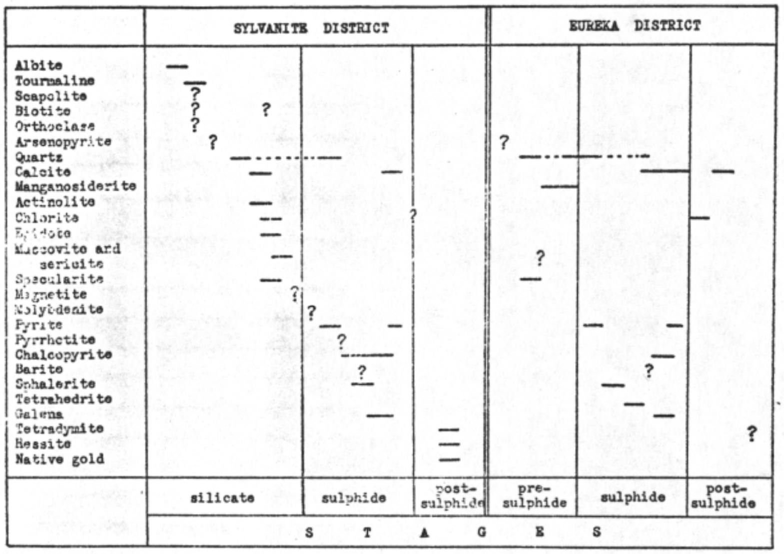


FIG. 4. Diagram showing mineral succession in the Sylvanite and Eureka mining districts, Little Hatchet Mountains, New Mexico.

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[6] Borchert, H.: Neue Beobachtungen an Tellurerzen. Neues Jahrb., BeilageBand 69-A, pp. 460-477, 1935.

certain are shown by a question mark, but there are many degrees of uncertainty and the use of a solid line for a few of the minerals indicates only a feeling of moderate assurance as to their proper position. Nevertheless, although the details of succession are not certain for all minerals, the general course of deposition is clear, and three stages characterized by particular mineral associations can be recognized. They are:

(1) The silicate stage, which may be separated into two substages—an albite-tourmaline stage and a quartz-calcite stage with most of the remaining silicates. The arsenopyrite may be intermediate between the two, because at the one place where relations are clear the arsenopyrite replaces albite-tourmaline rock but is veined by the white sub-glassy quartz. The little specularite and magnetite seem to belong to the silicate stage.

(2) The sulphide stage, which includes a little quartz, the barite and jasperoid of the Bader area, the second generation of calcite, and all the sulbhides except arsenopyrite.

(3) The telluride-gold stage.

Eureka District

The principal deposits of the Eureka district lie near the smaller of the two main monzonite outcrops, and the three productive shoots lie within the Broken Jug limestone at the same horizon as the monzonite. The combined production of the three shoots is about 55,000 tons of ore. One shoot was an oxidized lead-zinc replacement deposit about 3,000 feet south of the monzonite and a little beyond the metamorphic halo, one was on a short vein that cuts both the monzonite and the metamorphosed limestone, and one was on a vein about 1,000 feet north of the monzonite. Other veins crop out, elsewhere in the sediments, in the metamorphosed rocks, in both masses of the monzonite, and in the Hidalgo volcanics. All these deposits lie within a band 1 to $1^1/_2$ miles wide that encompasses all exposures of the monzonite and that parallels the general trend of the formations. The band extends northwestward from the main part of the district to include a few short veins about 2 miles beyond the monzonite, and southward to include some scattered prospects north of the Miss Pickle fault and a few stringers a little north of the Copper Dick fault.

The veins are similar in size to those of the Sylvanite district. Of the two that contained productive shoots one *is* traceable as a zone of several discontinuous or overlapping members for about 2,000 feet and the other *is* traceable for about 1,000 feet. The width of the stopes on these veins averages about 3 or 4 feet.

In general the deposits contain mixed sulphides in a manganosiderite gangue. Galena and sphalerite are the most abundant sulphides. Pyrite is general, arsenopyrite is common in two veins, and tetrahedrite is common locally. Chalcopyrite is sparse. Minor amounts of .specularite are present over most of the area. Tetradymite has been found in one prospect pit. The pyrite belongs to two generations and in age relations, mineralogy, and relative gold-silver content is identical with the two generations of pyrite in the Sylvanite ores. *As* in the Sylvanite ores, the second-generation or pyritahedral variety is intimately associated with calcite that belongs near the end of the sulphide stage. A second generation of calcite, the familiar scalenohedral variety, fills fault fissures that offset the sulphide-bearing veins, and velvety globules of chlorite accompany this variety. Quartz, most of which has a tendency to be milky and some of which *is* distinctly so, *is* widespread. Some veins, and particularly the tight parts between ore shoots, contain mostly quartz and the first-generation pyrite. Fine-grained barite *is* present here and there. In one of the arsenopyrite-bearing veins the arsenopyrite is embedded in a compact massive sericitic material of pale green color and very fine grain. Stringers that contain similar sericite, quartz and specularite cut altered country rock in an isolated area in which a fairly large volume of the rock has been impregnated with sericite, quartz, and specularite. A part of the quartz in these stringers resembles the white quartz of the Sylvanite district and a part the customary milky quartz of the Eureka district. Nearby, an insignificant isolated stringer contains muscovite in flakes fully half an inch across.

The wallrock alteration of the Eureka deposits, although much stronger than that of the Sylvanite veins, is nevertheless weak. Most veins have a silicified jasperoid selvage, and elsewhere the vein walls are replaced by manganosiderite, sericite, and calcite, accompanied by a few grains of pyrite and some hydrothermal quartz. The width of the jasperoid selvage is measurable only in inches, however, and the maximum width of the zone in which alteration of any kind is complete seems to be less than two feet.

The mineralogy of the Eureka deposits indicates that, in the main, they are mesothermal, despite the meagerness of wall-rock alteration. The wide distribution of specularite suggests that moderately higher temperatures prevailed at an early stage, and the scalenohedral calcite indicates a general cooling down to low temperature conditions at the close of the mineralization period. [7] The arsenopyrite in two of the veins, the muscovite in one stringer, and the little glassy quartz presumably indicate the uppermost reaches of underlying hypothermal conditions.

The right half of Fig. 4 summarizes the general order of deposition for the minerals of the Eureka deposits. The general remarks given for the Sylvanite half of the diagram also apply to the Eureka half. Three stages of deposition analogous to the stages for the Sylvanite district can be recognized. They are:

(1) A pre-sulphide stage, which includes arsenopyrite, muscovite, sericite, specularite, manganosiderite, and white quartz resembling that of the Sylvanite district. This group of minerals suggests the late phase of stage 1 of the Sylvanite ores, the position of the first generation calcite of the Sylvanite ores being roughly occupied by manganosiderite in the Eureka ores.

(2) A sulphide stage whose gangue minerals include milky quartz, barite, and the first generation of calcite.

(3) A past-sulphide stage, which includes the scalenohedral calcite, the associated chlorite, and perhaps the tetradymite.

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[7] Schaller, W. T.: The crystal cavities of the New Jersey zeolite region. U. S. Geol. Surv. Bull. 832, p. 47, 1932.

Among the details of paragenesis the similar positions of calcite, chlorite, and pyrite in the Eureka and Sylvanite assemblages may be emphasized, as each of them was formed at two different stages. The first-generation calcite of the Sylvanite district, an iron- and manganese-bearing variety, may be considered analogous, *as* mentioned above, to the manganosiderite of the Eureka district. In general, if the Eureka half of the diagram is super-imposed on the Sylvanite half, the two districts show not only analogous stages of deposition but also analogous positions of the minerals.

CONSIDERATION OF THE PROBLEM.

Summary of the Evidence

The several pertinent facts mentioned in the preceding descriptions may be summarized as follows:

(1) The entire sedimentary section, averaging close to 19,000 feet in thickness, has been duplicated by the Copper Dick fault, so that essentially the same sequence now crops out in the south part of the range as in the north part..

(2) Each of the fault blocks contains a center of mineralization — the Eureka district in the north block and the Sylvanite district in the south block.

(3) The ore deposits of each district are associated with and clustered in and around a monzonite mass.

(4) The two monzonite masses crop out in the same stratigraphic position, namely, at and near the disconformity at the top of the Broken Jug limestone.

(5) Each monzonite mass is parallel in cross-section with the enclosing sediments and hence may be expected to continue, nail-like for a greater or lesser distance, along the same general stratigraphic position in which it now crops out.

(6) The main stage of faulting along the Copper Dick and associated faults occurred after the monzonite was emplaced and the ore deposits formed.

(7) The deposits of the Sylvanite district are basically hypothermal whereas those of the Eureka district are mesothermal.

(3) The Eureka deposits contain small quantities of minerals that are characteristic of the Sylvanite hypothermal deposits, and the Sylvanite deposits in turn contain small quantities of minerals that are characteristic of the Eureka mesothermal deposits.

(9) The deposits of the two districts exhibit three analogous stages of mineral deposition and resemble one another in a number of details of mineralogy and paragenesis, particularly with respect to the minerals that were deposited during two stages.

These nine items may be grouped under three headings—(a) the structural evidence, which includes items 1 to 6; (b) the petrographic evidence, which includes only item 3; and (c) the mineralogic evidence, which includes items 5, 7, 8, and 9. Each class of evidence is separately discussed and interpreted in the following pages.

Structural Evidence

The significance of the structural evidence may best be investigated by restoring the different parts of the range to the relative positions they held before faulting.

Section **AB,** Fig. 2, has been selected to show most clearly the relations between the Sylvanite stock and the enclosing sediments. Because of the Copper Dick fault, the original northward continuation of the plane of this section now occupies approximately the position **CD** and similarly its continuation beyond the Miss Pickle fault now occupies the position **EF,** the negligible effect of the hanging-wall spur of the Copper Dick fault and of the parallel fault along the syncline axis being ignored. Geologic sections have been drawn along the lines, **AB, CD,** and **EF,** and these when joined end to end show the geology of the range prior to faulting. The composite section is reproduced as part (b) of Fig. 3, which as a whole shows the sequence of main events leading to present conditions. In joining the sections, the question arises as to how far one is justified in projecting the igneous masses beyond their observed relations, as stated in item 5 of the list of evidence. As indicated in section **AB,** the Sylvanite mass splits near the present surface into three main sill-like members, and the size and distribution of the visible parts of the stock suggest that at least the central and largest member should extend, without appreciable thinning, somewhere into the block between the Copper Dick and Miss Pickle faults. For section **EF,** across the Eureka district, it is believed that the monzonite mass may be conservatively projected below the surface, along the same stratigraphic horizon in which it now crops out, for about half its outcrop length, or for about 5,000 feet. When this is done the Eureka mass is brought so close to the Sylvanite mass that it would seem on this structural evidence alone that the two should be connected.

The alternative to this interpretation is that neither igneous body can be safely projected sill-like for any appreciable distance beyond its observed relations and that consequently the Sylvanite and Eureka monzonites must be separate intrusives. That alternative, however, has nothing in its favor beyond the present separate position of the outcrops. Moreover, it must rely upon the same fundamental idea as the other interpretation, and to a greater degree and with less justification, to explain existing structural conditions, namely, that a cross-cutting igneous mass rising from below found it easier to stream out along the bedding at a particular horizon than to cut across it. Under the one interpretation the sill-like streamer was large-7,000 feet thick in what is now the Sylvanite district—and it advanced upward and northward along the disconformity between the Broken Jug and Howells Ridge formations and forced its way into the comparatively unified mass of the Hidalgo volcanics when it encountered the wedge of that formation (Figs. 3a, 3b). Under the other interpretation this mass is denied the ability to extend much beyond the position of the Sylvanite district, yet a separate massy about one-fifth as large is permitted to rise through and across the weak horizons of the Broken Jug limestone in the Eureka district and—more improbably still—across the Ringbone shale and its upper and lower contacts and then, for no justifiable reason, to adopt a sill-like attitude in the heart of the Hidalgo volcanics.

Petrographic Evidence

All that has boon stated thus far about the petrography of the two stocks is that both are composed of monzonite and are petrographically similar. Further details, which relate to the character of the plagioclase, may be considered here.

In the smaller of the two main outcrops in the Eureka district the plagioclase *is* andesine, sodic in some grains and zoned about An32-42 in others. The larger mass is intensely altered and few of the plagioclase grains remain fresh enough for identification, but in some specimens both andesine (about An$_{40}$) and oligoclase (about An$_{15}$) were recognized, and in one specimen was found a phenocryst of andesine (An$_{39}$) partly replaced by oligoclase (An$_{14}$). In other specimens, too altered for precise determinations, the plagioclase includes some grains having all indices greater than that of balsam and therefore presumably andesine or calcic oligoclase, and other grains having some indices less than that of balsam and therefore sodic oligoclase or albite. In some small outliers near both masses the plagioclase is albite (about An$_{2}$) instead of andesine or oligoclase.

In the monzonite at Sylvanite some plagioclase grains consist wholly of intermediate andesine, and some are zoned from labradorite or andesine outward to sodic oligoclase. In some of the zoned crystals veinlike threads of composition An$_{20}$ extend from the outer oligoclase zone into the andesine core and replace it. Elsewhere in the stock there are a few spots in which the plagioclase *is* close to pure albite.

Presumably the replacement by oligoclase in some parts of the monzonite and the replacement by albite in others are the results of the same or related processes. If so, the oligoclase and albite are hydrothermal, for geologists seem generally agreed that essensentially pure albite is never pyrogenetic. hydrothermal oligoclase, however, is unusual, at least insofar as it has been recognized and described, and this unusual feature constitutes the main petrographic evidence in considering the relation between the Sylvanite and Eureka monzonite bodies.

It is not contended that the presence of the same unusual feature in two stocks of similar composition proves that the two are any more closely related than now outwardly appears, for it might be expected that two igneous bodies in the same neighborhood and of the same geologic age would be similarly altered, even if the altertion is an unusual type. On the other hand, if the Eureka and Sylvanite stocks were originally continuous, then the Little Hatchet

Mountains offer another example of the process, now generally accepted as common, in which altering solutions have accumulated in the topmost part of an intrusive body, the scattered albitic and oligoclasic parts in the Sylvanite exposure indicating the roots of the altered portion.

Mineralogic Evidence

The mineralogic similarities and differences between the Eureka and Sylvanite deposits are summarized in Fig. 4, the paragenesis di-

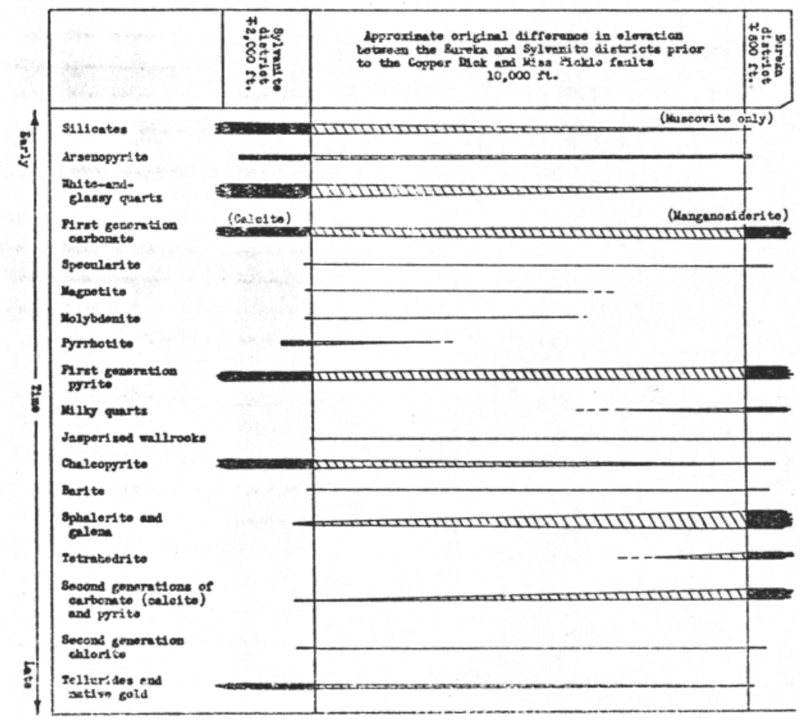

FIG. 5 Diagram showing original vertical zonal relations between the Eureka and Sylvanite districts, assuming that the monzonite of the two districts was originally continuous. Vertical distances ascribed to each district indicate range in which the deposits are exposed by topography and mining operations; vertical distance between the two districts is scaled from Fig. 3 (b). Length of solid lines indicates relative general distribution, and width of lines indicates relative importance.

agram, and in Fig. 5, which correlates them with the structure. The relations thus shown are interpreted as the natural interfingering of mesothermal and hypothermal zones—the muscovite, arsenopyrite, and glassy quartz of the Eureka district indicating the uppermost reaches of the Sylvanite hypothermal zone, and the sphalerite, galena, and second-generation calcite, pyrite, and chlorite in the Sylvanite veins, as well as the jasperoid at one place, indicating the lowermost reaches of the Eureka mesothermal zone. It may be significant that the strongest mineralization of the mesothermal type in the Sylvanite district is in the Bader area, which wa,3 originally closer to the Eureka country than any other point of the Sylvanite district (Fig. 3 (c)).

This zonal interpretation is based upon the assumption that the original continuity of the monzonite in the Eureka and Sylvanite districts has been demonstrated. On the other hand, similarities in paragenesis and mineralogy may be expected in neighboring districts of the same geologic age and of similar igneous affiliations—and it is probably a matter of opinion how far such similarities may go before they may be considered significant.

GEOLOGIC CONCLUSIONS.

The structural evidence seems strongly to favor the interpretation that the Eureka and Sylvanite districts were at one time geologically continuous, having been torn apart and brought to their present positions by the Copper Dick and related faults. The petrographic and mineralogic evidence, on the contrary, is inconclusive, as independently appraised, for it permits either alternative interpretation. When considered together, however, the three types of evidence seem to support one another so well in favor of the idea that the two districts were originally continuous that this interpretation is accepted as being by far the more probable.

The final conclusion, then, is that prior to faulting the monzonite of the Sylvanite and Eureka districts formed a single intrusive body, sheathed by a contact-metamorphic halo, that lay parallel with the bedding of the sediments for a distance of 7 miles or more at and near the top of the Broken Jug limestone. The three-dimensional shape of this reconstructed mass, to ignore details of outline, was that of a gigantic horseshoe nail, tapering from a thickness of about 7,000 feet and a width of 4 miles or more in what is now the Sylvanite district, to a thickness of about 2,500 feet and a width of 2 miles in what is now the Eureka district. Figs, 3 (c) and 6 show the inferred present extent of what is now left of the mass, after faulting and erosion.

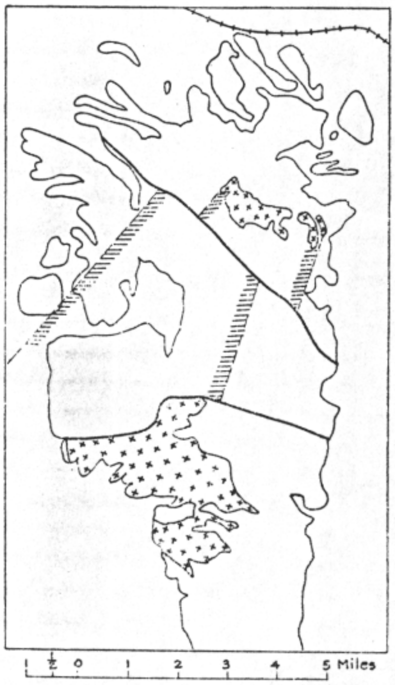

FIG. 6: Outline map of part of the Little Hatchet Mountains, showing the monzonite outcrops and the inferred approximate subsurface limits (shaded lines) of what is now left of the originally continuous nail-like mass.

The ore deposits are confined to this nail-like mass and to the country rock within a short distance of the contact, and they gradually change northward from the type characterizing the Sylvanite district to that characterizing the Eureka district. To judge from the deposits now exposed, the productive part of the ore zone would seem to lie within the invaded rocks, in an elliptical jacket that extends not more than 1,000 feet from the floor or roof of the igneous body and probably *less* than a mile from the ends.

PRACTICAL CONCLUSIONS

From the standpoint of the miner, the important fact *is* that, prior to faulting, the Little Hatchet Mountains contained an ore zone of limited thickness and width that *is* restricted, like a bedded deposit, to a particular stratigraphic position and in which the ores change along the length of the zone from those in which native gold *is* the principal mineral of value and in which few sulphides are present to those characterized by base-metal minerals containing only a trace of gold but appreciable silver.

Two immediate practical conclusions may be derived from that interpretation: first, that the mineralized country of the Eureka district should pitch southward until cut off by the Miss Pickle fault; and second, that the Miss Pickle-Copper Dick fault block should contain a hidden mineralized zone. However, more important to the miner than the existence of new prospecting ground are the depth to the ore zone, the character and richness of the probable ore, the structure and persistence of the veins, and the probable size of the ore bodies.

The approximate depth to the ore zone at any place can be estimated from the subsurface limits of the monzonite and from the structure of the formations. Thus, the main part of the Eureka zone, which crops out on the under side of the monzonite, should strike the Miss Pickle fault at a depth of the order of 5,000 feet In the Miss Pickle-Copper Dick fault block the depth to the ore horizon is probably variable because of the synclinal attitude of the formations; it probably becomes progressively greater from east to west as the ore zone pitches westward with the formations, and progressively greater from the Miss Pickle fault toward the Copper Dick fault (Fig. 3). The depth to the top of the productive part of the ore zone, which is assumed to extend not more than 1,000 feet above the roof of the monzonite, is estimated to range in this fault block from about 2,000 feet at the east edge of the monzonite (see Fig. 6) to perhaps over 10,000 feet at the west edge. Some small showings of galena and pale sphalerite that crop out in the Hidalgo volcanics in the Miss Pickle-Copper Dick fault block apparently indicate the frayed outcropping edge of the pitching ore zone.

The character of the ores may be deduced from the zonal picture; they should contain the minerals of the central block of Fig 5 and, therefore, should be argentiferous base-metal deposits containing also tellurides, native gold, and arsenopyrite in a gangue of carbonates, quartz, and, toward the Sylvanite end of the zone, silicates. Their tenor is impossible to predict. The veins are likely to be similar in structure and persistence to those of the present Sylvanite and Eureka districts, because all were formed under similar structural conditions. Since the deposits were scattered through such a great volume of rock—the ore zone had a length of 8 miles or more, an average width of about 5 miles, and an average thickness of about 7,000 feet, a total volume of 50 cubic miles or more-most shoots may be comparatively small, similar in size to those thus far discovered, but, in view of the fact that some limestone replacement deposits are known to have been formed, there is always the possibility that conditions at some place along the ore zone were right for the formation of replacement deposits of first magnitude.

Concerning future prospecting in the mineralized areas of the Sylvanite and Eureka districts as now known, nothing conclusive can be inferred because of the shallow depths to which the deposits can be examined. The zonal interpretation suggests that the native gold and tellurides of the Sylvanite veins will decrease at a relatively shallow depth, and inasmuch as no commercial shoot of gold ore has yet been developed, deeper exploration for gold should be undertaken only with a full appreciation of the commercial risks involved. For the Eureka district, it is probable, on the basis of present knowledge, that any new shoots found will be of similar size to the three shoots already developed, which have yielded from about 10,000 to 25,000 tons each and which had a maximum gross value of about $500,000 per shoot. It is not certain, however, that these shoots have been worked out; prospecting recommendations concerning some of the mines in the Eureka district will be included in the full report on the Little Hatchet Mountains, and if the suggested exploration should show the shoots to be larger than now supposed, these figures can be modified accordingly.

Other conclusions would follow if the Eureka and Sylvanite districts represent separate centers of intrusion and mineralization. Foremost among them would be that the part of the range between the two districts is as barren as has been supposed, instead of containing mineralized ground somewhere below the surface, and that future prospecting should be confined to the immediate vicinities of the monzonite exposures. Considered by themselves, the main prospects of the Eureka district are promising, and it might reasonably be concluded that solutions still carrying such quantities of ore when they reached the Cretaceous rocks of the range would have deposited much greater quantities where they crossed the Pennsylvanian and lower Paleozoic limestones at greater depths. The Pennsylvanian limestones, where observed locally in the Big Hatchet Mountains, the next range south, seem to be fairly thick and highly charged with organic matter, a fact that makes this interpretation attractive; but the field work thus far completed in the region fails to give any hint as to how deeply the Paleozoic formations lie in the Little Hatchets. A feasible place to determine that depth in the Eureka district by drilling would be at the edge of the bedrock pediment in sec. 31 of T. 27 S., R. 15 W. In the Sylvanite district the outlook would remain unchanged, because in any event the depth to the Paleozoic formations near the monzonite must be several thousand feet.

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