Tectonics in the Central Patagonian Cordillera related to Mio-Pliocene subduction of the Chile Ridge: Preliminary morphological, chronological and geochemical evidences

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Introduction

The Lago General Carrera – Buenos Aires (LGCBA, Chile-Argentina border, 46°30'S) region is located precisely above of where recent paleotectonic reconstructions place the Chile Ridge segment subducted ~6 Ma ago and the corresponding opened slab window under the South American Plate (Fig. 1). One important morphologic feature of this area is that it concentrates the highest and the deepest topographic levels in Patagonia: the San Valentín Mount (4058 m.a.s.l) and the EW-NW of LGCBA (-385 m.a.s.l); together with young plutonic bodies exposed at the lake level (200 m.a.s.l). Another interesting feature is the existence, at 2000 m.a.s.l, of wide plateau-like surfaces on top of the frontal cordillera at both north and south sides of the LGCBA. These plateaus were constructed by flood magmatism (starting at ~12-10 Ma, age of basal lavas at Meseta Chile Chico -MCC- and Meseta del Lago Buenos Aires -MLBA-) lasting up to ~4 Ma. In these plateaus, equivalent Early Pliocene basaltic lavas suggest the existence of prior continuous volcanism, and therefore the LGCBA depression development could have been tectonically generated after magmatism ends. Furthermore, several evidences of Late Miocene-Pliocene uplift are found in these plateaus.

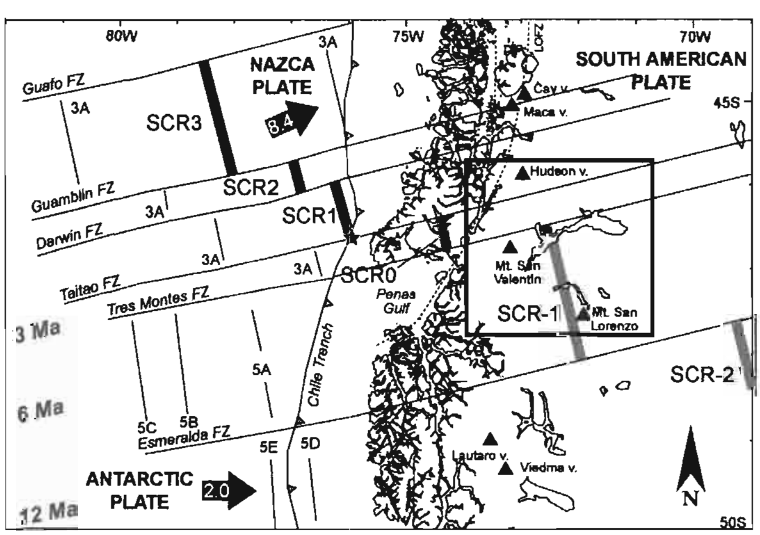

Figure 1: Tectonic setting of Southern South America showing the distribution of oceanic Fracture Zones (FZ) and South Chile Ridge segments (SCR 3 to SCR-2) (after Cande and Leslie, 1986). Gray numbers are the collision age of each segment. Black arrows indicate relative motion of the Nazca and Antarctic Plate with respect to the South American Plate; numbers in there are relative velocities in cm/yr (De Mets et al., 1990). Expected position of subducted segments of the Chile Ridge below the South American Plate (SCR 0 to SCR-2) is represented as thick grey lines. LOFZ: Liquiñe-Ofqui Fault Zone; grey triangles are recent volcanoes; black triangles are the highest picks of the Southern Andes. Location of the study area is shown by a frame (modified from

Lagabrielle et al., 2004).

Geotectonic Setting and Local Geology

The Chile Ridge is now left-obliquely subducting under the South American Plate (Cande and Leslie, 1986). It started subducting ~15 Ma ago at Tierra del Fuego latitude (55°S) and migrated northward, as the present-day relative motion vector of the Nazca Plate is oriented N80 (DeMets et al., 1990), up to its actual position in the Taitao Peninsula (46°S; Fig. 1). The studied LGCBA area is located in the back-arc region at the present-day latitude of the Chile Triple Junction (46°30'S), 350 km east from the Chile Trench, in a zone where Quaternary volcanism is lacking (Fig. 1). The MCC and MLBA basaltic plateaus, located in the south side of the LGCBA, form part of a widely spread magmatic province named "Neogene Patagonian Plateau Lavas" (Gorring et al., 1997; Gorring and Kay, 2001). Tectonic was active throughout the Cenozoic in the study area, starting in mid-Cretaceous times, with contractional, extensional and strike-slip events (Suárez and De La Cruz, 2000; Lagabrielle et al., 2004). Important phases of mountain building took place since Late-Early to Early-Middle Miocene, with evidences of rapid exhumation and erosion during the Late Miocene-Early Pliocene (Morata et al. 2002). The orographic front of the Patagonian Cordillera is well exposed in the area of study, with the cordillera mainly formed by the Jurassic Ibáñez Formation, thrusted toward the east, over Cretaceous and Cenozoic rocks (Suárez and De La Cruz, 2000; Lagabrielle et al. 2004) (Fig. 2). Recent field work shows that the cordilleran front presents a clear segmentation as the presence of N170 en échelon trending blocks is interpreted to be the result of a dextral transpressional deformation compatible with the oblique direction of convergence between the Nazca and the South American plate (Lagabrielle et al., 2004). Tertiary record in the area of LGCBA consists of thick sedimentary successions (marine and continental) and subaerial flood basalts, which represent the actual erosion surfaces in both mesetas (Fig. 2). Miocene and Pliocene isolated plutons crop out in the region south of the lake (see Suárez and De La Cruz, 2001), east of the Patagonian Batholith. The latter is a continuous body, sub-parallel to the present coastline, about 1000 km long and up to 200 km wide of Late Jurassic to Pliocene arc-related intrusive rocks (Fig. 2).

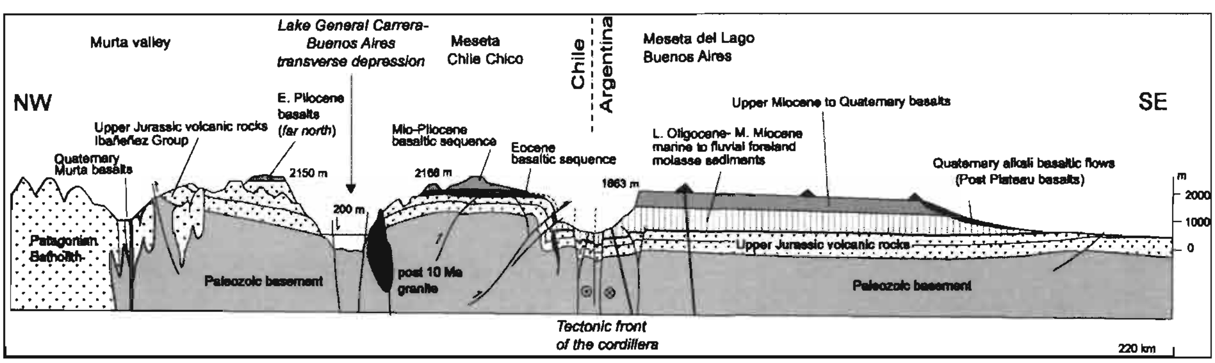

Figure 2: Simplified NW-SE geological section through the Southern Andean cordillera at the latitude of Lago General Carrera- Buenos Aires (46.5°S), from the Patagonian batholith (Chile) to the foreland basin (Argentina), inferred from surface geology (scale in the figure, modified from Lagabrielle et al., 2004).

Magmatism and Chronology

The Miocene magmatic history of the studied area is represented by a thick basaltic pile forming the MCC and MLBA plateaus together with some isolated plutons. These plateaus are chronologically and geochemically equivalent (Espinoza et al., 2005), then possibly they represent one big pre-Late Miocene basin fulfilled by flood basaltic lavas. Today, this plateau appears dissected by the Jeinemeni River which flows from the south to the

LGCBA,. Part of the basaltic sequence in both mesetas shows a particular "transitional" chemical signature (between alkaline and calcalkaline with Nb and Ti negative anomalies; see Espinoza et al., 2005) which it is distintive from the locally more common "primitive" basalts (OIB-type signatures). As reported by Espinoza et al. (2005), the highest (and youngest) lava flow forming the Mio-Pliocene Upper Basaltic Sequence of MCC is .4.4 Ma old, and shows this transitional signature (Fig. 3). One sample collected on top of the flat surface exactly north from MCC (Avellanos surface), on the other side of the LGCBA, yield a K-Ar whole rock age of 4.57 Ma and also shows a transitional signature (Fig. 3). After ~4 Ma, the complete opening of a slab window under the east border of the large plateau (today the east side of MLBA) generates unique highly HFSE-enriched magmas (<3 Ma post-plateau lavas of Gorring et al., 2003; Fig. 3) which postdate both the construction of the plateau and also the main uplift episode (see below). The plutonic activity is represented by the subduction-related Paso Las Llaves and the Las Nieves granites, which yield 10 and 3 Ma Fission Tracks ages, respectively (Morata et al., 2002), concordant with previous K-Ar, Ar-Ar and Rb-Sr ages (Petford and Turner, 1996; Pankhurst et al., 1999; Suárez and De la Cruz, 2001). Magmas forming the older granite probably act as a contaminant (among others) which account for the transitional signature in MCC magmas, as evidenced by the presence of ~9 Ma rhyolites with similar arc signature intercalated with the basalts (Espinoza et al., 2005).

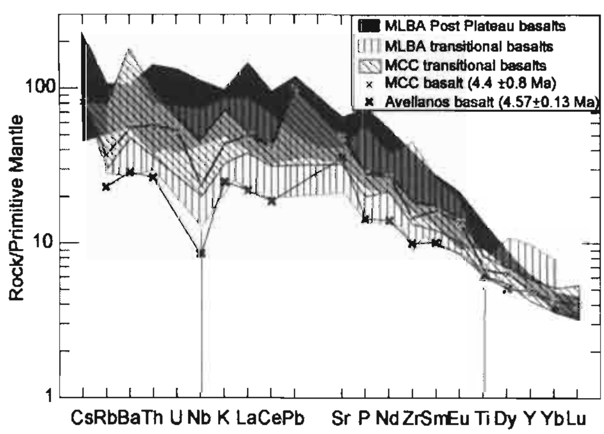

Figure 3: Primitive mantle-normalized trace elements diagram for Early Pliocene basaltic lava flows at the top of Meseta Chile Chico (MCC, Espinoza et al., 2005) and north of Lake General Carrera (Avellanos surface). Note the overall similar transitional signature of both lavas and their correspondence with basalts forming the Mio-Pliocene sequences at MCC and MLBA. Also note the very different (enriched) patterns of MLBA post-plateau lavas (Gorring et al., 2003)

Evidence of Late Miocene-Pliocene tectonism in LGCBA region

In both mesetas, fluvial matrix-supported conglomerates with granitic fragments and coarse-grained till sediments, appear intercalated with the Miocene lavas (6- 4 Ma). The first deposit probably evidences some tectonic event (see below) during basalts extrusion, and the last sediments have allowed to date the oldest Cenozoic glaciation in the southern hemisphere (7-5 Ma; Mercer and Sutter, 1982; Ton-That et al., 1999). At present, these sediments outcrop at 1700-2000 m, which is the mean elevation of the cordillera in Central Patagonia, and form sub-planar surfaces on top of the landslide, evidencing major uplift. In MCC, the local existence of young lava flows (~4-5 Ma) at low altitudes (lower than other flows with similar ages), and poured over ~12 Ma basalts, could indicate post 12 Ma tectonism (relief inversion), lava flowing over partially eroded surfaces or incision occurring in surfaces where lava flowed due to slope changes. In the southwestern side of the MLBA, several ~1 Ma lavas (Post Plateau basalts) flowed in little valleys incised in older (~3-4 Ma) flows, evidencing a Pliocene slope change, probably as a consequence of vertical movements. Another important aspect is that the highest elevations of the southern Andes (near 4000 m.a.s.l; main cordilleran altitude <2000 m) are found in the vicinity of the LGCBA (Fig. 1), and correspond to two Cenozoic granitic bodies: The San Valentín Mount (4058 m), which belongs to the Patagonian Batholith and forms part of the North-Patagonian Ice Cap basement, and the San Lorenzo Mount (3706 m), where a summital pluton yields an Ar-Ar age of ca. 6 Ma (Suárez and De La Cruz, 2001). As minor Cenozoic granites described above, their Mio-Pliocene ages of crystallization suggest rapid exhumation rates and consequently high rates of denudation and erosion.

Conclusions

Field and morphologic evidences indicate the occurrence of intense tectonic activity (mainly vertical -uplifting-, expressed in several different ways) in the area of LGCBA after ~6 Ma, when one segment of the Chile Ridge (SCR-1, Fig. 1) collided with the Chile Trench. Other previous tectonic events (post ~12 Ma) could be ascribed to the subduction of the Esmeralda fracture zone. These ridge features represent zones of weakness in the oceanic lithosphere, which would allowed the anomalous hot mantle material under Patagonia (Gorring et al., 1997; Murdie et al., 1999; Morata et al., 2002; Espinoza et al., 2005) to arise from deep levels and trigger a thermally driven uplift in the above area. The chemical data presented here for basaltic flows at both sides of the LGCBA account for the hypothesis presented by Lagabrielle et al (2004) where these lavas are supposed to form a large basaltic surface that was later deeply incised (post 4 Ma), probably by structures that tectonically controlled the development of the depression. Clearly, the glacial effect on the generation of the lake depression is irrefutable, as a well preserved system of near 12 terminal moraines east of Lago Buenos Aires, in Argentina (dated between 1.168±0.007 and 1.016±0.005 Ma, known as the "Greatest Patagonian Glaciation"; Ton-That et al. 1999) occurs. But this effect was perhaps initially induced by a tectonic event. The same type of assumption could be made for the trace of river Jeinemeni, which would have dissected the large basaltic plateau formed by MCC and MLBA in Late Miocene times. The development of planar surfaces in some segments of the frontal cordillera covered by the sub-horizontal flood basalts (12-4 Ma) has been ascribed to the occurrence of a period of peneplanation after dextral transpression and a first uplift phase of the region (Late Oligocene-Middle Miocene; Lagabrielle et al., 2004). The extrusion of major part of the basalts would have occurred in areas of low uplift rates (locally not compressive), east of the frontal cordillera, where low depressions accumulated the lava flows. Processes like relief inversion, slope variations and incision of basaltic surfaces would occur as uplift continue, maybe up to present days.

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