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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

Edward Charles Hakanson

Geologist, BSc.

Guanacaste, Costa Rica

edward_hakanson@yahoo.com

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ABSTRACT

The Liberia Formation is a Pleistocene rhyolitic biotite and quartz bearing pumiceous tuff that crops out in the periphery of the Las Pailas Geothermal Field, located on the Pacific slope of the Quaternary Rincón de la Vieja volcanic complex in northwestern Costa Rica and is used as a marker bed in the Las Pailas borehole field. A recently discovered outcrop at the base of the Liberia Formation, 1.5 to 2 kilometers east southeast of the wellfield, is a granitoid bearing horizon restricted to a 2 meter thick bed and spanning approximately 75 meters. The size and shape of these granitoid blocks may provide evidence for proximity to the source vent that produced the Liberia Formation as well as the implications that the explosive eruption may have had during the evolution of the Pailas geothermal reservoir. Although the actual source vent of the Liberia Formation has not been fully identified, careful mapping of the spatial and modal distribution of these granitoid lithic fragments provides useful clues as to its location. This paper presents field data and geostatistical analysis of these granitoid blocks, 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 Pailas Geothermal Field.

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.

Introduction

Costa Rica is a Central American country located between Nicaragua and Panama and is formed by the interaction of the converging oceanic crust of the Cocos Plate and the continental

crust of the Caribbean Plate, which meet at the Mid-American Trench. The backbone of Costa Rica is formed by three main mountain ranges: the Talamanca Range in the southeast, the Central Volcanic Belt in the central part of the country and the Guanacaste Volcanic Belt in northwestern Costa Rica (Figure 1). These two volcanic belts are Quaternary in age. The Liberia Formation, which is widespread in northwestern Costa Rica, is related with the Guanacaste Volcanic Belt.

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



Figure 1. Location map of Costa Rica showing the interaction of the Cocos and Caribbean Plates, including the three main mountain ranges Costa Rica.

are most commonly andesitic suggesting that andesitic eruptions occurred either prior to or during the explosive plinian 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 clues about the possible evolution history of the Geothermal Reservoir at the Las Pailas Geothermal Field.

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 in an 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, Kemper (1997) reports that although the lithic clasts typically found in the Liberia Formation are porphyritic andesites, diorites and granites also rarely occur.

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 volcanic complex in Guanacaste, Costa Rica, there is a two to three meter thick outcrop of a lithic facies of the Liberia Formation (Figure 3), 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

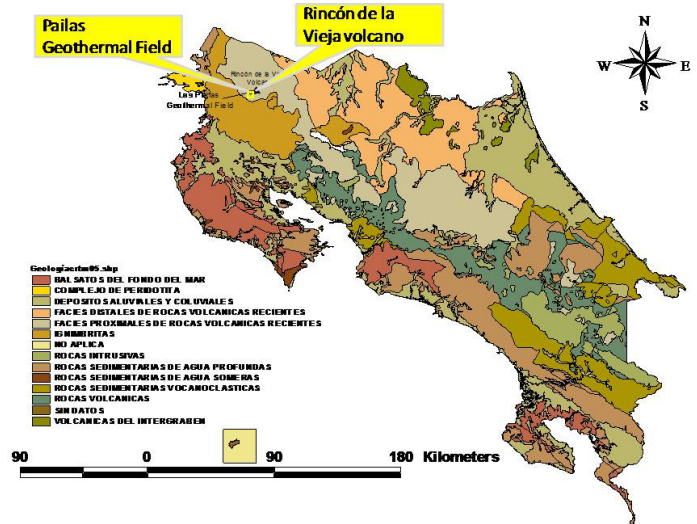


Figure 2. Generalized Geologic Map of Costa Rica showing the location of the Rincón de la Vieja Volcanic Complex and the Pailas Geothermal Field.

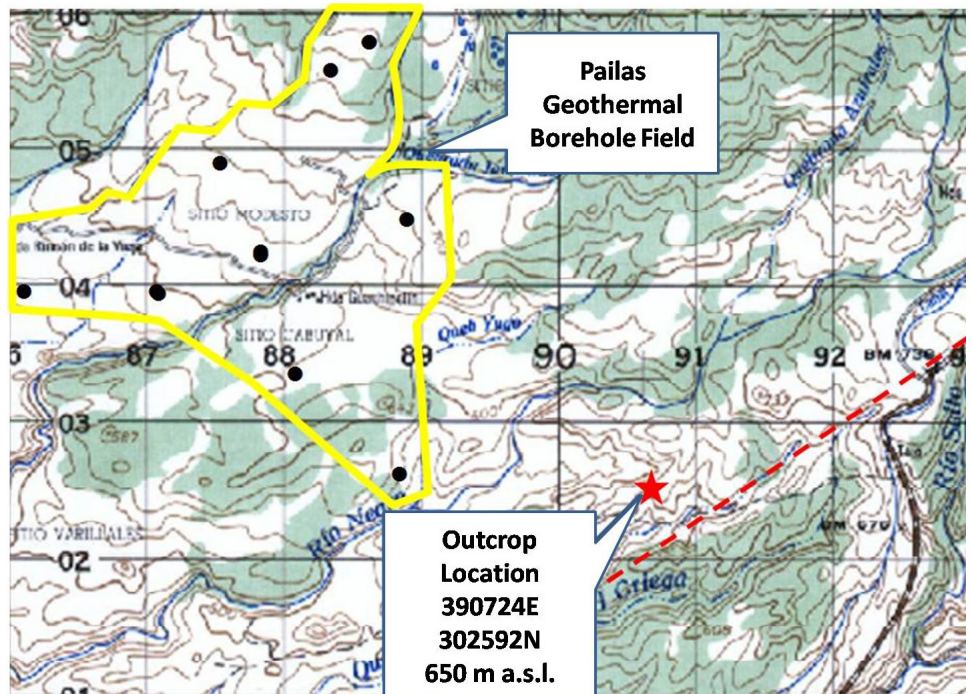


Figure 3. Location map of the granitoid bearing basal lithic horizon of the Liberia Formation. Curubandé 1:50,000 topographic base map using local Costa Rica coordinates (Lambert Norte). The outcrop is approximately 1.5 to 2 km to the ESE of the Pailas Geothermal Borehole Field.

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.

Fieldwork

During a field trip to the 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 lo-

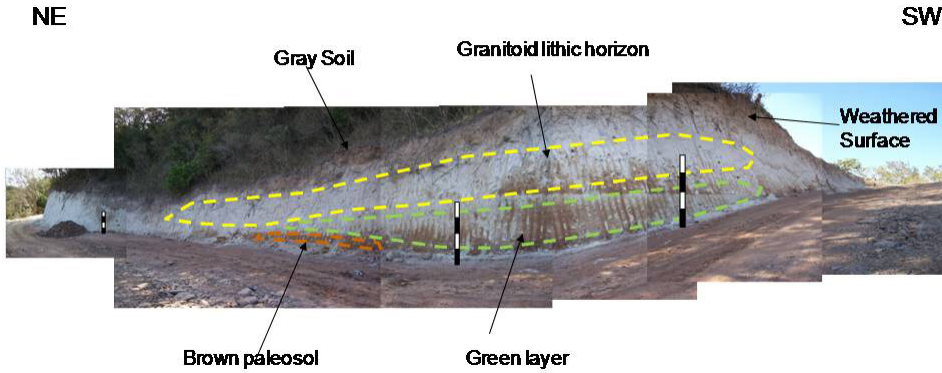


Figure 4. Panoramic view of the outcrop. The bar scale represents a 2 meter height and the outcrop spans approximately 75 meters.

cated 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 4).

Stratigraphy

The stratigraphic column measured at the outcrop (Figure 5) is four to six meters high. The chronostratigraphic (oldest to youngest) description of the stratigraphic column 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

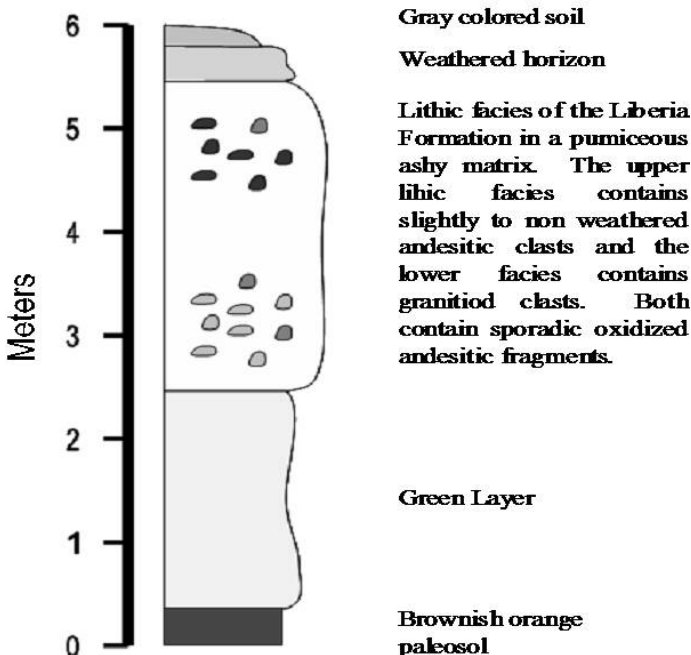


Figure 5. Stratigraphic column measured at the outcrop.

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 which contain 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.

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 clasts 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

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

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

observed. The coarse grained granitoids are smaller and more rounded than the fine grained ones are.

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

Laboratory Work

Of the five rock samples collected, thin sections were made of two (LPA3-23-02-08 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 6).

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 7).

These rocks are acidic in composition and contain equigranular crystals of quartz, biotite, plagioclase potassium feldspar and a

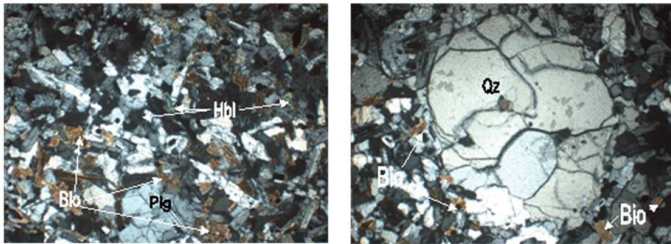


Figure 6. Thin section LPA3-23-02-08. Fine grained holocrystalline granitoid clast containing plagioclase, hornblende and biotite showing lath-shaped granular texture (left). Also, rounded quartz phenocrysts can be found in these clasts (right).

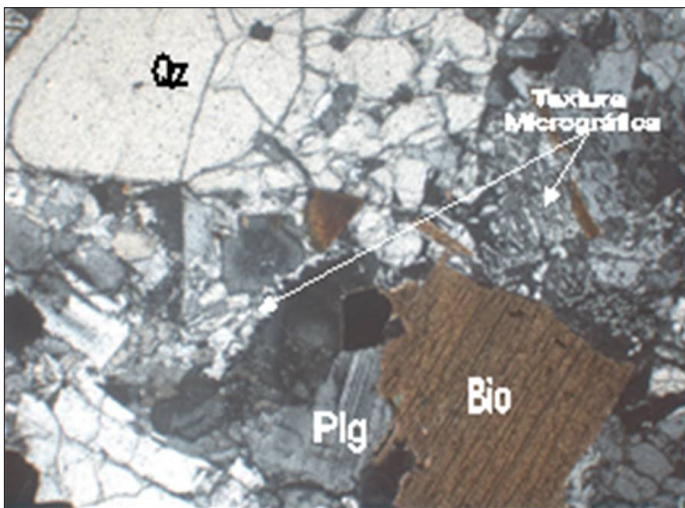


Figure 7. Thin section LPA3A-23-02-08. Coarse grained holocrystalline granitoid clast containing biotite, quartz and plagioclase crystals. Note also the micrographic texture where quartz and feldspar are mixing.

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 came from a nearby source vent possibly related with the Liberia Formation.

Closing Remarks

The discovery of this outcrop is particularly important because it not only provides evidence for the existence of these granitoid clasts in the Liberia Formation but also makes possible a petrographic description of them and helps to understand the geometry of Liberia Formation as well as provide clues to its possible source vent area. This is because these 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 they were among the first rocks to fall out of the flow, due to their density, and are near the source vent.

The rhyolitic composition and pumice content of the Liberia Formation suggest that it was produced by a violent Pleistocene eruption (or possibly numerous explosive eruptions), possibly related to the formation of the Las Pailas Geothermal reservoir. Such a violent eruption may have caused important fracturing in the deep rock (Aguacate and Bagaces Groups) at the Las Pailas Geothermal Field. The young age of the Liberia Formation (1.6 ma) therefore suggests that the Las Pailas Geothermal Field is rather young.

NE-SW striking fracture systems to the east of the Pailas Geothermal Field agree well with the the NE-SW strike of the Liberia Formation at this outcrop location.

The numerous amount, clast size and angularity of the granitoid lithics found locally at the base of the Liberia Formation suggest that they have not been transported very far from the source vent.

Additionally, the embayed, resorbed quartz crystals may have originated from a pre existing near surface location and could be associated with the conduit through which the Liberia Formation ascended.

No outcrops of the Liberia Formation are found within the Pailas Geothermal Borehole Field and thus far granitoid clasts have not been observed to the southeast of the outcrop presented in this paper.

However, a biotite bearing tuff that has been found in the deep wells of the Pailas Geothermal Borehole Field may be correlated with the Liberia Tuff.

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 clasts embedded elsewhere in the Liberia Formation that are possibly greater in size. This kind of field evidence would allow for a better modal size distribution analysis and more clues about the location of the source vent that the Liberia Formation came from.

Considering that the explosive nature of the eruption that produced the Liberia Formation may have played an important

role in the fracturing of the pre-existing rocks of the Bagaces and Aguacate Groups, a better understanding of Liberia Formation provides clues about the evolution history of the nearby Las Pailas Geothermal Reservoir, regarding age and the volcano-tectonic activities that may have occurred during its formation.

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