GALAPAGOS ISLANDS

A GEOLOGICAL FRAMEWORK RELATED TO THE OUTER LIMITS BASE ON THE NATURAL PROLONGATION ON THE CARNEGIE, COCOS, AND COLON RIDGES.

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GEOLOGICAL CONTEXT

The seabed off the coast of mainland Ecuador and around the Galapagos Islands reflects a complex interplay of active tectonic processes. The Islands are situated at the nexus of three ridges: Colon, Cocos, and Carnegie. The region’s primary geodynamic features include: the Galapagos Spreading Centre (GSC), occupying the Colon Ridge and separating the diverging Cocos and Nazca Plates; the Galapagos Hot Spot (GHS), lying northwest from the Fernandina Island[1], and giving rise to the Galapagos Volcanic Platform (GVP); the Peru-Chile Subduction Zone, consuming the Carnegie Ridge as it plunges beneath the South American Plate, the Carnegie Ridge (CAR) as an underwater aseismic volcanic ridge oriented to the east as a hot spot track, located at the north-western corner of the Nazca plate, the Cocos Ridge (COR) migrating north-eastward for the past 5 Ma[2], and southeast of East Pacific Ridge, and the Colon Ridge (CLR) as a ridge mainly formed on the GSC (Figure 1)

The Galapagos hotspot (GHS) is closed to the GSC, as a result different mantle sources and the different melting conditions are identified along the GVP[3], modifying the geochemistry composition of the seafloor surrounding; consequently, their basalt composition is different in the (GVP)[4]. In the area adjacent the GSC has more influence with mid ocean ridge basalts (MORB) modified by the plume-ridge interaction toward the direction of the islands. This initial point is important to understand the relationship between the plume and ridge interaction in their geological origin and evolution. The high content of $^{3}He/^{4}He$ ratios has found in Fernandina

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[1] Kurz, M. D. & Geist, D. (1999). Dynamics of the Galapagos hotspot from helium isotope geochemistry. Geochemical et Cosmochimica Acta 63, 4139–4156.

[2] Wilson, D. S. & Hey, R. N. (1995). History of rift propagation and magnetization intensity for the Cocos–Nazca spreading center.Journal of Geophysical Research 100, 10041–10056.

[3] DENNIS GEIST1, TERRY NAUMANN, AND PETER LARSON, Evolution of Galápagos Magmas: Mantle and Crustal Fractionation without Assimilation, Journal of Petrology, RECEIVED APRIL 8, 1997; REVISED TYPESCRIPT ACCEPTED DECEMBER 2, 1997,

[4] McBirney A., 1993, In magmatic processes and Plate Tectonicas, Geological Society Special Publication N0. 76, from Prichard, H.M. A. and et al, Differentiated rocks of the Galapagos hotspot, Geological society spetial publication.

Island where is located the GHS[5]. This composition is usually found in Ocean Island Basalt (OIB)[6].

The plume material feeding to the COR as a melt is part of the GSC and part comes from GHS. The tectonic history of the GVP has been summarized by Wilson & Hey (1995), Meschede & Barckhausen (2000), Barckhausen et al. (2001) and Werner et al. (2003). The formation of the CAR,COR, and CLR occurred as a result of the break up of the Farrallon Plate 23 million years ago. [Hey et al, 1977; Lonsdale and Klitgord, 1978; Meschede and Barckhausen, 2000], creating two new plates, the Cocos Plate, under the Panama Basin, to the north, and the Nazca Plate, under the Peru Basin, to the south.

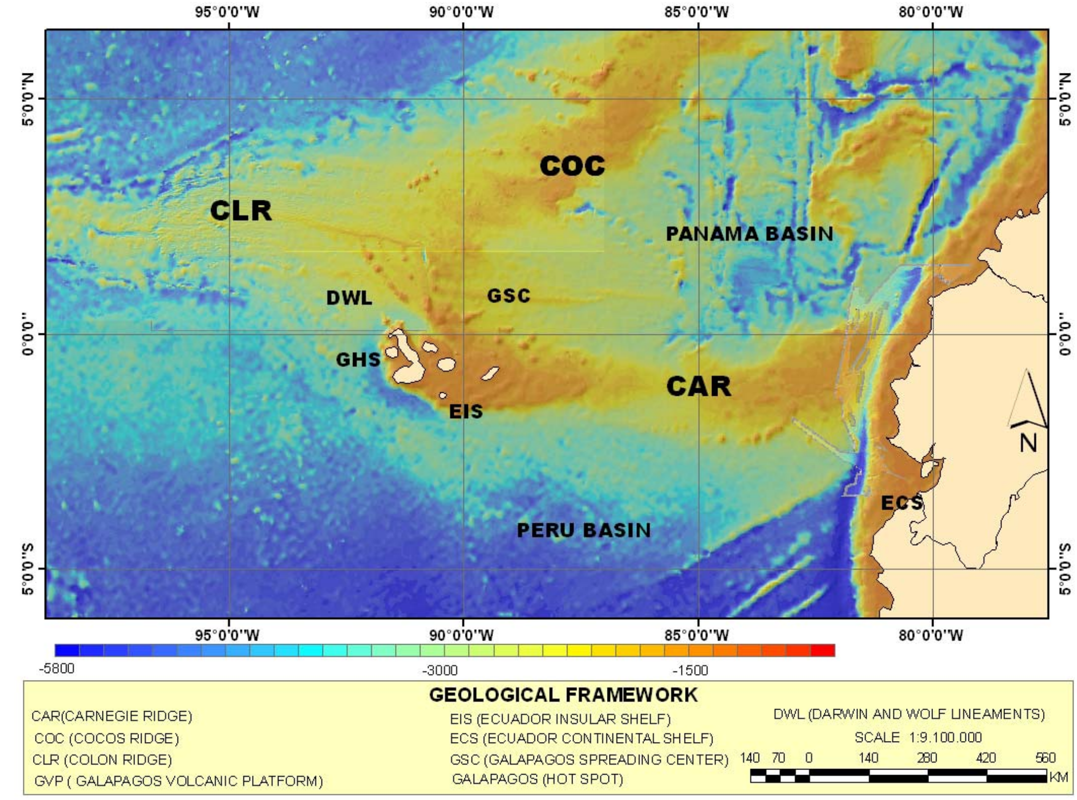

Figure 1. Seafloor mapping and major geological features on the study area.

Location of the CAR, COR and CLR, which are the natural components of the GVP.

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[5] M. Kurz, D. Geist, Dynamics of the Gala´pagos hotspot from helium isotope geochemistry, Geochim. Cosmochim. Acta 63 (23/24) (1999) 4139– 4156.

[6] Thomas Find Kokfelt, Craig Lundstrom,T, Kaj Hoernle, Folkmar Hauff , Reinhard Werner. Plume–ridge interaction studied at the Galapagos spreading center: Evidence from 226Ra–230Th 238U and 231Pa–235U isotopic disequilibria, Leibniz Institute for Marine Sciences (IFM-GEOMAR), Received 23 February 2004; received in revised form 7 February 2005; accepted 18 February 2005 Available online 12 April 2005

The formation of the CLR varies with the spreading rate of the GSC, and is not the only variable controlling ridge formation, the magma supply is also important in their formation and it depends of the distance from the GHS. Its tectonic history is base on rift propagation and ridge jumps to the south forming new spreading centers near the GHS[7]. The spreading center is influenced by the GHS to the south and from Nazca and Cocos boundary to the north.

THE CARNEGIE RIDGE (CAR)

The CAR, which is a hotspot trace of GHS, is considerate one of the extension of the GVP as a natural prolongation of the Ecuadorian continental shelf related to article 76 UNCLOS, moves along with the Nazca Plate in relative to the GHS. The CAR stands 1.2 to 2.7 km higher than the surrounding seafloor, and presently is being subducted beneath the South American plate. Support for the GHS as a source of material is the excessive volcanism in the GVP. The western flank could be considerate as a part of the GVP due to the not presence of deformations or structures that can separate from the CAR. The CAR evolution is observed inclusive in the saddle where the age is between 10 m.y. ago[8] based on magnetic data and rock sampling age[9], this specific area shows reduction of volcanic material emplaced on the Nazca Plate. This could be related to the ridge jumps between 14.5 to 7.5 Ma and the northward migration of the Cocos-Nazca spreading centre (CNSC) away from the Galapagos Hot Spot (GHS) [Hey et al., 1977; Hey 1977; Barckhausen et al., 2001].and the lithologic continuity can be inclusive to extend as far as a part of the basement from mainland Ecuador in the Piñón Formation.

The paleo- morphology existence is other evidence characterized by volcanoes that now are active in the Galapagos Islands, and seamounts laterally located of the CAR that suffering subsidence due to the thermo cooling located. If those seamounts are part of the evolution process of the hot spot tracking then the continuity could be identified.

Based on the interpretation of volcanic rock samples collected along CAR, Werner and Hoernle [2003] described drowned islands and classified the adjacent seabed as guyot-shaped seamounts, perhaps based upon paleo-beach or intertidal wave-cut platform deposits on the east and west ridge.

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[7] Canales et. Al.,1997, JGR

[8] Barkhausen and meschede, 2001

[9]

Those aspects would be considerate inside the studies to establish the natural prolongation. Moreover, the morphology continuity, the evidence of pre-existing morphology from volcanic basement, natural contours following the eastward elongated shaped as a tracks of GHS, and the eastward seamount trends are the morphology evidence for this hypothesis.

The sediment thicknesses are thin because very young oceanic crust, this graphic can help to understand the characteristics of the region. Figure 2

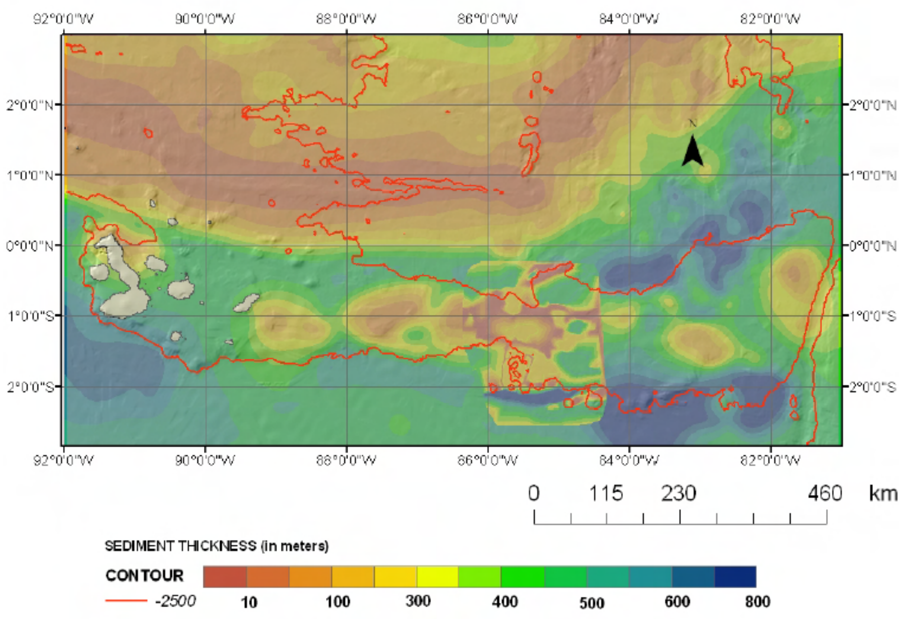

Figure 28. Sediment thickness along the Carnegie Ridge. The saddle area and hills are characterized by the absence of significant sediments.

THE COLON RIDGE (CLR)

CLR is product of interaction between the GSC and the GHS, in an east wet direction, separating the Cocos and Nazca plates. Along its axis changes in magma supply related to the nearby GHS is observed in the morphology. The crustal thickness was identified in the west part of the ridge of ~5.6 Km. [10].The plume influenced on magma supply is mainly observed in an area surrounding ~350km. from the GHS. Likewise, the compositional plume anomaly may extend for ~500 km along the CLR.

THE COCOS RIDGE (COR)

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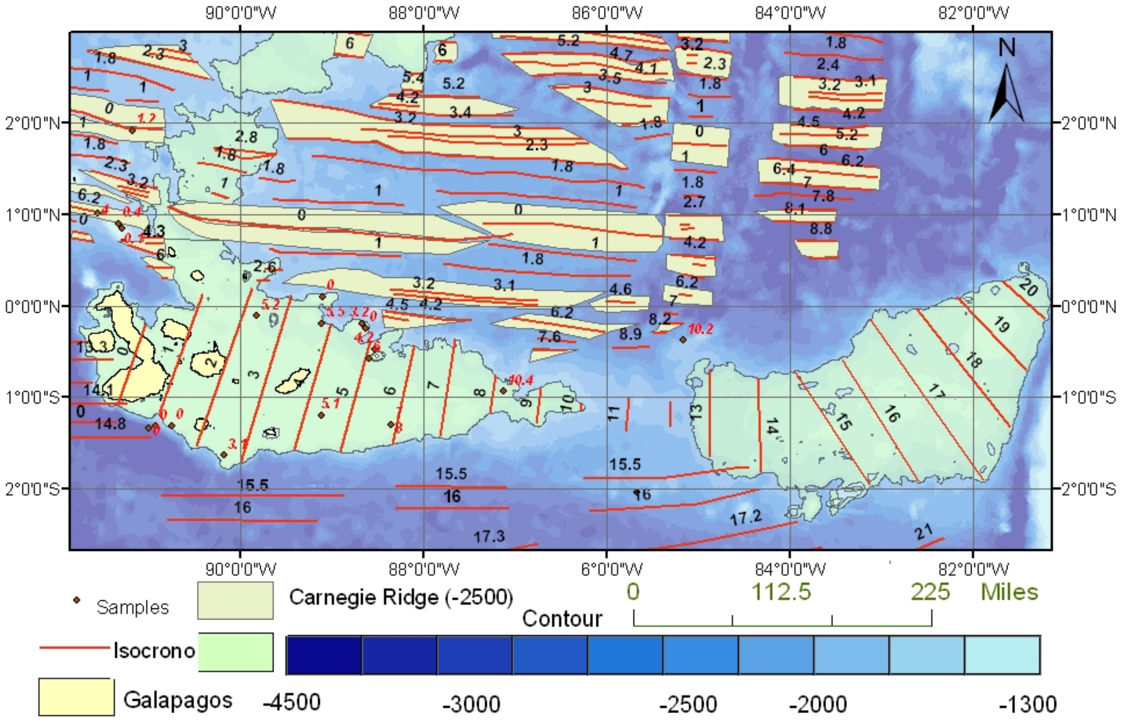
[10] J.P. Canales et al. / Earth and Planetary Science Letters 203 (2002) 311^327

COR is product of interaction between GSC and the GHS, in a northeast southwest direction, part of its curst in the Nazca and Cocos plate. Along its axis changes in magma supply is observed and it is related as a hot spot track.

NATURAL PROLONGATION

The seafloor of the Galapagos Islands is characterized by a platform on which are settled all its islands. Geomorphologic is formed by the CAR, COC, and CLR, which are considerate as a natural extension of the Ecuador Insular Platform (EIP). These three ridges can be considerate as submarine ridges, although they have oceanic crust formation, if since their origin can understand that their crust is different from the adjacent seabed. This point of view can be observed in the paleo reconstruction, base on the origin of crust and their origin reflects the complex tectonics of the area (figure 3).



Data source: Barckhausen 2001; Wilson and Hey,1995; Christie and Sinton,1996
Ages are based on the Geomagnetic Polarity Scale (Cande,S.C.,and Kent, D.V.1995)
Red Age are based on the Isochron age +/_ 1(Ma) Sinton ET.AL. 1996

Figure 3. Age prediction for the CAR. Compiled according to magnetic reversal time scale and reconstruction based on aging samples and magnetic anomalies in the CAR. [Integrated and modified [*Meschede and Barckhausen*, 2001], [*Wilson and Hey*, 1995], and [*Barckhausen et al*, 2001]].

The CAR age of the formation, based on magnetic anomalies, age of samples, and reconstruction [Meschede and Barckhausen, 2001] is older moving from west to east. This increase in the age of the ridge is related to reconstruction and to anomalies in the ridge–trench junction area close to 20 Ma [Hey, 1977; Lonsdale, 1978; Wilson and Hey, 1995; and Barckhausen et al., 2001]. In the eastern area of the section that includes the Galapagos Islands, the youngest crust is associated with active volcanism.

The age pattern obtained from volcanic samples suggests that the origin of the CAR was a hotspot [Christie et al., 1992; Meschede and Barckhausen, 2001]. The CAR is clearly a physical extension of GHS. COR has volcanic samples and similar origin and evolution than the GVP (Sallares, 2004). Morphologically continuous is observed from the bathymetry, dated seamounts show an age progression as indicated in the figure 2, and morphological evidence of drowning[11]. Additionally, plate tectonic models, first by Duncan and Hargaves, more recently by Meschede and Barckhausen:(Meschede, M., and Barckhausen, U., 2000). Plate tectonic evolution of the Cocos-Nazca spreading center were analyzed in Silver, E.A., Kimura, G., Blum, P., and Shipley, T.H. (Eds.), Proc. ODP, Sci. Results, 170 [Online]. Some additional models can support this natural prolongation base on geochronology. Finally, the oceanic crust is older, comes from the Farallon plate, south of the CAR than from younger lithosphere with the thicker more buoyant CAR crust.

The CAR along its entire length lies inside the outer edge of the Ecuador Island Margin (EIM) and the foot of the slope of the EIS is geomorphologic located at the end of the north and south slope. It shares the geological characteristics and its origin is the GHS. In sense, the CAR is defined in this study as a submarine elevation, due to be a natural component of the GVP.

The geological continuity base on the Galapagos Island origins and basalt composition are important to understand the natural prolongation. The CAR, COC, and CLR are defined as the submerged prolongation from EIM, referred to as the principle of geological continuity.

The CAR has geological, morphology, and tectonic setting related to the Galapagos Islands, therefore, it is a natural component of the EIM.

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[11] Cristhie D., 1992, Nature

The CLR, represents the boundary where the Cocos and Nazca Plates separate, and has been constantly modified base on the moving of the GSC relative to the hot spot [Hey, 1977; Lonsdale and Klitgord, 1978; Wilson and Hey, 1995; Wilson, 1996; Barckhausen et al., 2001].

The COR is part of the limit boundaries between Costa Rica and Ecuador so their natural extension beyond 200 miles can be defined by the natural extension in the middle line that is the existing boundary and a joint submission can be presented. Fig.4)

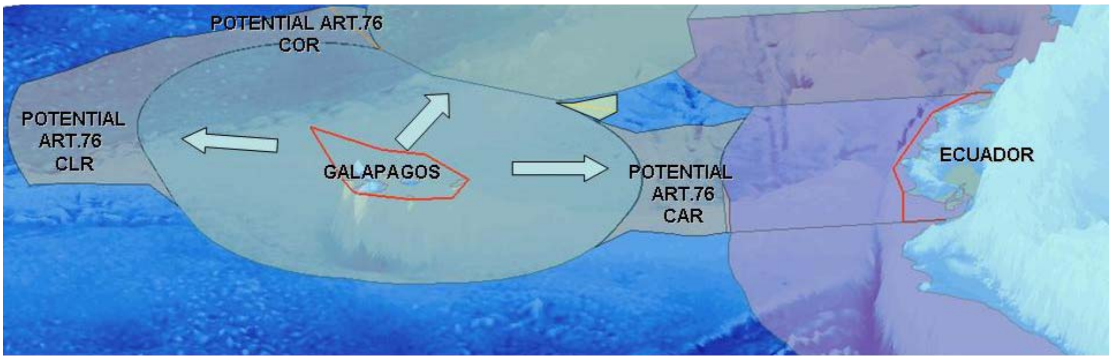

Figure 4. Ecuadorian potential outer limits beyond 200 miles. Straight baselines are in red. Outter platfarm beyond 200 miles in clear yellow

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