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Different plutonic events in extra-andine southern Patagonia, Chile

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Introduction

In Ultima Esperanza province, southern Patagonia, there are three Cenozoic plutons outcroping in the extra-andine zone, considered by [1] as part of a major north-south lineament of plutons (Fig.1). They intrude Upper Cretaceous rocks of the Magallanes basin and they are located aprox. 60 Km east of the Southern Patagonian Batolith (SPB). From north to south they are: Torres del Paine, Cerro Donoso and Monte Balmaceda plutons (Fig.1). Due to their closeness (they dist each other less than 50 km) and their predominant granitic litologies, they have been considered as generated in the same magmatic event during Miocene times (e.g. [1, 2]).

The most studied pluton of this group is Torres del Paine [1, 2, 3, 4, 5, 6, 7], in which it is possible to distinguish 3 main units: The Paine granite (PG); the Paine Mafic Complex (PMC); and the external gabbro (EG). It is argued by [4] that the EGis not cogenetically linked with the PMC rocks – supported by older ages of the external gabbros [5]- but the PMC and the PG, are considered to be consanguineous [4]. Even in the Paine complex, not all the magmatic rocks are considered to be cogenetic, it is not clear if either the granitic or dioritic rocks from Cerro Donoso and Monte Balmaceda are genetically linked with those of Torres del Paine.

Over the basis of field observations; petrology and geochemical data (mainly trace elements), we discuss how linked may be the magmas that originate these massifs, and their possible sources.

Petrography

The PG is composed mainly by silica-rich biotite granite and biotite/hornblende granites [4, 7]. They differ from the PMC which consists of monzonites, gabbros and dioritic rocks [4]. All units are cut by basaltic and/or rhyolitic dykes. There are mingling textures between felsic and mafic rocks in the contact zone between the PMC and PG units. This

suggests that both magmas coexisted in "plastic state".
The Donoso pluton (DP) is quite homogenous. It consists of a main biotite/hornfels granodiorite and a minor quartz-diorite facies. Dykes, principally rhyolitic, but also basaltic, are found nearby the main body.
In Monte Balmaceda there are disconnected outcrops, where three main lithologies are found: a perthitic leucogranite (BLG); an enclave rich granodiorite, and mafic rocks, including a massive diorite and enclaves in the granodiorite, here called Balmaceda Mafic Complex (BMC), where is possible to distinguish large areas of mingling between mafic and felsic magmas, and evidences of coexistence between them.

Geochemistry

Because the studied area has been affected by glaciation, the samples are quite altered and consequently the geochemical analyses considered in this work are mainly of trace elements. For comparison the plots are put together with the plots of Neogene rocks from the SPB, representing arc derived magmatism [8].
Major elements geochemistry shows that most of the samples are more alkaline than those of the SPB. Only DP and EG samples plot completely in the subalkaline field (Fig. 2a). Torres del Paine and Monte Balmaceda complexes have the greatest content in alkalies.
General trace elements patterns shows that EG, PG, PMC and DP, follow the SPB arc pattern (Fig 2b &c). Nevertheless, PG has major content of Nb –whose depletion is characteristic in arc derived magmas–than SPB. This also occurs with Zr and LREE. Only the aplites and miarolitic granites from Paine complex differ clearly with the SPB pattern (fig. 2b). Besides, BLG and BMC samples have different patterns than SPB (Fig. 2c), where BLG are very similar to the miarolitic granite samples from Paine complex.
Some remarkable geochemical features are found in the strong depletion of Ba and Sr in miarolitic granite samples from Paine complex and in the BLG (Fig. 2b &c). Even Sr content may be affected by meteorization and/or alteration processes, the Sr anomaly is supported by low CaO content (< 1% wt) and strong Eu anomalies of these samples (PG most silicic sample has Eu/Eu*= 0.1), similar to the BLG (Eu/Eu*=0.09-0.2) (Fig. 2d &f)). The 3 plutons are enriched in LREE respect to the SPB, and only Monte Balmaceda complex samples have higher HREE than the SPB. Nevertheless, DP differs with Torres del Paine samples in HREE pattern, where TdP is flatter ($(Dy/Yb)_N$ = 0.98-1.3 for TdP *vs* 1.1-1.8 for Donoso).

Discussion and conclusions

The evidence presented shows substantial differences between the different plutonic units which allow refuting the hypothesis that all the plutons have been originated in the same magmatic event. However, the magmatic rocks geochemical differences suggest at least two different sources for their magmas, and each source may be related to a different magmatic event. In this way, the DP and EG have affinities with the SPB patterns,

sugesting that these plutonic rocks are derived from arc magmatism.
Otherwise, Paine and Monte Balmaceda complexes share many features, including the large areas of mingling and the coexistence of felsic and mafic magmas. Chemically both are alkali rich and present bimodal features. It is remarkable that the most silicic samples differ strongly with the basic ones (PMC and BMC) in the spidergram features. All this data suggest that both complexes may have a similar origin. Nevertheless, the magma source for these complexes is not fully constrained. Some possibilities are suggested by [4], and we also propose as a possible source strong contamination of arc derived magmas.

Acknowledgments
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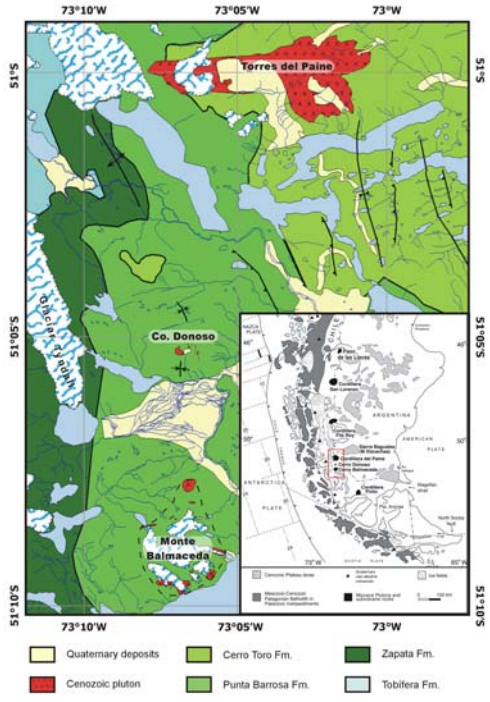

Fig. 1: Geologic Map of Ultima Esperanza province. Modified from Soffia, 1988; Wilson, 1991 and Sernageomin 2002.

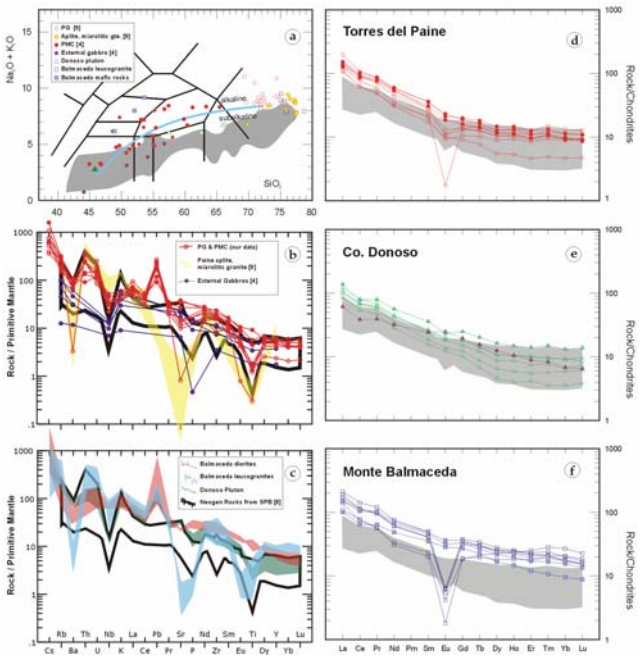

Fig. 2: Geochemical diagrams. (**a**) Most of Torres del Paine and Balmaceda samples are more alkaline than those of the SPB measured by [8] (shadow). The exception for Torres del Paine complex are the EG samples. (**b**) and (**c**) are sipider-grams from Sun&McDonough, 1989. The SPB [8] and aplite PG [9] samples have not Pb measurement It is possible to note that DP and EG samples are closer to SPB pattern than Balmaceda and Paine complexes. The same is possible to note in (**d**), (**e**) and (**f**) REE diagrams (Nakamura, 1974). The shadows represent plot area of neogene SPB samples [8]. Open and filled symbols represents felsic and mafic rocks samples respectivelly.