RED BUTTE MALHEUR

GOLD MINERALIZATION IN A FOSSIL HOT SPRING SYSTEM: RED BUTTE, OREGON

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The Red Butte Au prospect is a well preserved hot spring system located 10 km west of the Owyhee Reservoir on the northwestern margin of the 15.5 Ma. Mahogany Mountain caldera. Mineralization is hosted by N to NW-striking normal faults in volcaniclastic sedimentary rocks of the Deer Butte Formation.

Red Butte is capped by 30 to 40 m thick sequence of syngenetic sedimentary rocks, consisting of a basal silicified mudstone overlain by arkosic sandstones and conglomerates interbedded with siliceous hot spring sinter. The sediments at this paleosurface horizon have been cemented by hydrothermal quartz and adularia to form the resistant cap of the butte which covers an area of over 3 km^2. The upper 30 m of the butte also contains zones of zeolitic alteration, which includes heulandite and stellerite, and oxidation zones, containing hematite with minor calcite, kaolinite and illite-smectite. A stockwork of quartz-adularia veins and breccias with minor pyrite, marcasite, electrum, bladed calcite, and chlorite occurs beneath the paleosurface horizon. Stellerite persists to a depth of 50 m below the paleosurface, but has been replaced by quartz at lower elevations. Stability limits of stellerite indicate that temperatures were less than 150^{o}C. A zone of intense argillic alteration 20 to 30 m below the paleosurface marks the position of the thermal water table during the later stages of hydrothermal activity. This zone of argillic alteration and the overlying sedimentary rocks are crosscut by a 50 m wide hydrothermal eruption crater filled with bedded breccia deposits.

INAA analyses of altered sedimentary rocks and hydrothermal vein and breccia samples from surface exposures reveal the presence of anomalous concentrations of Au, Ag, As, Sb, and Hg. Highest Au (18.16 ppm) and Ag (19.20 ppm) concentrations occur in electrum-bearing quartz-adularia veins. Highest As (330 ppm) and Sb (41 ppm) concentrations are found in rare zones of abundant sulfide minerals. Highest Hg (3.97 ppm) concentrations are found near the rim of the butte within the argillically altered zone. INAA analyses also reveal slightly anomalous concentrations of Mo (13 ppm), W (8 ppm), U (8 ppm) and Th (11 ppm).

$\delta^{18}O$(SMOW) values for hydrothermal quartz and adularia range from 5.3 to 8.3 and 0.1 to 2.4 per mil respectively. $\delta^{18}O$(SMOW) and $\delta^{13}C$ (PDB) values for calcite range from -3.6 to 8.9 and -8.9 to -5.2 per mil. These values are consistent with those of minerals from meteoric hydrothermal systems. A plot of $\delta^{18}O$ versus $\delta^{13}C$ values for calcite shows that $HCO3^-$ was the dominant aqeous carbon species.

Red Butte can be distinguished from other epithermal gold prospects in eastern Oregon by the large proportion of adularia and low amount of sulfides in the hydrothermal mineral assemblage. Stability of adularia at the paleosurface indicates that the fluid maintained a slightly alkaline pH and suggests that boiling of the hydrothermal solution may have been an important factor controlling Au-mineralization.

RECONNAISSANCE GEOLOGY OF THE RED BUTTE AREA, MALHEUR COUNTY, OREGON

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ABSTRACT

The Deer Butte Formation, a Barstovian age sequence of volcaniclastic sandstones, siltstones, shales, basalt flows, and tuffs, has been divided into seven members, named from base to top: Red Butte, Orlano Spring, Ferguson Spring, Quartz Mountain Basalt, Burnt Mountain, Sourdough Mountain Basalt, and Mitchell Butte. In the vicinity of Red Butte, near the southern end of the Owyhee Reservoir, reconnaissance geologic mapping has determined the distribution of members of the Deer Butte Formation.

The stratigraphic subdivisions of the Deer Butte Formation are based on the positions of two packages of basalt flows: the Quartz Mountain Basalt and Sourdough Mountain Basalt members. More detailed study needs to be completed in areas where these basalt members are absent to characterize the contacts between the volcaniclastic units of the Deer Butte Formation. These preliminary results indicate that the Orlano Spring Member of the Deer Butte Formation may need to be redefined in the study area.

INTRODUCTION

Anomalous gold concentrations occur in the area of Red Butte near the southern end of the Owyhee Reservoir (Gray and others, 1983; Bukofski and others, 1984; Robinson and others, 1985; Figure 1). Evans (1986) and Evans and Cummings (1985, 1986) identified the presence of a gold-bearing paleo-hot spring system, within the Deer Butte Formation, centered on Red Butte.

These Miocene - Pliocene (?) age hydrothermal emanations occurred along north- and northwest-trending faults and resulted in silicification, the formation of quartz-adularia veins, and hydrothermal explosion breccias with zeolitic, chloritic and argillic alteration halos.

To understand better the stratigraphy and mineralization at Red Butte, a study of the stratigraphy, sedimentology, and geochemistry of the Deer Butte Formation has been initiated. This report presents an outline of the stratigraphy of the area surrounding Red Butte and a reconnaissance geologic map showing the distribution of the members of the Deer Butte Formation.

Terms identifying bedding thicknesses and cross-stratification types are those of McKee and Weir (1953) as modified by Ingram (1954). Sandstones are classified according to Folk (1974). Color designations correspond to the Rock-color Chart of Goddard and others (1948). The classification schemes of the IUGS (Streckeisen, 1979; Schmid, 1981) are followed in the descriptions of flows, intrusives and pyroclastic units. Textural relationships observed in the igneous rocks correspond to the usage in MacKenzie and others (1982).

PREVIOUS WORK

The Deer Butte Formation was named for exposures of Miocene to Pliocene (?) age sediments at Deer Butte, 6 miles north of the Owyhee Dam, by Kittleman (1962). Johnson (1961) was the first to describe the lithologic variations within the Deer Butte Formation. He recognized seven members, in ascending order: Red

Butte, Orlano Spring, Ferguson Spring, Quartz Mountain Basalt, Burnt Mountain, Sourdough Basin Basalt, and Mitchell Butte.

Figure 2 shows regional stratigraphic relations for units in the Owyhee Reservoir region. The Sucker Creek Formation, a 488+ m sequence of volcaniclastic sandstones, vitric tuffs, arkosic sandstones, granite-cobble conglomerates, carbonaceous tuffaceous shales, air-fall and ash-flow tuffs (Corcoran, 1965; Kittleman and others, 1965), is the oldest unit exposed in the study area. Within the map area, only the Leslie Gulch Ash-Flow Tuff Member, of the Sucker Creek Formation, is present. The Leslie Gulch Ash-Flow Tuff Member consists of non-welded ash-flow tuffs, base surge, and well bedded air-fall tuffs (Rytuba and others, 1985; Rytuba, personal communication, 1986).

Northeast of the map area, the Sucker Creek Formation is unconformably overlain by the Owyhee Basalt, a 396 m thick sequence of pilotaxitic, intersertal and intergranular, microporphyritic, olivine-poor basalt flows (Kittleman and others, 1965). Interbedded tuff beds occur locally with the basalt lava flows (Corcoran, 1965).

Unconformably overlying the Deer Butte Formation is the Grassy Mountain Formation, a 335 m thick sequence of arkosic sandstones, arkosic granite-cobble conglomerates, volcaniclastic sandstones and ophitic, coarse-grained, olivine basalts (Kittleman and others, 1965). This formation does not crop out in the study area, and is restricted to parts of the Owyhee Reservoir region north of Dry Creek (Kittleman and others, 1967).

Capping North Table and South Table Mountains is a single, nearly horizontal lava flow of "the basalts at Cow Creek Lakes." Kittleman and others (1965, 1967) used the informal designation "the basalts at Cow Creek Lakes" for a series of six basalt flows that originated from the Cow Creek Lakes area, 30 km to the south. These flows comprise the youngest Tertiary unit in the region.

GEOLOGY OF THE RED BUTTE AREA

Plate 1 is a reconnaissance geologic map of the study area. Stratigraphic unit symbols used on the map are keyed to unit descriptions presented below. A generalized composite section of units in the map area is presented in figure 3.

Sucker Creek Formation

Leslie Gulch Ash-Flow Tuff Member (Tlg)

Pyroclastic flows, air-fall tuffs, rhyolite porphyry flows (?) and numerous basaltic sills and dikes belonging to the intra-caldera unit (Rytuba, personal communication, 1986) of the Leslie Gulch Ash-Flow Tuff Member occur in the southeast part of the map area. No detailed work was done on this unit.

Deer Butte Formation

Red Butte Member (Tdr)

The Red Butte Member consists of yellowish-gray to pale-yellowish-brown tuffaceous siltstones and fine to coarse devitrified vitric tuffs; pale-yellowish-brown tuffaceous coarse- to medium-grained litharenites to coarse- to fine-grained lithic arkoses; and grayish-brown to dark-yellowish-brown shales. Coarse-grained sandstones form thickly to very thickly bedded lenses and shoestring deposits which can be traced from outcrop to outcrop for up to 2 km (Figure 4). Planar and trough cross-stratification is commonly found in these sandstones.

Unidentified gastropods and pelecypods have been collected from the upper part of this member. Numerous plant stems, silicified and calcified logs, and leaves are present in the finer grained units of this member.

At least 122 m of the Red Butte Member is exposed in the vicinity of Red Butte. Where the Red Butte Member and the underlying Leslie Gulch Ash-Flow Tuff Member of the Sucker Creek Formation are in contact, the formation boundary is either a fault or an angular unconformity. The contact between the Red Butte Member and the overlying Orlano Spring Member is sharp. Where the basal unit of the Orlano Spring Member is a mudflow, the contact is erosional. However, where the mudflow is not present, the contact is gradational to sharp and marked by a slight change in color of the units. In general, the upper part of the Red Butte Member is composed of units that have a reddish tint, while the non-mudflow units in the Orlano Spring Member typically have more of a brownish gray tint.

Orlano Spring Member (Tdo)

The Orlano Spring Member consists of pale-grayish-brown to light-brownish-gray medium- to fine-grained litharenites to coarse- to medium-grained arkoses; light-brownish-gray tuffaceous siltstones; brownish-gray to moderate-brown carbonaceous shales; and moderate-brown pebble litharenites (Figure 5). The Orlano Spring Member is most easily identified in the field by the presence of a brownish colored pebble litharenite which represents a mudflow. This mudflow consists of a dusky yellow to moderate-yellowish-brown medium-grained litharenite matrix with clasts of dusky-yellowish-brown to greenish-black vesicular basalt cobbles and fragments, 5 mm to 30 cm in diameter, and moderate-yellowish-brown to dark-yellowish-brown pumice fragments, 5 mm to 15 mm in diameter (Figure 6). The clasts in the mudflow are unsorted, although indistinct bedding is present toward the base and the top of this 10 m to 50 m thick unit. Ripple lamination to planar cross-stratification may be present in the upper two meters. Fine-grained sandstones and siltstones are typically very thickly bedded with parallel and rare wavy laminations. Some cut-and-fill channel structures are present. Discontinuous lenses of rounded, oblong, tuffaceous mudstone clasts up to 3 cm in length are present in some of the sandstone beds. Siltstone beds may contain concretions up to 30 cm in diameter.

No identifable fossils have been collected from the Orlano Spring Member, although abundant plant detritus may be present in some of the beds.

The Orlano Spring Member ranges from 0 m to 133 m in thickness in the map area. The clast size and the ratio of basalt to pumice clasts in the mudflow unit to decrease to the southwest, indicating a possible source area to the northeast. The source for the basalt clasts is assumed to be the Owyhee Basalt. Because the Owyhee Basalt crops out to the northeast and an angular unconformity occurs between it and the overlying Deer Butte Formation, this implies that there existed a paleo-surface upon which basalt clasts would have been deposited and then incorporated into a mudflow.

Ferguson Spring Member (Tdf)

The Ferguson Spring Member consists of yellowish-gray to very-pale-orange medium- to fine-grained feldspathic litharenites to litharenites, to moderate-yellowish-brown medium-grained lithic arkoses; moderate-brown to pale-yellowish-gray to white tuffaceous siltstones; olive-gray to pale-yellowish-brown shales; and white to very-pale-orange to pinkish-gray coarse to fine crystal tuffs to vitric tuffs (Figure 7).

Strata in the Ferguson Spring Member are generally thinly laminated, although some thickly bedded units area present. Near the top of this member are several beds displaying high angle, planar cross-stratification. The Ferguson Spring Member is between 30 m and 63 m thick; the thickest sections occurring in the southeast part of the map area.

Fish scales have been collected from silicified siltstones and shales in the vicinity of North Table Mountain (Plate 1). A single, unidentified tooth (mammal?) was collected in float from the Ferguson Spring Member. Shotwell has identified 34 species of mammals, as well as examples of fish, turtles, lizards and birds indicating a Barstovian age fauna (Shotwell, 1968).

Quartz Mountain Basalt Member (Tdq)

The Quartz Mountain Basalt Member consists of multiple flows of olivine basalt. The basalts are composed of laboradorite feldspar, pigeonite, olivine, magnetite and various alteration minerals (smectite, chlorite, iron oxides, and calcite). Textures observed in thin-section include ophitic, subophitic, intergranular and intersertal, with subophitic to intergranular being the most commonly observed textures (Figure 8).

In the northwest corner of the map area (Plate 1), seven individual flows were distinguished. At this locality, the member is 108 m thick. Each flow is identified by the presence of a reddish-orange to grayish-red vesicular flow top (up to 20 percent of the flow thickness) and a more massive flow interior. Vesicles are spherical to pipe-shaped and range from 1 mm up to 30 mm in length. Only four flows were positively identified in the vicinity of Red Butte, and no basalt flows were noted in the area south of Red Butte and South Table Mountain.

Flows of the Quartz Mountain Basalt Member are poorly exposed. They are mantled by a well-developed moderate-brown sandy soil, in some places exceeding 1 m in thickness. Surface exposures of basalt are iron-stained and friable, although a fresher surface is present a few mm to a few tens of mm toward the interior of the outcrop.

The contact with the underlying Ferguson Spring Member is sharp and marked by a reddish zone between 15 cm and 2 m thick. This contact feature may represent a paleosol. The upper contact of the Quartz Mountain Basalt Member is also sharp.

Burnt Mountain Member (Tdb)

The Burnt Mountain member is only exposed in the vicinity of Red Butte and North Table Mountain (see Discussion). Around North Table Mountain, 50 m to 100 m of this unit is exposed and the member appears to rest conformably upon the Ferguson Spring Member. No intervening basalt flows are present. The Burnt Mountain Member is poorly exposed and consists of pale-yellowish-brown medium- to coarse-grained arkoses to lithic arkoses; pale-yellowish-brown to pale-yellowish-gray tuffaceous siltstones; and grayish-brown to dark-yellowish-brown shales. Units are very thinly bedded to mediumly bedded.

On the flanks of Red Butte, the Burnt Mountain Member is covered, to a large degree, by talus. Where exposed, the member consists of pale-olive to grayish-olive coarse- to fine-grained litharenites, grayish-yellow to dusky-yellow tuffaceous siltstones and shales.

Sourdough Mountain Basalt Member (Tds)

The Sourdough Mountain Basalt Member is only exposed in two places: on Red Butte, and on a small hill just north of North Table Mountain (Plate 1). It consists of one to four flows of olivine basalt, 10 m to 60 m thick, similar in appearance to the basalts of the Quartz Mountain Basalt Member. Only a cursory examination of this unit has been completed. Primary minerals are more extensively weathered in samples of Sourdough Mountain basalt as compared to samples of Quartz Mountain basalt.

Mitchell Butte Member (Tdm)

The Mitchell Butte Member consists of silicified tuffaceous shales and siltstones interbedded with coarse-grained arkoses to litharenites. Red Butte is capped by 75 m of silicified, coarse-grained lithic arkoses and pebble conglomerates (Evans, 1986) belonging to the Mitchell Butte Member. Many of the sandstone beds display high angle, planar cross-stratification.

A small outcrop of opalized vitric tuffs and opalized tuffaceous siltstones which caps a small hill just to the north of North Table Mountain is tentatively mapped as Mitchell Butte Member.

Tertiary Intrusive Basalts (Tbi)

Dikes, sills and irregular, discordant bodies composed of fine-grained basaltic material are found throughout the study area. The basalt is composed of plagioclase, pyroxene, olivine and magnetite crystals set in a fine-grained groundmass of altered glass. Alteration of the primary framework grains is generally moderate. These intrusives are believed to have been intruded at a shallow level in the crust. No detailed work has been done on these basalts.

The Basalts at Cow Creek Lakes (QTb)

The basalt flow capping North and South Table Mountains represents the oldest of six flows described from the Cow Lakes area, 30 km to the south, by Millhollen (1965). The flow is 5 m to 10 m thick and composed of fine-grained, ophitic to intergranular, olivine basalt of uncertain age (Millhollen, 1965).

Quaternary Deposits

Debris Flow Deposits (Qdf)

Debris flow deposits are characterized by very poor sorting of clasts ranging from sand- to house-sized. Relict bedding is present in some parts of the deposit, but bedding is discontinuous; it can be traced for only a few meters. This bedding reflects original bedding in coherent blocks that were incorporated into the debris flow. The surface of the flow is hummocky.

Pediment Surfaces and Deposits (Qp)

Pediment deposits are gravel to boulder conglomerates which occur as thin sheets on planar erosion surfaces. The deposits were not studied in detail.

Alluvial Fan Deposits (Qaf)

A single alluvial fan deposit was identified at the mouth of small gully southwest of Red Butte.

Landslide Deposits (Qls)

Landslide deposits are found on the steeper slopes around Red Butte and North Table Mountain. These deposits are distinguished from debris flow deposits on the basis of their more restricted extent and the lack of any relict structures in landslide deposits.

Alluvium (Qal)

Recent surficial deposits related to sedimentation by the Owyhee River, Owyhee Reservoir, and ephemeral streams in the study area are mapped as alluvium. Alluvium includes unconsolidated mud, silt, sand and gravel deposits.

DISCUSSION

Strata of the Deer Butte Formation are subdivided based on two distinct packages of basalt flows (Quartz Mountain Basalt and Sourdough Mountain Basalt members) and the presence of a mudflow (Orlano Spring Member). Marker units and the strata above and below the markers have been designitated as members (see Figure 3). As presently understood, stratigraphic subdivisions of the Deer Butte Formation rely on the presence of distinctive volcanic-related beds -- basalts and mudflows.

The distribution of the members of the Deer Butte Formation, as defined by Johnson (1961) and mapped here, is shown in plate 1. In general, there is an increase in grain size with stratagraphic position. The Red Butte Member is composed of sediments of about the same grain size as the overlying Ferguson Spring Member. The Burnt Mountain Member consists of coarser grained sediments than those in the Red Butte or Ferguson Spring members. The same pattern is noted between the Burnt Mountain and Mitchell Butte members. Variability, both laterally and vertically, within each member complicate the picture. This means that there are numerous sections where the Red Butte, Ferguson Spring, Burnt Mountain and Mitchell Butte members are very similar in appearance. For example, around South Table Mountain no Quartz Mountain Basalt flows are present. The area is mapped as Ferguson Spring Member. Sedimentary units of the Burnt Mountain Member may be present, but no Burnt Mountain Member was mapped because the contact between the Burnt Mountain and Ferguson Spring members around North Table Mountain (the only other area where the two members are in direct contact) is poorly exposed, and the member, in general, is poorly exposed.

CONCLUSIONS

Johnson (1961) and Evans (1986) have both interpreted the Deer Butte Formation as having been deposited in a low-relief fluvial system. In such a depositional setting, the influx of volcanic flows, detritus and ash would be expected to have a significant impact on topography and on the location of river and stream channels and lakes. Mapping of the distribution of mudflows in the Orlano Spring Member should highlight one or more stream drainage systems. Detailed study of the Red Butte and Ferguson Spring members may identify paleosol horizons which could be utilized for reconstruction of past surfaces.

Future work on the detailed stratigraphy and sedimentology of the members of the Deer Butte Formation will be directed toward developing a depositional model which incorporates the observed sedimentary features, volcanic activity, and the hydrothermal events in the Red Butte area. Understanding of the development of the basin in which the Deer Butte Formation was deposited will allow for assessment of mineralization potential for the basin as a whole.

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FIGURE CAPTIONS

Figure 1. Index map showing location of study area in northern Malheur County, Oregon. Area covered by Plate 1 is outlined.

Figure 2. Correlation chart for study area and Owyhee Reservoir Region in general. Tertiary Mammalian Stage names from Kittleman and others (1965). Regional correlation chart compiled from Kittleman and others (1965) and Corcoran and others (1962). KB = Kern Basin Formation; JC = Jump Creek Rhyolite; LG = Leslie Gulch Ash-Flow Tuff Member, Sucker Creek Formation.

Figure 3. Columnar section cartoon depecting units in the map area. Units are identified by map symbol: Tlg = Leslie Gulch Ash-Flow Tuff Member, Sucker Creek Formation; Tdr = Red Butte Member, Tdo = Orlano Spring Member, Tdf = Ferguson Spring Member, Tdq = Quartz Mountain Basalt Member, Tdb = Burnt Mountain Member, Tds = Sourdough Mountain Basalt Member, Tdm = Mitchell Butte Member, Deer Butte Formation; QTb = "basalts at Cow Creek Lakes." Facies pattern A = sandstone, B = siltstone/mudstone, C = sandstone with poorly developed trough cross-stratification, D = siltstone with planar cross-stratification, E = channel, F = silty sandstone, G = mudflow, H = basalt, I = pebble conglomerate with planar cross-stratification, J =

pebble conglomerate, K = pebbly sandstone with high-angle, planar cross-stratification.

Figure 4. Photograph of Red Butte Member, Deer Butte Formation two km north of Red Butte. View is to the north. Note the presence of a resistant sandstone unit capping both of the hills.

Figure 5. Photograph of outcrop of Orlano Spring Member, Deer Butte Formation, about four km north-northwest of Red Butte. Lower part of hill is composed of tuffaceous sandstones and siltstones of the Orlano Spring Member. Upper third of the hill is a brownish mudflow unit about 15 m thick. The contact between the Orlano Spring Member (Tdo) and the overlying Ferguson Spring Member (Tdf) is indicated. View is to the north.

Figure 6. Detailed view of pumice clasts in Orlano Spring Member mudflow unit. Outcrop is located on southeast side of Red Butte. Scale is in mm.

Figure 7. Photomicrograph of vitric tuff from Ferguson Spring Member, Deer Butte Formation. Note altered glass shards. Field of view = 3 mm. Sample from northwest corner of map area.

Figure 8. Photomicrograph of Quartz Mountain Basalt Member, Deer Butte Formation. Field of view = 3 mm. Sample from northwest corner of map area.

Plate 1. Reconnaissance geologic map of Red Butte area, Malheur County, Oregon. Refer to text for discussion of stratigraphic unit symbols.