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GEOLOGIC REPORT

ALUM and FISH LAKE Prospects

Esmeralda County, Nevada

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Summary

The Alum and Fish Lake geothermal prospects are located in Esmeralda County, Nevada. Both prospects are near trunk lines of the Nevada power grid and in environmentally insensitive areas with easy access. Basin and Range Front type faulting is prevalent in both areas providing deep circulation conduits for hydrothermal circulation.

The Alum prospect lies in the center of a triangular basin. Cambrian and Ordovician carbonate rocks are exposed south and east of the Alum sulfur mine. The remainder of the prospect lies in Tertiary sedimentary rocks of the Esmeralda Formation. A silicic tuff is interbedded with these sediments in the upper portion of the formation. Holocene basalt overlies the Esmeralda south of the prospect area.

The Fish Lake prospect is located at the southern end of the Volcanic Hills. The prospect is within two silicic tuff units of Early Pliocene age. An olivine basalt of Quaternary age intrudes Quaternary alluvium southwest of the prospect. Extensive small displacement normal faulting has occurred throughout the prospect.

ALUM PROSPECT

Introduction

The Alum Prospect is located at the Alum Sulfur mine, Section 29, T1N, R39E Esmeralda County, Nevada. The prospect may be reached from Blair Junction on Highway 50 by traveling south on Highway 47 for a distance of 8.7 miles. At this point an unmaintained dirt road leads northeast and then east for two miles to the prospect site.

The prospect lies at an elevation of 4900 to 5300 feet at the western extremity of the Weepah Hills and the southwestern terminus of the Big Smoky Valley. Isolated and prominently uplifted blocks of the Tertiary Esmeralda Formation form the western boundary of the prospect. Eastward from the sulfur mine site, the Weepah Hills rise slowly in highly dissected west-trending ridges to an elevation of 7700 feet, ten miles to the east. The Alum prospect lies at the drainage divide between the Big Smoky Valley to the north and the Clayton Valley to the south. The valleys, both of which are closed basins, contain large supplies of brackish water at shallow depths.

The climate is extremely arid and supports only sparse and patchy growths of sage and grass which are confined to stream bottoms of the lower western area. No permanent human habitation or other cultural activities exist in the vicinity of the prospect at this time. A main trunk line of the Nevada power grid passes within five miles of the prospect site.

A general geologic description of the Alum district and Weepah Hills is found in Albers and Stewart (1972). Detailed stratigraphy of the Tertiary sedimentary-pyroclastic section is given by Robinson and others (1968).

Regional Geology

The Alum Prospect lies at the center of a triangular basin bounded by three mountain ranges: the Monte Cristo Range to the north, the Silver Peak Range to the southwest, and the Weepah Hills and Lone Mountain to the east. The three ranges contain rocks ranging in age from Precambrian to Quaternary.

The Precambrian-Paleozoic rocks consist of fine-grained clastic and carbonate facies. They exhibit extensive low angle thrust faulting of large horizontal displacement. The pre-Mesozoic section is intruded by monzonite of Mesozoic age. The Lone Mountain Batholith is the largest exposure of the intrusives, while much smaller stocks occur in the Monte Cristo and Silver Peak Ranges. The intruded sedimentary rocks are deformed in conformance with the dome-shaped intrusive bodies. Tactites, marbles and hornfels are common at the monzonite-sedimentary contacts.

Large volumes of Tertiary intermediate to silicic pyroclastic and flow units overlie much of the Paleozoic and Mesozoic rocks of the Monte Cristo and Silver Peak Ranges but are absent in the Weepah Hills-Lone Mountain region.

Fluviatile and lacustrine deposition in basins roughly paralleling present topography took place during the Upper Miocene and Lower Pliocene. Silicic and intermediate pyroclastic and flow units are interbedded with these sediments. The youngest volcanic events in the region are represented by very late Pleistocene and Recent basalt flows and cinder cones which occur in the southern part of the map area.

Basin and Range faulting with up to 10,000 feet of vertical displacement began in the early Tertiary and continues to the present. Fault scarps in Quaternary alluvial fans along the northern boundary of the Weepah Hills and Lone Mountain indicate currently active faulting. This faulting is the primary factor in the formation of major topographic features in the region (Albers and Stewart, 1972).

Rock Units

The Alum prospect lies entirely within the Esmeralda Formation which is exposed throughout the western half of the Weepah Hills and Southern Great Smoky Valley (Figure 1). The basement is composed of Cambrian and Ordovician fine grained lacustrine and carbonate rocks (€Ols). These rocks are overlain by carbonate breccias derived from Cambrian and Ordivician rocks to the east. The Esmeralda Formation uncomformably overlies these breccias and consists of lacustrine and fluviatile deposits of sandstone, shale and siltstones interfingered with conglomerates and pyroclastic units. A tuff unit in the upper part of the formation has a K-Ar date of 6.9 m.y. The unit is locally covered by Quaternary alluvium. More than 9,000 feet of strata are exposed in the map area, though some of the apparent thickness may be due to faulting. The bottom of the formation is not exposed in the map area. The very poorly bedded, tan to black, well indurated carbonate breccias overlying the basement are Paleozoic in age. They are composed of limestone, silty limestone, limey siltstone, siltstone shale and sandstone which form angular to subangular clasts up to 30cm in diameter.

The Esmeralda Formation in the mapped area generally strikes northeast and dips 25° to the southeast. The predominate lithology is an alternating sequence of well bedded siltstone, shale and sandstone (Tes). This sequence is interbedded with a pyroclastic unit and in turn is unconformably overlain by conglomerates. The well bedded clastic sequence is dominated by well indurated tan to buff siliceous siltstone with minor sandy horizons. The siliceous unit alternates with argillaceous, poorly indurated, green brown siltstone which weathers to rounded soil covered slopes. The siliceous and argillaceous beds form alternating sequences 30 to 50 meters thick. Thinner beds of fine to medium grained sandstone ranging from 0.2 to 1.0 meters thick occur within the siltstone sequence. These sandstone beds contain siliceous cement, are very hard, and form prominent ridges in the map area. Conglomerate lenses up to two meters thick are interbedded with the sandstone beds. One to five meter thick beds of light brown, highly fissle shale are common throughout the sequence. Occasional chert beds 2 to 5cm thick occur in the siltstone dominated parts of the section.

The upper part of the fine grained clastic section contains a lithic and crystal tuff (Tef) which varies in thickness from 3 to 10 meters. The tuff unit contains pumice and siliceous volcanic rock fragments in addition to the abundant euhedral quartz and feldspar crystals indicating a rhyolitic or dacitic composition. This unit is very well indurated and forms resistant cappings on the most prominent ridges in the central portion of the map area.

A conglomerate and coarse sandstone unit 10 to 30 meters thick overlies the fine grained clastic sequence. The contact is an angular unconformity with underlying truncated siltstones dipping 20° to 30° more steeply than the overlying conglomerates and sandstone. The lower part of the coarse grained clastic unit consists of poorly sorted pebbly arkosic sandstone. The sandstone exhibits current cross bedding and cut and fill structures. The sandstone grades upward into a poorly bedded conglomerate containing sand lenses.

The conglomerate and coarse sandstone unit (Tec) grade upward into a sequence of thinly interbedded, tan to buff, calcareous siltstones, sandy siltstones and fine to medium grain sandstones. Minor calcite veining 1 to 10mm thick is evident in the upper sections of the Esmeralda Formation along with lenses of poorly sorted conglomerate up to two meters thick and chert lenses up to 10cm thick. The conglomerate lenses are not evident in the upper portion of the Esmeralda along the eastern border of the map area.

Several outcrops of poorly bedded limestone and silty limestone breccia (Tls) uncomformably overlie the Esmeralda east and north of the Alum Mine. These outcrops of limestone breccia appear to be similar to the limestone breccia which underlies the Esmeralda and is observed on the Monocline Peak and the horst blocks east of the Monocline Peak. The Esmeralda pinches out to the east and south of the map area.

Overlying the Esmeralda in the southern portion of the map area are viscular olivine basalt flows (Qb). These flows are Holocene in age and conformably overlie the Esmeralda. The basalt ranges from 10 to 30 meters in thickness, with the thickest exposures on The Monocline, at the southern boundary of the mapped area.

Structure

The map area has three structural zones. The structural zone west of the Alum Mine consists of northeast striking beds which have been gently folded to form southeasterly dipping anticlines and synclines. The folds are truncated in the north and east by northeast trending normal faults (Figure 2).

Surrounding the mine is a highly faulted and deformed area approximately three kilometers in length. It is characterized by small scale (5 to 10 meters) folding, high angle faulting and fracturing and a prominent topographic discontinuity. The sulfur mine workings and associated alteration zone is entirely located within this structurally disturbed zone. Beds of the Esmeralda Formation outside the zone do not show any deformation or faulting aside from the regional tilting of 20° to 30° to the southeast. The deformation zone may be explained as a partially ruptured, plunging fold with dimensions of approximately two kilometers on each limb. Exposures of the fault zone in the mine pits indicate a nearly vertical orientation. Flexure of the bedding in the vicinity of the faulting indicate right lateral strike slip movement with a cumulative offset of tens of meters. The topographic step within the fault zone in the otherwise uniform western slope of the Weepah Hills indicates a dipslip component of fault movement with the uplifted block to the east.

The third major structural feature is the Monocline Peak and associated horst blocks to the east. All three of these areas appear to be uplifted blocks of Paleozoic basement. The Esmeralda Formation has been tilted due to emplacement of these blocks. The limestone breccias which unconformably overlie the Esmeralda in the northeastern portion of the map area dip less steeply to the east than the underlying Esmeralda Formation.

The folds in the area represent a series of southeast dipping anticlines and synclines with the limbs varying from less than one kilometer to more than two kilometers. Basin and Range type faulting truncates the structure to the northwest and south. The Esmeralda Formation has been tilted to the west in the vicinity of The Monocline and as a result of the emplacement of these blocks, the horst block east of The Monocline.

Alteration and Hydrothermal Activity

Alteration in the map area is confined to the zone of strongest deformation where fault brecciation and intense fracturing are present. The alteration consists of argillization resulting in a friable, highly bleached, very low density rock. Accicular clumps of sulfur crystals fill cracks and joints, while coarsely crystalline sulfur fills vugs and larger cracks. White opalite is a minor constituent of the altered zone. The sulfur mineralization is confined to the intensely argillized zones within three to ten meters of brecciated faults. Alunite is abundant in the fractures, appearing as dense, translucent replacement veins up to 10cm thick. Examination of cuttings from drill hole number A3A show a disseminated pyrite horizon at a depth of 160 to 175 feet. The pyrite appears as 1 to 2mm stringers in the siltstone and as individual 2 to 3mm euhedral crystals.

Scarcity of siliceous deposits, such as sinter or opalite, indicate that near surface alteration is primarily fumarolic with little or no hydrothermal activity involved. The occurrence of alunite and elemental sulfur at the surface indicates that the fumarolic activity has ceased only very recently. The fumoralic activity may be related to the late Pleistocene, to Holocene basalt flows and eruptive centers south of Monocline Peak. Gaseous emanation from the basalt source at depth may have penetrated the thick sedimentary blanket of the Esmeralda Formation by way of the localized faulting within the map area. It is most likely that the northeast trending faults in the map area and the faults associated with the horst blocks southeast of the mine are deep circulation conduits of a convective hydrothermal system. This is borne out by the high heat flow values observed in the syncline northeast of Monocline Peak and around the Alum Mine site. This model accounts for both the recent age and distribution of fumoralic activity, the recent tetonic activity in the area and the observed high heat flow.

FISH LAKE VALLEY PROSPECT

Introduction

The Fish Lake Valley Prospect is located in TIS, R35E Esmeralda County, Nevada. The prospect is 16.3 miles south on State Highway 3A from U.S. 6/95. Here, a graded county road leads three miles east to a point one mile south of the prospect. An unmaintained dirt road connects the county road to the prospect site.

The Fish Lake Valley Prospect is a mercury prospect consisting of a seven meter deep vertical timbered shaft and two bulldozed pits three meters deep and 100 meters long. The prospect is located on the southern edge of the Volcanic Hills at the northern end of Fish Lake Valley. The prospect is located between two major northwest trending uplifted blocks of the Basin and Range Province; the Silver Peak Range to the east and the White Mountains to the west. The climate is arid but the Fish Lake Valley receives abundant ground and surface water run off from heavy precipitation in the White Mountain Range. A shallow groundwater table results in heavy sage vegetation over two meters high. Numerous farms in the region exploit the groundwater for growing alfalfa. Aside from the scattered farms, the only community in the area is Dyer, which is located 15 miles southwest of the prospect.

A general geologic description of the Volcanic Hills and surrounding ranges is given by J.P. Albers and J.H. Stewart (1972).

Regional Geology

The Silver Peak Range which forms the eastern boundary of Fish Lake Valley contains rocks ranging in age from Precambrian to Quaternary. The northern half of the range consists of Upper-Precambrian and Lower Paleozoic fine-grained marine clastic and carbonate units. Much of the pre-Tertiary sediments are overlain by Pliocene silicic and intermediate flow rocks which have K-Ar dates of 5.9 m.y. (J.P. Albers and J.H. Stewart, 1972, page 47). This part of the range exhibits Late Plio-Pleistocene, closely spaced normal faulting which trends north and northeast and cuts Late Pliocene Volcanics. In addition, the Early Pliocene volcanics are tilted 5° to 15° to the east and north. Overlying Late Pliocene volcanics are not tilted. Recent fault scarps cutting Quaternary alluvium are found along the northwest pediment of the range, indicating that range front faulting is still active. The southern half of the range has been extensively intruded by a quartz-monzonite pluton of Late Mesozoic age.

The western boundary of Fish Lake Valley is formed by the quartz monzonite White Mountain Batholith of Late Cenozoic Age. The batholith contains several roof pendants of Paleozoic marine sediments. Range front faulting with displacement of over 10,000 feet forms the eastern border of the range and accounts for the 14,000 foot elevations of the range crest. Scarps in Quaternary alluvium indicate ongoing movement along the fault.

Moderate topography consisting of Late Tertiary and Quaternary silicic pyroclastics and basalt flows dominate the north end of Fish Lake Valley. These units contain closely spaced high angle normal faulting which trends north and northeast. The units show regional tilting of 5° to 15° to the east and north.

Rock Units

Two silicic pyroclastic units of Early Pliocene age outcrop in the map area (Figure 3). The lower unit, whose base is not locally exposed, has a thickness of 170 meters. The mercury prospect pits are completely contained within this unit. South of the prospect the unit is buried under Quaternary alluvium of Fish Lake Valley. The lower unit is overlain by a silicic welded tuff which reaches a thickness of 30 to 40 meters in the northern part of the map area. These units are exposed extensively in the Silver Peak Range to the south with a distribution of more than 150 square miles.

The lower pyroclastic unit (Taf) is a poorly sorted air-fall lithic tuff. Color varies from white to light tan with darker tan on weathered surfaces. The rock is orange-brown and forms resistant nobs where silicified along fractures. The unaltered rock is poorly indurated, friable and forms elongated, rounded ridges. Pumice fragments make up 10 to 30 percent of the rock while angular quartzite and rhyolite clasts from 1 to 20mm make up the rest of the coarse material. A fine grained glass shard matrix with occasional quartz crystals up to 2mm makes up the remaining 20 to 30 percent of the rock.

The overlying welded tuff (Tw) contains abundant euhedral plagioclase and biotite phenocrysts to 1mm. The rock consists of approximately 50 percent glass which displays flow banding and is slightly vesicular. Fresh surfaces are medium gray to brown while weathered surfaces are dark red-brown. The unit forms prominent outcrops with talus aprons.

A Quaternary alluvial apron (Qal) consisting of decomposed Taf surrounds the map area to the west and south. The alluvium consists of 70 to 90 percent sand and silt sized particles of glass, pumice and quartz grains. Pebble and cobble size clasts of quartzite and rhyolite derived from the Taf, along with fragments of the welded tuff unit Tw, make up the remainder of the unit.

A vesicular dark gray olivine basalt (QTb) intrudes the Quaternary alluvium in the southwest corner of the map area, forming a low hill with dimensions of 200 by 300 meters. Horizontal vesicle elongation to the southwest and southeast indicates flow from an eruptive center at the northeast edge of the outcrop. At this point, vesicle density is greatly reduced and banding of vesicular and nonvesicular basalt is vertically oriented.

Structure

Structure in the map area is dominated by high angle normal faulting of small displacement (Figure 4). The faults trend north-northeast and are separated by 0.5 to 1.5 km. The resulting faulted blocks dip approximately 10° to the southeast. Fault zones are characterized by drag folding, slickensides and chalcedony filled breccia. Major gullies and canyons are developed along the fault traces. Offset of the Tw-Taf contact indicates a maximum vertical movement of 120 meters. Faults of less displacement trending west and northwest connect between the more prominent northeast trending faults. The western edge of the map area is bordered by a 120 meter high NNW trending escarpment which indicates a major range front fault. The fault truncates the pyroclastic section to the west where it is probably buried beneath the valley fill. Down warping accompanied by small displacement faulting cause the pyroclastic section to plunge more gradually under the valley fill along the southern edge of the map area.

Alteration and Hydrothermal Activity

Two types of mineralization are found in the map area. The more widespread type which is found throughout the southern third of the area consists of chalcedony and quartz veining. The less common type which is confined to the prospect pits consists of argillic alteration accompanied by opalite and disseminated native sulfur deposition.

The chalcedony-quartz veins vary in thickness from 0.5 to 10cm and occupy fractures and fault planes. Two stages of deposition are indicated by amorphous, banded chalcedony overlain by euhedral, accicular quartz. The free growing quartz crystals indicate open fissure filling rather than replacement of wall rock. Veining is more intense in and near major faults and becomes sparse between faults.

Argillic alteration with opalite deposition dominates in the prospect pits. The tuff is uniformly bleached and is more friable over the 300 X 300 meter area of the prospect pits as compared to the surrounding rock. Vertical eastwest fractures in the pits are opalized to a width of 30 to 40cm. Quartzite clasts in the tuff near the opalized fractures exhibit silicic halos of 3 to 10mm thick. The clasts apparently form a nucleus for silica deposition. Minor amounts of native sulfur appear in rocks removed from the vertical shaft at a depth of less than ten meters. Native sulfur was not found in place in the pit walls or floor.

The quartz veining was apparently produced by widespread low to moderate temperature hydrothermal flow which was controlled by faults and fractures. Alteration in the prospect pits is primarily gaseous with mobilizations and redeposition of wall rock silica accompanied by leaching of calc-alkalai elements. The fumarolic nature of the alteration is further indicated by the presence of native sulfur. The presence of sulfur in the near surface environment is indicative of recent fumarolic activity and intense heat flow.

References

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