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A Recently Discovered Granitoid Rich Lithic Basal Horizon in the Liberia Formation and Its Possible Implications on Source Vent Location and the Evolution History of a Geothermal Reservoir at the Las Pailas Geothermal Field, Guanacaste, Costa Rica

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ABSTRACT

The Liberia Formation is a Pleistocene rhyolitic biotite and quartz bearing pumiceous tuff used as a marker bed at the Las Pailas Geothermal well field. A recently discovered outcrop at the base of the Liberia Formation is a granitoid bearing horizon restricted to a 2 meter thick bed. at Las Parcelas de Santa María, Guanacaste, Costa Rica and may provide evidence for proximity to the source vent that produced the Liberia Formation as well as the implications that it may have had during the evolution of the geothermal reservoir at the Las Pailas Geothermal Field. The Liberia Formation crops out at the outer perimeter of the Las Pailas Geothermal Field and to date there are no known outcrops of this formation within the field itself. However, at depth a rock layer has been correlated with the Liberia Formation. Nonetheless, the actual source vent of the Liberia Formation has still not been fully identified, although careful mapping of the spatial and modal distribution of granitoid lithic fragments in this basal bed may provide useful clues as to its location.

This report presents the findings of this investigation and conclusions on the possible location of the source vent of the Liberia Formation and the implications that this may have with regard to the evolution of the geothermal reservoir at the Las Pailas Geothermal Field.

1. INTRODUCTION

Many investigators (Chiesa, S. 1991; Guillot et al., 1994; Deering, C.D. 2005; Denyer and Kussmaul, 2000; Kempter, K.A. 1997; Kussmaul et al., 1982; and Vogel et al., 2004), to name a few, have written about the widespread mid to late Pleistocene age Liberia Formation, a rhyolitic biotite and quartz bearing pumice rich crystalline tuff located on the southern and southwestern slopes of the Rincón de la Vieja Volcano in northwestern Costa Rica (Figure 1). Lithic fragments are rare in this formation and are most commonly andesitic suggesting that andesitic eruptions occurred either prior to or during the explosive plinean eruption that emplaced the Liberia Tuff. In this paper, field observations at a recently discovered horizon rich in granitoid fragments within the Liberia Formation, may provide clues to the location of a possible nearby source vent, due to a similar chemical composition as the Liberia Tuff, as well as possible evolution history of the Geothermal Reservoir at the Las Pailas Geothermal Field.

2. LOCAL GEOLOGY

The Pacific slope of the Rincón de la Vieja Volcanic Complex is dominated by Holocene andesitic volcanic products consisting mainly in thick lava flows, coluvial deposits and thin lahar aprons which cap a sequence of Post-Liberia Formation late Pleistocene crystalline, pumice-rich and lithic crystalline tuffs. Below this pyroclastic sequence lies the Liberia Formation, cropping out between the 300 and 650 m contours. This formation crops out in a arched shape, convex towards the north-northwest and at the outer boundary of the Cañas Dulces Caldera between the towns of Cañas Dulces to Las Parcelas de Santa María. The base of the Liberia Formation is marked by a green-colored pumice-rich layer (Deering, 2005) and a orange-brown paleosol. The mineralogic composition of the Liberia formation is characterized as containing mainly embayed quartz crystals, plagioclase, biotite, and lithic fragments locally, in a white pumiceous to ashy matrix. The Liberia Formation comprises the most acidic volcanic rocks in Costa Rica (Kussmaul et al., 1982) and based on trace element analysis Vogel determined that the Liberia Formation as well as the granitoids found in the Talamanca Mountains (southeastern Costa Rica) is very similar in composition to continental crust (Vogel et al., 2004). Regarding the lithic facies within the Liberia Formation, Kempter (1997) states that although the lithic clasts typically found are porphyritic andesites, diorites and granites also rarely occur.

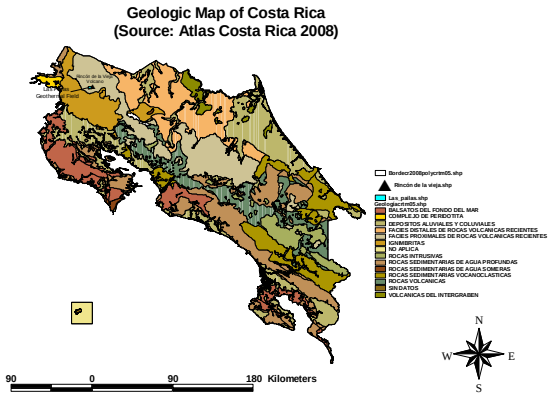

Figure 1: Geologic Map of Costa Rica (Source: Atlas Costa Rica, 2008).

3. DISCOVERY OF A GRANITOID RICH BASAL LITHIC HORIZON IN THE LIBERIA FORMATION

At Las Parcelas de Santa María, located on the southern slope of the Rincón de la Vieja volcancic complex in Guanacaste, Costa Rica, there is a two to three meter thick outcrop of a lithic facies of the Liberia Formation (Figure 2), having a minimum of 195 clasts which are divided into three different clast types. The base of this lithic facies has sub-angular to sub-rounded granitoid clasts measuring from 7 to 22 cm. This lithic facies is in the basal part of the Liberia Formation and is in direct conformable contact with

the green layer below it, which is underlain by a brown-orange paleosol. Petrographically, the granitoid clasts are described as granitoids with a holocrystalline texture, locally micrographic and composed of quartz, plagioclase, biotite, and green hornblende.

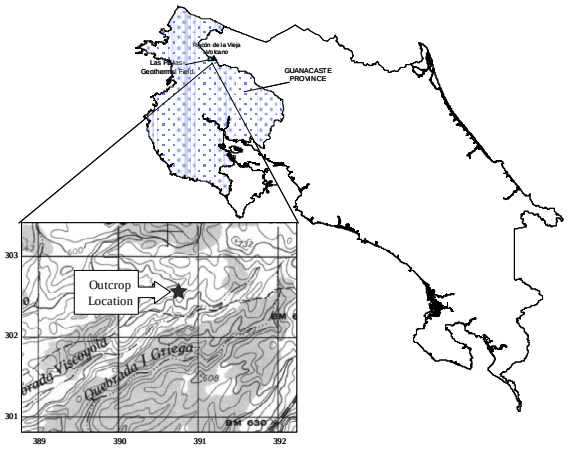

Figure 2: Location map of the granitoid bearing basal lithic horizon of the Liberia Formation. Curubandé 1:50,000 topographic base map using local Costa Rica coordinates (Lambert Norte).

3.1 Fieldwork

During a field trip to area of Las Parcelas de Santa María, a four to six meter high and 75 meter long outcrop of the Liberia Formation was observed in a recently constructed road cut located at the 390724 E, 302592 N and 650 m a.s.l. Lambert Norte Costa Rica (local Costa Rica map coordinates) on the 1:50,000 scale Curubandé topographic base map. The base of the Liberia Formation is exposed at this location overlying a green pumice rich layer and an orange-brown paleosol (Figure 3).

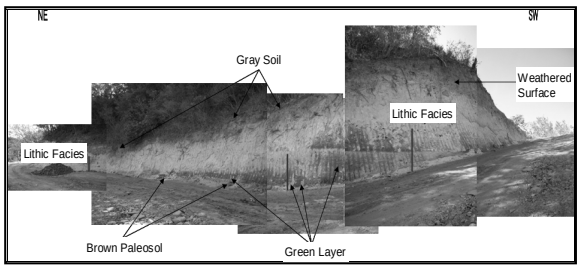

Figure 3: Panoramic view of the granitoid bearing basal lithic horizon found in the Liberia Formation. The black vertical line is two meters long. The view from the left to the right is Northeast to Southwest. Gray soil; Weathered surface; Green Layer; Orange-Brown Paleosol; and Lithic Facies.

A lithic facies containing decimetric subangular lithic fragments (3-5% of the overall composition) in a white ashy pumiceous matrix overlies the green layer. In the basal section of this bed, phanerític granitoid clasts were found and five rock samples were taken: LPA1-23-02-08, LPA2-23-02-08, LPA3-23-02-08, LPA3A-23-02-08 and LPA4-23-02-08.

3.1.1 Stratigraphy

The stratigraphic column measured at the outcrop is four to six meters high and approximately seventy-five meters long (Figure 4). The chronostratigraphic (oldest to youngest) description follows:

Paleosol: Orangish brown massive paleosol measuring 37 cm high and 15 m wide with no bioturbations. Minimum thickness: 37 cm.

Green Layer: Green colored, locally oxidized, slightly cohesive layer containing white pumice and sporadic plagioclase crystals. Maximum measured thickness: 210 cm.

Ashy Pumiceous Pyroclastic Flow: This moderately cohesive layer forms the matrix of the outcropping Liberia Formation and extends from the Green Layer to a tannish orange weathered layer above which a recent soil has formed. It is white and contains primary embayed quartz, biotite, plagioclase and pumice fragments measuring from 5 mm to 4 cm bearing scarce plagioclase and biotite crystals. Outcrop thickness: three to four meters. Within this unit a lower and upper lithic facies are distinguished.

Lower Lithic Facies: Gray-colored fine to coarse-grained decimetric phaneritic granitoid lithic fragments containing quartz, biotite and plagioclase crystals; also sporadic oxidized andesitic fragments are observed. Thickness: 1 – 2 meters.

Upper Lithic Facies: Porphyritic dark gray to black locally vesicular andesite lithic fragments containing plagioclase and pyroxene phenocrysts. Thickness: 1 meter.

Weathered Layer: Tannish orange weathered layer in gradational contact with the upper part of the Liberia Formation. Thickness: 0.5 – 0.75 m.

Soil: A gray colored soil layer caps the sequence. Thickness: 0.25 – 0.5 m.

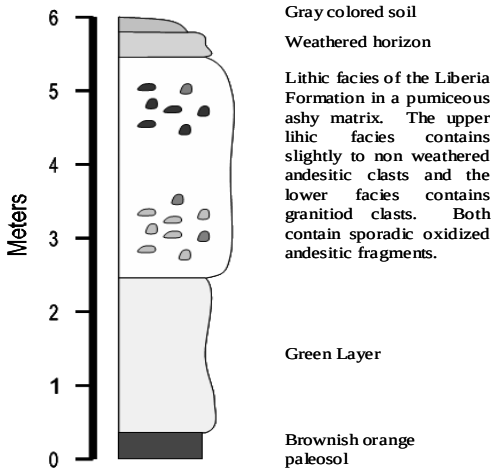

Figure 4: Stratigraphic column of the outcrop.

3.1.2 Clast Type and Size Distribution

In a statistical survey made in the lower and upper lithic facies of this outcrop, 195 sub angular lithic fragments were counted and an approximate density of 2.6 lithics per square meter was determined. Among these lithic fragments, three types were differentiated (Table 1): (1) highly weathered and oxidized sub angular andesitic lithics; and (2) slightly to non weathered light gray angular to sub angular granitoid lithics containing biotite, feldspar and quartz crystals are in the lower lithic facies; and (3) slightly to non weathered dark gray to black porphyritic locally vesicular andesitic

clasts containing plagioclase and pyroxene phenocrysts are in the upper lithic facies. Regarding the granitoid clasts in the lower lithic facies, coarse and fine-grained ones were observed. The coarse grained granitoids are smaller and more rounded than the fine grained ones.

Table 1: Three different lithic types found in the basal part of the Liberia Formation

Lithic type	Description	Count
1	Orangish sub angular highly weathered and oxidized (OxFe and OxMg) clasts.	84
2	Light gray angular to sub angular granitoid clasts containing biotite, quartz and feldspar.	96
3	Dark gray to black sub angular to sub rounded locally vesicular porphyritic andesite clasts.	15

Lithic clast sizes were measured randomly within the lower and upper lithic facies and the modal clast size was detemined to be 10 – 12 cm (Table 2).

Table 2: Statistical analysis of the three different clast types found in the basal part of the Liberia Formation

Lithic Type	Number of measurements	Minimum size (cm)	Maximum size (cm)	Average size (cm)
1	12	5	20	11.5
2	12	7	22	10.7
3	5	4	20	11.8

3.2 Laboratory Work

Of the five rock samples collected, thin sections were made of two (LP3-23-02-08 y LP3A-23-02-08), which are described as follows:

LPA3-23-02-08: Holocrystalline unaltered granular rock containing plagioclase, quartz, biotite > alkali feldspar > green hornblende, clinopyroxene and magnetite. Micrographic and myrmectic textures are observed. Classification: Granitoid (Figure 5).

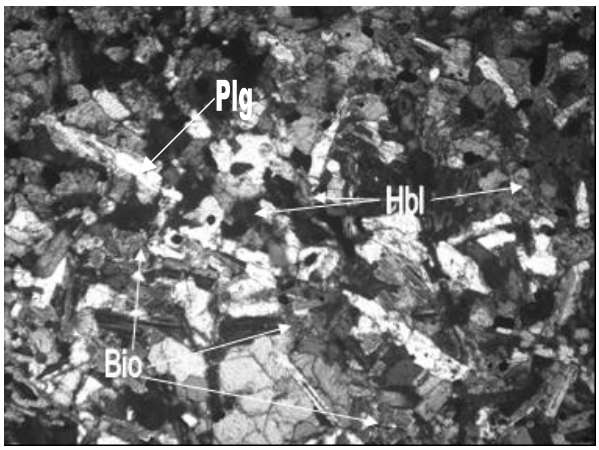

Figure 5: Microphotograph of rock sample LPA3-23-02-08. Plg: Plagioclase; Hbl: Hornblende; Bio: Biotite.

LPA3A-23-02-08: Large plagioclase, quartz and biotite crystals contained in a finer-grained holocrystalline matrix composed of quartz, plagioclase, alkali feldspar, biotite, green hornblende and magnetite. Micrographic and myrmectic textures are observed between quartz and alkali feldspar. Classification: Micro granitoid (Figure 6).

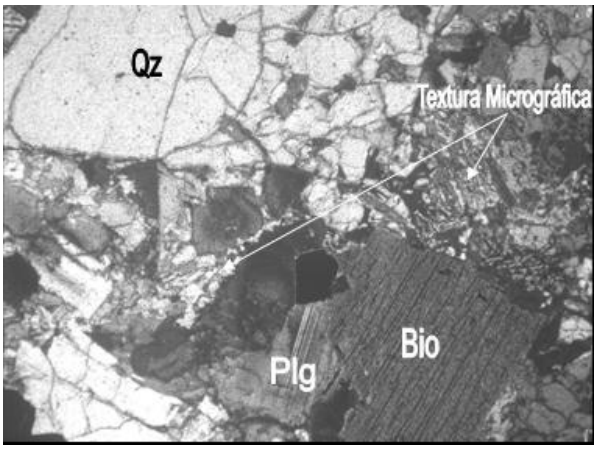

Figure 6: Microphotograph of rock sample LPA3A-23-02-08. Plg: Plagioclase; Qz: Quartz; Bio: Biotite; and Micrographic Texture.

These rocks are acidic in composition and contain equigranular crystals of quartz, biotite, plagioclase potassium feldspar and a small percentage (< 2%) of green hornblende. Also, micrographic texture is observed petrographically between quartz and potassium feldspar. The size, angularity and composition, of these clasts suggest that they come from a nearby source vent possibly related with the Liberia Formation.

3.3 Closing Remarks

The discovery of this outcrop is particularly important because it not only provides evidence for the existence of and granitoid clasts in the Liberia Formation but also made possible a petrographic description of and helps to understand the geometry of this rock formation as well as provide clues to its possible source vent area. This is because granitoid lithics have a mineralogic composition very similar to the Liberia Formation and may come from the same source vent. Moreover the angularity and size of these clasts suggest that they have been transported only a short distance.

The position of these granitoid lithic fragments at the base of the Liberia Formation suggests that due to their density they were among the first rocks to fall out of the flow and are near the source vent.

Approximately 700 meters south of the outcrop described in this paper another small outcrop of the Liberia Formation bearing much smaller granitoid lithic fragments (millimetric to a few centimeters) has been found, suggesting a greater distance from the source vent.

The rhyolitic composition and pumice content of the Liberia Formation suggest that it was produced by a violent Pleistocene eruption, possibly related to the formation of the Las Pailas Geothermal Field. Such a violent eruption may have caused important fracturing in the deep rock at the Las Pailas Geothermal Field.

More field work towards the north-northeast of the outcrop discussed in this paper (towards the nearby Rincón de la

Vieja volcanic complex) may reveal more granitoid lithics that are possibly greater in size, thus providing better clues to the location of the source vent for the Liberia Formation and a better understanding of the evolution history of the Las Pailas Geothermal Field.

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