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Item 44

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GEOLOGY AND MINERAL RESOURCES

OF

TOWNSHIP 34 NORTH

RANGES 39 AND 40 EAST

MOUNT DIABLO BASE AND MERIDIAN

HUMBOLDT COUNTY, NEVADA

Geology and Report by:

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INTRODUCTION

Township 34 North, Ranges 39 and 40 East, MDBM., Humboldt County, Nevada, is located seven miles south of Golconda, a rail point on the westbound line of the Southern Pacific.

A portion of the northwest part of the eastern township is not included on the geologic map, No. R 3940-34, and only Sec. 36 of the western township is shown. The south end of the Edna Mountains is in the northeast and central portions of the eastern township, and a part of the rugged west flank of the Sonoma Range is located in the southwest part of the east township and on Section 36 of the west township. This portion of the Sonoma Range is in the Gold Run (Adelaide) mining district.

CONCLUSIONS

Twp. 34N., Rge. 39E.

No Company ownership.

Twp. 34N., Rge. 40E.

Mineral Rights Only Owned by Southern Pacific Company

Sections 1, 3, 9 (E½), 11, 13 (except N½SW¼), 15, 23, 27, 31 (W½SW¼ and SW¼NW¼), and 33 . . . . Nonmineral.

Section 9 (W½) . . . Prospective mineral. Potential scheelite in tactite zone.

Section 29 (E½) . . . Prospective mineral. Potential southern extension of ore deposits from Adelaide mine area where copper-lead-zinc have been produced from southerly trending limestone replacement zones; and potential auriferous gravel deposits in major stream channels.

Section 31 (S½SE¼ and E½SW¼) . . . Potential mineral. Potential lead-zinc-silver deposits in veins along southern extension of Adelaide Crown fault system.

Section 33 . . . Potential mineral. Potential auriferous gravels in stream channels in alluvial fans.

TOPOGRAPHY AND ACCESSIBILITY

The topography, road systems, trails and accessibility are shown on geologic map, No. R 3940-34, which covers this area. The regional setting may be ascertained by inspecting the Winnemucca, Nevada (NK 11-11) topographic sheet of the Army Map Service, Corps of Engineers, published by the U.S. Geological Survey in 1958 at a scale of 1:250,000. Access to the area is provided by a graded gravel road which connects with U.S. Highway 40 at Golconda.

MINERAL RESOURCES-EXAMINED

Metallic Deposits

Lead, Zinc, Silver Potential on Southern Pacific Land

The $S\frac{1}{2}SE\frac{1}{4}$ and $E\frac{1}{2}SW\frac{1}{4}$ Sec. 31 are on the trend of the Adelaide Crown vein, which has produced base metal sulphide ore to the south on the Hot Springs claim ($NW\frac{1}{4}$ Sec. 5, T.33N., R.40E.) and to the northwest at the Nevada Lead mine near the north line of Sec. 31. No valuable minerals were observed at the few prospect pits in the Company-owned portion of Sec. 31, however.

On the basis of projection of a mineral trend, the $S\frac{1}{2}SE\frac{1}{4}$ and $E\frac{1}{2}SW\frac{1}{4}$ Sec. 31, T.34N., R.40E. has some potential for sulphide ore associated with a westerly dipping normal fault fissure of Tertiary age. The maximum length of such a potential vein deposit is 1,500 feet on Sec. 31.

The country rock is hornfels of the Preble formation of Cambrian age, which is the same host which contains the sulphide metal deposits in Sec. 5 of the township to the south and which forms the hanging wall of the mineralized fault at the Adelaide Crown mine three miles to the northwest. The southwest one-half of this 40 acre tract is composed of coarsely crystalline alaskite with an estimated 25 per cent quartz, which is a portion of an intrusive igneous complex of Cretaceous or Tertiary age.

Scheelite Potential on Southern Pacific Company Land

In the W½ Sec. 9 of the eastern township, the low rounded hills contain two tactite zones, both of which strike about N.20°W. and are several hundred feet long. The western tactite zone appears to be the most highly mineralized of the two and is up to 120 feet wide on Sec. 9, and perhaps twice this wide on the hilltop to the west in Sec. 8.

The tactite zones are grayish green to tan and are composed essentially of epidote and garnet. Locally, there is considerable coarsely crystalline calcite which may represent recrystallized limestone of the Preble formation. The tactite was sampled across 120 feet of width, but ultraviolet light failed to show any scheelite crystals in this sample.

The country rock is hornfels ("welded" phyllite) of the Cambrian Preble formation. Thermal metamorphism resulting from the heat of a buried igneous intrusive mass was undoubtedly the cause for the welding and recrystallization of the phyllite to hornfels. The intrusive mass is exposed along the west flank of the Edna Mountains across the valley from the tactite zones and probably underlies the tactite at shallow depth. It is nowhere exposed in the vicinity of the tactite, however.

Auriferous Gravel Potential on Southern Pacific Company Land

All streams that drain the Adelaide mining district contain potential deposits of auriferous gravels. Many of these have been worked for placer gold and some have been worked extensively (S½S½ Sec. 8, immediately west of mapped area). Potentially, the easterly trending stream channels which cross Sec. 29 in the extreme north and south parts of the E½ of this section contain auriferous gravels. The alluvial fan in the eastern 2/3rds of Sec. 33 may contain placer gold in buried stream channels which built this fan.

Gold, Silver and Base Metal Deposits on Property Not Owned by the Southern Pacific Company

The portion of the Sonoma Range shown on the geologic map, No. R 3940-34, is within the Adelaide (Gold Run) mining district, which has been an important source of gold, silver, lead, zinc and copper. These deposits are contained for the most part in veins which strike northerly and dip west associated with Tertiary normal faults, and are found at numerous places in Secs. 18, 19, 20, 29, 30 and 31 of the eastern township.

Gold and silver production was greatest from the Adelaide Crown workings in the W½W½ Sec. 19, while base metal sulphide ores were mined largely from the Adelaide mine in the SE¼ Sec. 20, the Nevada Lead mine in the NE¼NW¼ Sec. 31, and in the south-central portion of Sec. 19 and north-central portion of Sec. 30. Placer gold has been worked extensively in Sec. 8 (off the mapped area) and less extensively along Gold Run Creek in Secs. 20 and 28 and along a tributary to Gold Run Creek in the north-central portion of Sec. 20.

The Adelaide (Gold Run) mining district is geologically complex as it contains Paleozoic rocks within at least two separate thrust sheets of Paleozoic age which have been displaced by Tertiary normal faults. The Carboniferous (?) Leach (?) formation occurs in the lower plate of the lowest thrust (Gold Run), and the Cambrian Preble formation is in the upper plate of this thrust. The Preble formation has been overriden by the Ordovician Valmy formation along the Adelaide thrust. The main hanging wall of the Adelaide Crown vein, which is the westernmost mineralized fault in the district, is composed of the Preble formation which has been dropped down into juxtaposition with Leach (?) formation. This fault and several subsidiary faults in the footwall are marked by steeply dipping, brecciated quartz vein up to 20 feet wide. Both the Leach (?) and the Preble formations are hosts to the metallic mineral deposits, but no mineral deposits of any consequence were observed in the Valmy formation of the upper thrust plate.

Scheelite on Property Not Owned by the Southern Pacific Company

Scheelite in very minor amounts occurs in an 8 to 20 foot wide tactite zone between granodiorite of Cretaceous or Tertiary age and limestone of the Pennsylvanian to Permian Havallah formation. This tactite is located in the S½NE¼ Sec. 22 of the eastern township. An open cut has exposed nearly pure garnet of dark amber brown within the tactite in a replacement zone up to 12 feet wide. The garnet is euhedral, coarsely crystalline, and contains some epidote.

Molybdenite and Copper on Property Not Owned by the Southern Pacific Company

At two places in Sec. 13 and in the SE¼SE¼ Sec. 14 of the eastern township, traces of oxidized copper minerals and scattered molybdenite crystals occur in gently dipping quartz veins. Country rock is Cretaceous or Tertiary granodiorite and pyroxene-rich metavolcanics of the Carboniferous (?) Pumpernickel formation. Minerals observed in the quartz veins, which are less than 1 foot wide, include chrysocolla, malachite, azurite, chalcopyrite, garnet, epidote and molybdenite. The latter occurs in silver gray hexagonal crystals up to 0.4 inch in diameter with a metallic luster, greasy feel and perfect micaceous (basal) cleavage.

Nonmetallic Deposits

No nonmetallic deposits of present or potential commercial value were observed on Southern Pacific Company property.

Nonmetallic deposits observed on lands not owned by the Southern Pacific Company include the garnet described above and a white, bladed carbonate mineral, probably either strontianite or aragonite, which occurs in the steep hillside immediately south of the garnet and scheelite in Sec. 22.

Construction Materials

The only construction materials observed on this township are sand and gravel deposits contained within the older alluvium and alluvial fans. These materials would depend upon development of local demand before they would have any economic value.

Water Resources

None of the streams of the mapped area are perennial, although portions of Goldrun Creek probably contain flowing water throughout most of the winter months. Water stands in all of the prospect trenches (placer gold) along this creek throughout the year. All of the idle workings of the Adelaide Crown and Adelaide mines are flooded. The water stands within a few feet of the surface in most of these workings. It is reported that such a flow of water was encountered in the Adelaide mine workings that the pumps could not handle it (Gregory Andrews, caretaker at Adelaide Crown mine, oral communication). Quality of the water and economic factors permitting, it may be possible to obtain water for agricultural purposes from the old mine workings.

The only water well observed in the mapped area is at the Tucker Ranch in the center of the N½ Sec. 35 of the eastern township. According to the foreman at the ranch, the well has a pumping capacity of 1,300 gallons per minute. No other data regarding performance, depth to water-bearing strata, etc. are available for the well, which appears to be ideally located in respect to recharge from Goldrun Creek. The well pumps from the valley fill materials of Pumpernickel Valley.

MINERAL RESOURCES-COMPILED

Metallic Deposits

There has apparently been no production of metallic minerals from lands presently owned by the Southern Pacific Company.

Production of Copper, Lead, Zinc, Gold and Silver from Gold Run District

According to Ransome (1909, p. 62) the Gold Run district, located in the southwest part of the mapped area, was organized in 1866. Lincoln (1923, p. 99) states:

> "From 1908 to 1920, the district (Adelaide or Gold Run) produced 23,583 tons of ore, containing $75,364 in gold, 65,206 ozs. silver, 812,841 lbs. copper, 297,883 lbs. lead, and 1,700 lbs. zinc, valued in all at $349,942 according to Mineral Resources, U. S. Geol. Survey."

Vanderburg (1938, p. 26) gives the value of production between 1907 and 1936 as $567,402, mainly in gold, silver and copper.

The Adelaide Crown area is located about two miles west of the original Adelaide mine and was not developed until 1920, according to Ferguson, Muller and Roberts (1951). Part of the production recorded by Vanderburg above may have come from the Adelaide Crown area. A cyanide mill was erected at the property in 1938 and production continued until 1941 (Ferguson, et al., 1951). The mill is still on the property. The ore blocked out in 1938, was reported to run $4 to $5 per ton in gold and silver (Vanderburg, 1938, p. 27).

Ransome (1909, p. 62-64) describes the Adelaide mine workings, mineralization and milling facilities:

> "No attempt was made in this reconnaissance to study their lithology or structure (of the rocks of this portion of the Sonoma Range) except at the Adelaide mine, where they have been mapped as Star Peak Triassic by the geologists of the Fortieth Parallel Survey.
>
> This company (Glasgow and Western Exploration) built 12 miles of narrow gauge railway (in 1897) from Golconda to the mine and erected a smelter and concentrating mill at the junction of its road with the Southern Pacific railroad. This plant, consisting of two roasting furnaces and three reverberatory smelting furnaces, with the ordinary arrangement of crushing and concentrating machinery, was operated for a time on ores from Battle Mountain and from Adelaide, and some matter was shipped. The process, however, proved unsuited to the Adelaide ore and was abandoned. A few years ago the mill was remodeled and 120 concentrating tubes of the Macquisten type were installed. An interesting description of this remarkable plant has been given by W.R. Ingals ('"Concentration upside down"': Eng. and Min. Jour., vol. 84, 1907, pp. 765-770), and from this the reader may obtain some idea of the ingenuity, simplicity and effectiveness of this novel process, in which the heavy sulphides are floated off while the gangue minerals sink. Its total capacity was given as 120 tons in twenty-four hours. It produced when in full operation a 20 per cent concentrate from 2.7 per cent copper, leaving about 0.2 per cent in the tailings. The weakest point in the process appears to be in the relatively low recovery from the slimes.
>
> The main shaft of the Adelaide mine, 300 feet deep, is situated on the south side of Gold Run Creek, close to the site of the old settlement of Cumberland. The general country rock is dark calcareous slate, within which is a layer or series of beds of limestone from 50 to 75 feet in total thickness. This bed strikes north and dips 65°E. This limestone layer carries the ore, which in some places occupies the full width from one slate wall to the other, although as a rule the zone contains horses of altered limestone that is nearly free from sulphides. The ore body is undoubtedly large and has been extensively stoped above the 100 foot level for 400 feet without

> any indication of a diminution in size. Below this level, which is approximately at the bottom of the zone of partial oxidation, exploratory drifts have been run at vertical intervals of about 50 feet, revealing abundant ore. The bottom level was under water at the time of visit.
>
> The ore is a metasomatic replacement of the limestone and consists of pyrrhotite, chalcopyrite, sphalerite and a little galena, in a gangue of garnet, vesuvianite, diopside, calcite, orthoclase, and a very little quartz. Common pyrite is probably not altogether absent. As a whole the ore is of low grade, averaging about 3 per cent of copper; but the quantity available appears to be large, and the difficulties in the way of its successful concentration and treatment will probably soon be overcome.
>
> About 600 feet north of the main shaft, on the opposite side of the little creek, is a tunnel that runs north in the ore zone for 2,000 feet. For a distance of 500 to 600 feet from the portal the tunnel is in ore. Beyond this the limestone zone is generally lean or barren ... "

According to Tickell (1918, p.3), the ore mined at the time of his report averaged 5.75 per cent copper, $2.00 per ton in gold and 6 to 7 oz. per ton of silver. Tickell further states:

> "On the 300 foot level the ore-body is displaced by a fault whose plane is normal to the plane of the dip. So far the operators have been unsuccessful in finding the faulted portion of the ore-body and the problem seems to be that of determining whether the fault is normal or reversed.
>
> When the property was examined December 15, 1917, the company was working about 20 men and hauling 30 tons of ore per day to Golconda from where it is shipped to a smelter."

Vanderburg (1936, p. 91) states in regard to the placer mining in the Gold Run district:

> "The amount of placer gold produced has been small. It is reported that in the early days some hydraulicking was done in the ravine below the Adelaide mine.
>
> The Bonanza, Gold Run, and several other small properties were worked by lessees in a sporadic manner from 1914 to 1922. The gravel was mined by sinking shafts and drifting along bedrock. Rockers were employed for recovering the gold. In the last three years there has been a little activity in the District, and rich gravel was being worked on one claim."

Nonmetallic Deposits

There has been no production of nonmetallic mineral deposits from Southern Pacific Company property. There is no evidence of any such production from any portion of the mapped area, either on the ground or in the literature.

Construction Materials

There is no evidence on the ground or in the literature of any production of construction materials except for minor local road building and concrete foundations.

GENERAL GEOLOGIC SETTING

Previous Mapping

The western 2½ tiers of sections of the mapped area are shown on the geologic map of the Winnemucca Quadrangle, Nevada (Ferguson, Muller and Roberts, 1951), and the remainder of the mapped area is on the geologic map of the Golconda Quadrangle, Nevada (Ferguson, Roberts and Muller, 1952). Both of these published maps by the U.S. Geological Survey are at a scale of 1:125,000, and represent the first serious attempt to map the areal geology of this extremely complex area in any detail.

The major differences in the interpretations of the areal geology as shown on the accompanying map, No. R 3940-34, and those of the published maps are as follows:

1. That portion of the area south of Gold Run Creek that was mapped as the Preble formation on the published maps was interpreted to be the Leach (?) formation on the accompanying map. These strata are distinct from the lithology of the Preble formation and are separated from the Preble strata by a thrust fault along Gold Run Creek. This

fault is herein called the Gold Run thrust and it carried the Preble formation of Cambrian age over the Leach (?) strata.

2. Strata designated as Edna Mountain sandstone and Antler Peak limestone on the published map were interpreted to be the Havallah formation on the present map (north flank of steep hill in Secs. 22 and 23).

3. Strata designated as the Havallah formation on the published map were interpreted to be the Leach (?) formation on the present map (low hills in S½ Sec. 28).

4. Location of the Golconda thrust was interpreted to be between the Leach (?) strata and overriding Pumpernickel chert in Secs. 27 and 28 of the present map rather than between the Edna Mountain and Antler Peak formations overridden by the Pumpernickel formation in Secs. 22 and 23 as shown on the published map.

5. No Osgood Mountain quartzite was observed by the writer. A portion of a highly siliceous, low mafic intrusive rock was mapped in the approximate position as shown to be the Osgood Mountain quartzite on the published map.

6. The intrusive mass in the Edna Mountains mapped as "granitic intrusive" on the published map does not cut completely across the mountains along the southeast-trending canyon in Secs. 13, 14, 23 and 24 as shown on the published map. The eastern portion of the mountains here is composed of pyroxene-rich metavolcanic rock, not granitic intrusive rock.

Summary of Geologic History

Paleozoic Rocks of the Cordilleran Geosyncline in North-central Nevada

Roberts, Hotz, Gilluly and Ferguson (1958) have published a "suggested synthesis of the Paleozoic history" of north-central Nevada. These men visualize three distinct sedimentary assemblages of pre-Late Mississippian age which were deposited in that portion of the Cordilleran geosyncline which extended for 335 miles west of Eureka, Nevada.

They postulate that throughout all of Paleozoic time prior to the Late Mississippian, miogeosynclinal conditions characterized by deposition of limestone and dolomite existed in eastern Nevada; eugeosynclinal conditions characterized by deposition of clastic rocks with large amounts of chert and volcanics existed in western Nevada, and a depositional environment which contained elements of both the eugeosynclinal and miogeosynclinal environments existed in north-central Nevada. Thus, three distinct assemblages of pre-Late Mississippian rocks were deposited in the Paleozoic geosyncline. These assemblages are termed "eastern", "western" and "transitional".

In the area under present consideration, the Preble formation is a representative of the transitional assemblage and is autochthonous (occurs at site of original deposition). The strata mapped as the Leach (?) formation appear to belong to the transitional assemblage when their lithologic character is considered. However, the true Leach strata of the East Range are considered to be part of the western assemblage by Roberts, et al. (1958). All of the other Paleozoic formations in the area of the present report are representative of the western assemblage and have been transported to this area (allochthonous) in the upper plates of overthrusts.

The Antler Orogeny

According to Roberts, et al. (1958), the Paleozoic rocks of Early

Mississippian and older were folded and thrust faulted during the Antler orogeny. These orogenic movements began in western Nevada during early Late Devonian times and culminated in the Roberts Mountains thrust fault of Late Devonian to Early Mississippian age. The Antler orogenic belt was 80 miles wide and extended north-northeast through central Nevada. Winnemucca is on the hypothetical west edge of the orogenic belt and a line through Mountain City, Carlin and Eureka marks the eastern edge. The Antler orogenic belt is another name for the Manhattan geanticline of Eardley. The Roberts Mountains thrust carried rocks of the western and transitional assemblages eastward over those of the eastern assemblage. The Adelaide and Gold Run thrusts in the area of this report were probably associated with this episode of thrusting.

Overlap Assemblage of Roberts, et al. (1958)

After the Roberts Mountains thrust fault occurred, coarse clastics of Middle Pennsylvanian age (Battle formation) were derived from the Antler orogenic belt and deposited in pronounced angular unconformity on the deformed rocks of the western and transitional assemblages. The unconformity at the top of the eastern assemblage is much less distinct and dies out farther east. The rocks of the overlap assemblage do not crop out in the area under present consideration, but include formations of Middle Pennsylvanian and Permian age which crop out in the northern part of Edna Mountains and in the Antler Peak quadrangle.

Major Orogeny of Permian Age

The rocks of western Nevada experienced severe folding during a major orogeny which occurred at some time during the Permian Period. The Permian and older formations of north-central Nevada were uplifted and gently warped during this orogeny.[1] These formations include the Ordovician Valmy, Carboniferous (?) Pumpernickel, Pennsylvanian and Permian Havallah formations, and possibly the Carboniferous (?) Leach (?) formation of the area of this report. The Pumpernickel and Havallah formations were thrust eastward in the upper plate of the Golconda - Tobin thrust during this orogenic episode.

<u>Compilation of the Geologic History</u>

For a summary of the episodes of the geologic history of north-central Nevada, the reader is referred to the township report for T.35N., R.41-42E., MDBM (Oesterling, 1959).

Cambrian Rocks of the Transitional Assemblage

<u>Preble Formation</u>

This formation was named by Ferguson, Muller and Roberts (1951) from Emigrant Canyon in the vicinity of Preble station in T.36N., R.41E. Here the formation is perhaps as much as 15,000 feet thick. According to Roberts, et al. (1958, p. 2826-2827):

> "The Preble consists of a lower brownish and greenish micaceous shale member, an intermediate limestone and shale member, and an upper shale member. Fossil collections range from early Middle Cambrian to early Late Cambrian."

It should be noted that no mention is made of argillite, chert or quartzite in the description of the Preble formation by Roberts, et al. Much of the outcrop belt south of the Gold Run Creek mapped as Preble formation by Ferguson, Roberts and Muller (1952) contains a considerable amount of argillite, chert and quartzite, and was interpreted to be the Leach (?) formation by the present writer. Except for the scarcity of

1 To be termed "Sonoma Orogeny" in a forthcoming publication by N. J. Silberling and R.J. Roberts (Silberling, oral communication, Nov. 30, 1959).

greenstone, the strata closely resemble the upper portion of the Leach strata of the East Range (see township reports for T.30N., R.36E., and T.31N., R.36E., by the writer).

According to the interpretations of the present writer, the Preble formation is contained within a thrust fault wedge between the superjacent Valmy formation which lies above the Adelaide thrust and the subjacent Leach (?) formation which is below the Gold Run thrust. The breccia zone of the latter thrust is well exposed in an incline adit driven into the south flank of the low rounded hill immediately north of the northerly workings of the Adelaide mine area. These workings are located near the west ¼ corner of Sec. 21. The upper portion of the hill is composed of the Preble formation and the lower portions, below the breccia zone, are made up of the Leach (?) strata of distinctly different lithology. The Adelaide workings are in the Leach (?) strata.

The Preble formation is considered by Roberts, et al. (1958, p. 2826) to be one of the transitional formations linking the western and eastern assemblage Paleozoic rocks. In the mapped area, the Preble strata are atypical in that they have been metamorphozed to hornfels or "welded " phyllite. The metamorphism was probably due to heat from a shallow intrusive mass, but such intrusive rock does not crop out in the mapped area.

The Preble hornfels is gray-gréen and tan, soft, with a fine-grained groundmass composed largely of chlorite and sericite. Scattered throughout the groundmass are porphyroblasts of coarse, dark green to gray metamorphic minerals, probably including cordierite. The porphyroblasts give the hornfels a spotted appearance. Original cleavage planes of the phyllite are generally apparent, but complete recrystallization prevents the possibility of physically cleaving the rock along any planes.

Ordovician Rocks of the Western Assemblage of Roberts, et al. (1958)

Valmy Formation

The Valmy formation was named by Roberts (1951) from outcrops in the north part of Battle Mountain. It contains grptolites of Early, Middle and Late Ordovician age (Roberts, et al., 1958, p. 2833). As postulated by Roberts, et al. (1958, p. 2832), the Valmy strata belong to the western eugeosynclinal assemblage and have been transported eastward in the upper plate of the Roberts Mountains thrust. This thrust occurred in Late Devonian or Early Mississippian time (Roberts, et al., 1958, p. 2813).

Valmy strata are limited to the extreme western edge of the mapped area. Trace of the Adelaide thrust, which limits the east side of the formation, trends generally northerly near the east township line of T.35N., R.39E. Subjacent to the Valmy rocks are strata probably correlative with the Cambrian Preble formation. Rhyolite porphyry of Tertiary age overlies the Valmy chert and quartzite in Sec. 36 of the western township.

The Valmy formation here consists largely of light gray, gray and black, vitreous to subtanslucent quartzite which is generally finely crystalline and contains interbedded black to dark gray chert. The outcrop area is typically fragmental with little continuity of bedding evident in most places.

Carboniferous (?) Rocks of the Western Assemblage of Roberts, et al. (1958)

Leach (?) Formation

Strata tentatively correlated with the Leach formation form about six square miles of the eastern flank of the Sonoma Range, largely south of Gold Run Creek. This area was mapped by Ferguson, Muller and Roberts (1951) as Preble formation, but the lithology is distinctly different from the Preble rocks. These strata resemble the Leach formation in that phyllite and limestone lenses occur in both, but they are distinctly different in that there is abundant chert, argillite and quartzite in the Leach (?) formation while these rocks are absent to rare in the Preble formation. Also, there is local greenstone in the strata mapped as the Leach (?) formation, and greenstone has not been recognized in the Preble strata.

The Leach formation was named by Ferguson, Muller and Roberts (1951) from Leach Canyon in the northeast corner of T.30N., R.36E. and the southeast corner of T.31N., R.36E. According to Roberts, et al. (1958, p. 2847):

> "No fossil evidence for dating the Leach formation has been founded * * *. For the present, the Leach can only be considered as Mississippian or older."

However, a Mississippian coral was found by Roberts and Silberling (Roberts, 1959, written communication) in beds mapped by this writer as the upper member of the Leach formation in Reed Canyon (west flank of East Range) in the southwest part of T.31N., R.36E. Roberts (oral communication) considers it distinctly possible that the limestone bed containing the coral is a thrust fault sliver belonging to an unnamed Late Mississippian formation observed in the Osgood Mountains and north part of the Hot Springs Range.

Throughout most of its outcrop area, the Leach (?) strata are poorly exposed. They compose rounded, float-covered slopes. However, these strata are excellently exposed in cuts along the access road to the Adelaide mine in the SE¼ Sec. 20 of the eastern township. Here slate, argillite and dark, platy limestone predominate.

In the poorly exposed areas the Leach (?) formation was mapped as undifferentiated argillite, chert, slate, conglomerate, limestone and greenstone. Argillite and black chert are the most common lithologies. Locally, limestone was mapped which is dark gray to black, finely crystalline, platy to medium-bedded, and weathers medium gray. Quartzite was mapped only in a single outcrop near the center of Sec. 31 of the east township. The gray, vitreous quartzite beds strike northeast and dip steeply to the southeast beneath a greenstone unit. The greenstone is grayish green, fine-grained, and weathers to thin plates, probably representing original flow banding. Phyllite was differentiated only at the south-central part of the eastern township (SE¼SE¼ Sec. 32). These strata are similar to the phyllite of the Preble formation but are generally less contorted. They are typically medium gray to dark gray, locally greenish gray, and have perfect slaty cleavage and the typical phyllitic sheen due to abundance of sericite.

The Leach (?) rocks are interpreted to form the lower plate of a thrust herein called the Gold Run thrust and the Cambrian Preble formation forms the upper plate of this thrust, which is probably associated with the Roberts Mountains thrusting of Late Devonian to Early Mississippian time. A younger thrust of probable Late Permian age has brought Carboniferous to Permian rocks over the previously described Paleozoic formations along the Golconda thrust. This thrust is inferred to trend northerly, separating the Paleozoic strata of the Sonoma Range from the Late Paleozoic formations of the Edna Mountains.

Pumpernickel Formation

The oldest rocks of the upper plate of the Golconda thrust are the Carboniferous (?) Pumpernickel formation named by Muller, Ferguson and Roberts (1951) from outcrops in the western township and farther south along both sides of Pumpernickel Valley. No fossils have been found in the formation, but it appears to be conformable beneath the Pennsylvanian and Permian Havallah formation (in excellent exposures in the west flank of Battle Mountain) and is, therefore, designated as questionably Carboniferous in age. Roberts, et al. (1958, p. 2846) consider the Pumpernickel formation to be of Mississippian age or older.

Roberts, et al. (1958, p. 2846) postulate the Pumpernickel formation is allochthonous, having been deposited in a eugeosynclinal environment in western Nevada and carried to its present site by large scale overthrusting along the Golconda thrust. The formation is largely fragmental in the mapped area, with few areas exhibiting continuity of bedding. Locally, the beds are closely folded.

The Pumpernickel strata are in thrust fault contact with the subjacent Carboniferous (?) Leach (?) formation near the low pass separating the Sonoma Range from the Edna Mountains and are in normal fault contact with rocks interpreted to be Havallah strata about one mile north of the south end of the Edna Mountains. Along the west flank of the Edna Mountains, the Pumpernickel rocks have been intruded by a granodiorite stock of Cretaceous-Tertiary age. To the southwest of the stock conglomerate, rhyolite and rhyolitic tuff of probable Miocene-Pliocene age overlap the Pumpernickel chert.

Pumpernickel rocks form the greater part of the Edna Mountains. The most common lithology of the Pumpernickel formation here is dark chert. This chert is dark gray, black, green and brown and locally contains a little metavolcanic rock of apparently basaltic composition. The chert is largely fragmental, but where there is continuity of bedding the chert is commonly contorted or dips steeply.

The next most abundant lithology of the Pumpernickel formation is heavy metavolcanic rock of andesitic to basaltic composition which has been thermally metamorphosed to a coarsely crystalline, pyroxene-rich metavolcanic rock. At first glance this dark green metamorphic rock appears to be a peridoite. Field relationships, however, show beyond doubt the true origin of the rock to be a result of recrystallization of metavolcanics. The intensity of recrystallization is inversely proportional to the distance from the granodiorite intrusive mass which has clearly invaded the metavolcanics. That is, the closer to the contact with the granodiorite the more complete the recrystallization. Within a zone perhaps 200 feet wide adjacent to the contact, the metavolcanic rock has been so completely recrystallized to pyroxene that it approaches a pyroxenite. This rock is composed of 75-80 per cent pyroxene porphyroblasts which are dark green and are ¼ to ½ inch long. Remainder of the rock is a fine to medium-grained groundmass of somewhat lighter green color. There is a gradual reduction in number of porphyroblast as the distance from the contact increases, and also a general reduction in size of the pyroxene crystals. The rock is distinctly porphyroblastic for several hundred feet from the contact and the zone of the thermal metamorphism is surprisingly wide. This may indicate that the surface of the subjacent granodiorite along the east flank of the Edna Mountains in Secs. 12, 13 and 24 is at shallow depth and is inclined gently toward the east at an angle only slightly greater than the present topographic slope.

The pyroxene-rich metavolcanic rock grades into meta-andesite and metabasalt, especially at the north end of the outcrop belt near the crest of the Edna Mountains in Secs. 1 and 12. The metavolcanics are dark brown, black and green, and finely crystalline. They are intercalated with dark colored chert. Farther north, in Sec. 1, chert and greenstone are intercalated. A similar association of chert and greenstone rocks was mapped in the SE¼ Sec. 23 near the south end of the Edna Mountains. In the latter area, a few limestone lenses occur with the chert and greenstone. The limestone is bluish gray and white, recrystallized, and is finely to coarsely crystalline. It contains some local unimportant tactite zones with light green epidote.

In the S½ Sec. 1, a narrow outcrop of hornfels trends north-northeast. This hornfels is dark brown to black and is fine-grained. It is probably the result of thermal metamorphism of local argillaceous strata of the Pumpernickel formation. In the extreme northeast corner of the mapped area, a northeast-trending outcrop of quartzitic sandstone was mapped. This rock is gray and tan, fine to medium-grained, and weathers dark brown and to smooth surfaces.

Pennsylvanian to Permian Rocks of the Western Assemblage of Roberts, et al. (1958)

Havallah Formation

This formation was named from the Havallah Range (Indian name for

Tobin Range) by Muller, Ferguson and Roberts (1951). A fusilinid fauna ranging in age from Middle Pennsylvanian to Leonard (Permian) is contained in the formation (Roberts, et al., 1958, p. 2848). A fern-like plant fragment collected by the writer from the formation in Sec. 23, T.32N., R.42E. on the east flank of Battle Mountain was identified by Axelrod (1959, written communication) as a Lepidodendron of probable Permian age.

Roberts, et al. (1958) postulate that the Havallah formation was deposited in western Nevada in a eugeosyncline and was carried into its present site by eastward movement of the upper plate of the Golconda thrust. The formation crops out along the lower slope of the steep mountain which forms the southern termination of the Edna Mountains in Secs. 22 and 23. Here it is in normal fault contact with dark chert of the Pumpernickel formation which composes the remainder of this mountain. Along an indefinite contact in Sec. 23, the Havallah strata are in depositional contact with the subjacent strata of the Pumpernickel formation. Another small outcrop of Havallah rocks was mapped along the crest of the Edna Mountains in Sec. 1. Here the Havallah strata are interpreted to be in both normal fault contact and depositional contact with the Pumpernickel formation. The Havallah rocks here are composed of interbedded sandstone and chert. The sandstone is light gray and white, fine-grained, calcareous, and locally quartzitic. The chert is gray, dark gray and tan.

The Havallah formation in Secs. 22 and 23 was largely mapped as undifferentiated Havallah formation consisting of interbedded chert, sandstone and limestone, largely poorly exposed and fragmental. Local limestone beds were differentiated which are recrystallized to gray and light gray marble. The lowermost marble bed on the steep north slope of the steep mountain in the E½ Sec. 22 has been replaced by a tactite zone from eight to twenty feet in width. This tactite contains, in some places, nearly pure, coarsely crystalline garnet up to 12 feet wide. Elsewhere, the tactite is composed of garnet with much epidote and some scheelite.

In the central part of the W½ Sec. 23, light gray and black chert crop out. The light colored chert distinguished the Havallah chert from the Pumpernickel chert. South and east of this chert is a narrow belt of sandstone which is white and light gray, fine-grained, calcareous, and locally quartzitic.

Cretaceous-Tertiary Intrusive Rocks

Granodiorite

Much of the west flank of the Edna Mountains within the mapped area is composed of medium gray, medium-grained granodiorite with an estimated 10-15 per cent biotite and scattered black hornblende crystals, the latter especially prevalent at the south end of the intrusive. The stock probably extends westerly from its outcrop for some distance but is covered by alluvium. It probably is at shallow depth below the thermally metamorphosed Preble strata along the northwest part of the mapped area.

The granodiorite weathers rapidly to a coarse grus which covers the lower slopes of the mountains below the outcrop area. Close joints cut the granodiorite along the north side of the canyon in the SE¼ Sec. 14. These joints are 6 inches to 3 feet apart and strike northeast and northwest, nearly at right angles to each other. The northeast joints are essentially vertical while the northwest joints dip from 25-50° south-westerly and give the rock a pseudo-bedded appearance. Conspicuous joints near the north end of the intrusive strike northeasterly and dip gently to the northeast and vertically.

According to Roberts (Kiersch, written communication), granodiorite of similar appearance in Trenton Canyon in the west flank of Battle Mountain (T.32N., R.42E.), about 20 miles to the southeast, has been dated by lead-alpha methods to be 45 million years old (Eocene). However, Roberts considers it likely that all coarsely granular, holocrystalline igneous masses are Cretaceous in age in this part of Nevada (Kiersch, written communication). Therefore, the granodiorite is designated to be Cretaceous-Tertiary in age.

The granodiorite is in intrusive contact with pyroxene-rich metavolcanic rock of the Pumpernickel formation along most of the east side of the intrusive mass. This contact roughly parallels the crest line of the Edna Mountains.

<u>Intrusive Complex</u>

The north end of an intrusive mass of complex composition extends onto the SE¼ Sec. 31. The rock is for the most part a coarsely crystalline alaskite with an estimated 25 per cent quartz, but varies to diorite. The mafic-free alaskite contains potash feldspar and quartz in crystals to ¼ inch long. This intrusive mass is thought to be of the same age as the granodiorite described above. It invades the Preble formation of Cambrian age and is overlain by rhyolite porphyry of Tertiary age.

<u>Alaskite Pegmatite, Diorite and Aplite</u>

Three different types of dike rocks were mapped. Alaskite pegmatite fills a fault fissure between granodiorite and metavolcanics of the

Pumpernickel formation in the $W\frac{1}{2}W\frac{1}{2}$ Sec. 1, extending north-northeasterly from the brass cap marking the southwest corner of this section. Aplite dikes fill normal faults in the upper plate rocks of the Golconda thrust. One of these trends easterly along the sinuous trace of the fault between Pumpernickel chert and strata of the Havallah formation in the $N\frac{1}{2}SE\frac{1}{4}$ Sec. 22. Another aplite dike strikes northwesterly near the trace of the Golconda thrust in the $SW\frac{1}{4}$ Sec. 27. These aplite dikes are light gray and tan, fine-grained and siliceous.

A grayish green, medium-grained diorite dike with an estimated 15-25 per cent mafic content fills a normal fault which strikes northerly near the trace of the Adelaide thrust in the $E\frac{1}{2}E\frac{1}{2}$ Sec. 18 of the western township. This dike separates chert and quartzite of the Ordovician Valmy formation on the west from hornfels of the Preble (?) formation of Cambrian age on the east.

Tertiary Volcanic and Sedimentary Rocks

Rhyolite Porphyry

Tan rhyolite porphyry with sanidine (?) phenocrysts up to 2 inches long and quartz and mica crystals in a fine-grained groundmass crops out in the southwest part of the mapped area. Except for local iron staining, the rhyolite is the same color in fresh break and weathered surfaces. The groundmass is pink to tan, very fine-grained, and is probably largely composed of potash feldspar. Perhaps 1-3 per cent biotite in the form of tiny flakes is scattered throughout the groundmass. The sanidine (?) phenocrysts are pale yellow or honey colored and their large size makes the rock unusual for this area. The phenocrysts (quartz, sanidine (?) and mica) compose up to 60 per cent of the total volume of the rock.

The rhyolite porphyry exhibits striking flow bands in some places. These are approximately vertical and strike northerly in the NW$\frac{1}{4}$ Sec. 31, where they probably are located along the fissure through which the lava was extruded. The coarse-grained character of the phenocrysts suggests that the lava, where now exposed, did not reach the surface before crystallization was largely complete; otherwise a much finer textured lava would have resulted due to rapid cooling.

Extensive masses of similar rhyolite porphyry occur north of the Izenhood Ranch in T.35N., R.45E. and T.36N., R.46E, and east of Rock Creek in T.35N., R.47E. At the latter location, field relationships clearly indicate the rhyolite to be older than the tuff of the Humboldt formation of Miocene to Pliocene age. Therefore, the rhyolite porphyry of the mapped area is regarded as early Tertiary age.

"Truckee" Formation

The mapped area is located at the approximate eastern extent of the Truckee formation (Van Houten, 1956, Fig. 5, p. 2814). The rhyolitic tuff mapped in the low hills in the central part of the eastern township is correlated with Van Houten's (1956, p. 2801) "vitric tuff unit", which he describes as Miocene to Pliocene in age. The Truckee formation was originally described by King in the reports of the 40th Parallel Survey, and the type locality is at some indefinite location south of Lovelock along the Humboldt River Valley.

The essentially horizontal Truckee formation is nonconformable over the Pumpernickel formation in the W$\frac{1}{2}$ Sec. 22. Four mappable units of the Truckee formation occur. Two are conglomerate units which are separated by a rhyolite flow and the fourth unit is the rhyolite tuff at the bottom of the exposed portion of the formation in this area.

The tuff is rhyolitic, mouse gray, fine-grained, earthy to sugary textured, soft, and commonly pumiceous. The conglomerate units are composed of mostly rounded vitreous quartzite cobbles and boulders with a few chert clasts. The rhyolite is light gray to pale pink, fine-grained, suffaceous, and locally pumiceous.

Quaternary Deposits

Basalt

Outcrops of basalt are limited to a narrow belt trending northwesterly in the NW$\frac{1}{4}$ Sec. 14 and the SW$\frac{1}{4}$SW$\frac{1}{4}$ Sec. 11. The basalt is black and dark gray, dense, and locally scoriaceous. It is only slightly weathered and is assumed to be of Pleistocene age. It overlies granodiorite and is overlain by older alluvium.

Older Alluvium

The lower slopes of the mountains and much of the valley floors are covered with unconsolidated, roughly sorted clastic material ranging from silt to boulders. These materials were derived from weathered outcrops of bedrock in the mountainous regions and were transported by slope and stream wash during periods of heavy rainfall in Pleistocene times. The clastics have been laterally sorted on a large scale, with the finer materials being carried farthest from the range fronts. There is also probably a general vertical sorting with coarser materials at depth, caused by steeper slopes and stream gradients and heavier runoff during the time the deeper clastics were deposited.

In many areas west of Winnemucca, wave cut terraces and beaches of Late Pleistocene Lake Lahontan are obviously younger than the older

Alluvium and older alluvial fans upon which they have been built. Therefore, the older alluvium of this entire region, including the mapped area, can be confidently designated as Pleistocene in age. The materials of the older alluvium have not been reworked to any appreciable extent by slope wash since Lake Lahontan times but have, of course, been reworked along the present stream channels.

Older Alluvial Fans

At the same time the older alluvium was being deposited, alluvial fans were built beyond the mouths of the larger canyons. The unconsolidated and roughly sorted clastics of these fans were derived from the weathered bedrock crossed by the parent streams. Like the older alluvium, these materials exhibit lateral sorting on a large scale with the finer clastics being deposited farther from the mouths of the canyons. There is a gradational contact between the materials of the older alluvium and the older alluvial fans.

Alluvium and Alluvial Fans

The modern stream channels are in line with Recent alluvium in the form of well sorted, locally cross bedded silt, sand and gravel with interspersed cobbles and boulders. Many of these clasts are well rounded; others are subrounded to subangular, depending upon their hardness and the amount of stream abrasion. The trough of Pumpernickel Valley contains a stream-fed deposit of silt and fine sand which has accumulated during infrequent periods of stream flow.

Recent alluvial fans are being built beyond the mouths of two streams in the southeast part of the eastern township. These fans are composed of similar materials as the Recent alluvium, but represent terminal deposition of the stream-transported debris in the form of fanshaped deposits.

STRUCTURAL FEATURES

Introduction

Many of the major structural features of this complex area are described above in order to clarify the stratigraphic picture and the genesis of the base metal deposits. For a summary of these major structural features, the reader is referred to the compilation of geologic episodes under "Summary of Geologic History" in the township report for T.35N., R.41-42E., MDBM (Oesterling, 1959).

Paleozoic Thrust Faults

The traces of three thrust faults occur within the mapped area. At least two of these are of regional extent - the Adelaide thrust and the Golconda thrust. The third is herein named the "Gold Run thrust" and is of probable local extent, being confined to the map area. Initial movement along these three thrusts was probably during Paleozoic times. Furthermore, the movement was probably from west to east. These two conclusions are based upon regional study and have been published by Roberts, et al. (1958), who give an interesting account of possible correlation between the Adelaide thrust and the Roberts Mountains thrust (p. 2851-2852). Later movement along these thrusts may have taken place during late Mesozoic time and direction of movement may have been from east to west.

The Roberts Mountains thrust, which may be equivalent to the Adelaide thrust, culminated the tectonics of the Antler orogeny during Late Devonian or Earl Mississippian time (Roberts, et al., 1958, p. 2813). The allochthonous strata of the Valmy formation of Ordovician age were brought into this area from western Nevada in the upper plate of the Adelaide (Roberts Mountains) thrust. Regarding this thrust Roberts, et al. (1958, p. 2852) state:

> "Inasmuch as no basement rocks have as yet been found in Western Nevada there is no reason to regard the Roberts Mountains thrust as having roots. Gilluly suggests, therefore, that the thrust is possibly an ecoulement structure; he considers that the imbrivation and folding of both the main thrust and many subordinate ones are more readily explicable by gravitative sliding than by compression of the whole crust. Possibly the "fluid pressure" mechanism suggested by Hubbert and Rubey (1957, pp. 1748-49) may have played a part in reducing shear stress as the Roberts Mountains thrust fault moved eastward."

It is of interest to consider the possibility that "basement rocks" (or Precambrian rocks) may occur in the west flank of the East Range, a likely site for them considering the regional pattern of the thrust faults. These rocks were originally mapped as the Inskip formation of Permian age by Ferguson, Muller and Roberts (1951) but have been designated as Cambrian or Precambrian in age by this writer (Oesterling, 1959b).

The Gold Run thrust is apparently overlapped by the upper plate rocks of the Adelaide thrust, but is thought to be approximately contemporaneous with the Adelaide thrust. The Gold Run thrust has Preble strata of Cambrian age in the upper plate and the Leach (?) formation of Carboniferous (?) age in the lower plate. Breccia along this thrust is excellently exposed in an incline adit driven westerly in the south flank of the hillside immediately north of the Adelaide mine. Elsewhere, the thrust is covered by alluvium along the valley of Gold Run Creek.

The Golconda thrust is not evidenced by brecciation or slickensides but is interpreted on a lithologic basis to occur in the prominent saddle in the east central part of Sec. 28 of the eastern township. The northerly continuation of the thrust is in the wide valley separating the Sonoma Range from the Edna Mountains, and the actual thrust surface may have been destroyed by the later Cretaceous-Tertiary granodiorite intrusive mass which likely underlies a large part of this valley.

The Golconda thrust was interpreted to be of Late Mesozoic age by Ferguson, Roberts and Muller (1952), as they show the Lower Middle and Upper Triassic Augusta Mountain sequence of formations as being a part of the upper plate of this thrust. However, the Augusta Mountain sequence of formations is not folded whereas the Havallah and older Paleozoic formations are closely folded. This fact makes it necessary to postulate intense compression associated with a Late Permian orogeny in western Nevada prior to deposition of the China Mountain formation, which is the lowest formation of the Augusta Mountain sequence. Furthermore, the Golconda thrust would have had to take place without any folding of the Augusta Mountain sequence of formations. It appears to be more reasonable to postulate that the Augusta Mountain sequence is autochthonous in central Nevada and deposited as "overlap" formations upon the highly deformed rocks of the upper plate of the Golconda thrust after the thrusting occurred. Furthermore, the mountainous terrain probably formed by these upper plate rocks during the orogeny with which the Golconda thrust was associated was the source for the coarse conglomerates and fanglomerates so common in Lower and Middle Triassic formations of the Augusta Mountain sequence. This latter interpretation will be expanded in a forthcoming publication by N.J. Silberling and R.J. Roberts of the U.S. Geological Survey and the orogeny with which the Golconda thrust was associated will be named the "Sonoma orogeny" (Silberling, 1959, oral communication).

Normal Faults (Basin and Range Faulting)

The above described Paleozoic thrust faults bear no topographic expression. The present topography is largely the result of basin-range block faulting which commenced at some time during the Tertiary Period and probably reached a climax in Plio-Pleistocene times (after deposition of "Truckee" formation), and has continued into Recent times.

An excellent example of a basin-range fault, although an unusual one in some respects, marks the eastern extent of the Sonoma Range and the southern termination of the Edna Mountains in the south-central part of the eastern township. This normal fault, with downthrow on the south-east side, is unusual in the following respects:

(1) It makes an abrupt and nearly right angle bend at the low pass between the Sonoma Range and the Edna Mountains.

(2) Although it had its initial, and greatest, displacement at some time during the Tertiary Period, it has had renewed movement in Recent times. This is evidenced by the Recent scarp, at least 30 feet high, which is marked in places by thermal springs. Relatively speaking, this latest movement has had the effect of elevating the pediment (on the west of the fault) which was cut in the Leach (?) strata, probably during the pluvial episodes of the Pleistocene Period. The Recent scarp is vividly displayed on the aerial photographs.

(3) The fault bounds two different mountain ranges, the Sonoma Range and the Edna Mountains.

Normal faults which are subsidiary to the larger basin-range block faults are numerous in the mountain masses. For the most part, these faults strike either northeast or northwest and have downthrow on the east. For example, the north-northeast trending normal faults in the Sonoma Range in the southwest corner of the mapped area appear to be a series of step faults with downthrow towards Pumpernickel Valley on the east. An ancient erosional surface with gently rolling topography has been segmented by these faults.

Farther north, along the west boundary of the eastern township, some of these faults have been mineralized - first with fissure filling quartz and later by fluids containing base metal sulphides. Where the faults intersect host rock of favorable permeability and chemical composition, portions of the wallrock have been replaced by silica and base metal minerals. Most of the mineralized faults dip west from 40° or less to about 75°.

FIELD WORK

Between May 25 and July 30, 1959, a total of 10 man days were used in the field investigation of this area.

Geophysics

Selected samples were tested with a scintillometer but no anomalous radioactivity was noted. Some of the tactite zones in the W½ Sec. 9 were examined under ultraviolet lamps but no scheelite crystals were observed.

RECOMMENDATIONS

Under the present economic situation, probably none of the potential mineral areas listed under "CONCLUSIONS" in this report have any value. However, if the economics of mineral exploitation should become more favorable in the future, it would be wise to investigate more thoroughly these potentially valuable deposits, especially the possibility of base metal and silver in Secs. 29 and 31 along extensions of known deposits and the possibility of scheelite in the tactite zones in Sec. 9.

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