ASSEMBLY OF SHALLOW INTRUSIONS FROM MULTIPLE MAGMA PULSES IN LA ESPERANZA PLUTONIC COMPLEX, NORTHPATAGONIAN MASSIF, ARGENTINA

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ABSTRACT

Anisotropy of magnetic susceptibility and field fabrics study, combined with mineral cooling/ exhumation ages in the La Esperanza Plutonic Complex (LEPC), North Patagonian Massif, Argetina, was carried out. Coupled data reveals a multistage evolution of the magmatic system.

Keywords: Permo-Triassic, emplacement, magnetic fabric analysis, cooling ages, Patagonia.

RESUMEN

Se llevó a acabo un estudio combinado de fábricas macroscópicas y de anisotropía de susceptibilidad magnética en conjunto con edades de enfriamiento / exhumación en el Complejo Plutónico La Esperanza. El ensamble de dato revela una evolución multi episódica de construcción de sistema magmático.

Palabras clave: Permo-Triásico, emplazamiento, análisis de fábricas magnéticas, edades de enfriamiento, Patagonia.

Introduction

In the last three decades there has been an enormous advance in the understanding of the timing and development of the pluton building and its emplacement processes (Petford *et al*. 1993, Coleman *et al*. 2004; Cruden 1998 among others). It is widely recognized that field fabrics in plutons are variably well developed and that its macro and microstructural assessment and interpretation are meaningful to understand magma emplacement mechanisms in the crust (Paterson *et al*, 1998, among others).

The La Esperanza Plutonic Complex (LEPC) is a subvolcanic composite assembly of Permian to Triassic plutons whose extension has been constrained in more than 1600 km^2 by Martínez-Dopico (2013), in the central part of the North Patagonian Massif. Pankhurst *et al*. (2013) tied up the geological evolution of the LEPC to several regional events such as the Gondwanide Orogeny in Argentina. LEPC is mainly composed of three high-K calcalcaline units: Donosa Granite, Giménez Granite and Prieto Granodiorite (273 ± 2 Ma U-Pb SHRIMP taken from Pankhurst *et al*., 2006). The former unit is most extended and is developed in three facies: (1) an equigranular, (2) an inequigranular and (3) a porphiritic facies. The LEPC is related to an apparent small contemporary volcanic edifice composed of a *sensu lato* Rhyolite Dome (264 ± 2 Ma U-Pb SHRIMP taken from Pankhurst *et al*., 2006) and Collinao Dacite (Dos Lomas Volcanic - Plutonic Complex). The last pulse of this magmatic system was dominated by the intrusion of the Calvo Granite (250 ± 2 Ma U-Pb SHRIMP taken from Pankhurst *et al*., 2006) and related acidic dikes. Petrographic details and geochemical evolution of the LEPC can be check out in Martínez-Dopico (2013).

One of the most powerful tools used to determine fabrics in plutons bearing poor-quality macroscopic magmatic markers (weak fabrics) is the anisotropy of magnetic susceptibility (AMS) technique. The aim of this abstract is to rethink the final stage of the magmatic process that formed the LEPC by the means of a combined study of magnetic fabrics and cooling ages on two units of the LEPC, the Prieto Granodiorite and the Donosa Granite.

Geochronological Data Analysis and emplacement depth

The only available crystallization dating for the LEPC points towards a 273 ± 2 Ma age (U-Pb SHRIMP in zircon) for the equigranular facies (1) of the Prieto Granodiorite. A K-Ar cooling age on biotite obtained for the same locality where this U-Pb SHRIMP dating was obtained, yielded 259±6 Ma. This age would bracket the age of cooling at 300ºC. In addition, two K-Ar cooling ages were obtained for the inequigranular facies (2) of the Prieto Granodiorite yielding 251 ± 6 Ma and 249 ± 4 Ma. Even though no constrain has been obtained yet for the porphiritic facies (3), transitional contacts with the inequigranular facies might allow to extend the validity of the cooling age. Al-Hornblende barometer applied for the equigranular and inequigranular facies indicates similar pair-equilibrium pressures around 1-1.5 ± 0.5 kbar (Martínez-Dopico *et al.* 2013).

On the other hand, a K-Ar cooling age for a muscovite from a pegmatite miarole (350ºC) in the Donosa Granite of 265±3 Ma suggests that this unit is older than the Prieto Granodiorite. The analytical data of this set of cooling ages can be found in Martínez Dopico (2013). Even though there is no control neither on the emplacement depth nor its crystallization age, subvolcanic textures were detected, indicating also a very shallow emplacement depth.

Directional Data Processing and Analysis

This study is based on 66 stations all over the road cuts and stalls around La Esperanza ranch, such sampling sites were mainly obtained in the Prieto Granodiorite, Giménez Granite and Donosa Granite (Raw data is available in Martínez-Dopico, 2013). A few sites were collected from the Calvo Granite and volcanic rocks for comparison. Around 7 to 19 specimens per site of 22 x 25 mm were obtained from the collected samples and measured by the anisotropy of magnetic susceptibility (AMS, Tarling and Hrouda, 1993) with a static Kappabridge MFK-1B (AGICO) at INGEODAV in the University of Buenos Aires. The AMS tensor and associated magnitudes and orientation of the principal axis of the AMS-ellipsoid were calculated using the ANISOFT 4.2. The major source of AMS in the LEPC is MD magnetite with an increasing contribution from the paramagnetic silicates in samples with lower K values. Directional data are shown according to the distribution of K3 (pole to magnetic foliation and K1 (magnetic lineation) in Figures 1 and 2, respectively.

The Donosa Granite shows well defined NW-SE lineations. In the central body they are subhorizontal (< 30°), with moderate dips (between 35° and 41°) close to its western and eastern borders (fig. 2). Macroscopic lineations were determinated through K-feldspar megacrysts alignments. These macroscopic fabrics were consistent with the lineations shown in K1 (fig. 2). K3 of the sites of the central body tend to cluster near the center of the equal-angle projection indicating subhorizontal foliation planes, whereas K3 of the marginal westernmost outcrops cluster around the SW border of the projection. Magmatic structures and therefore, emplacement controlled magmatic flux mechanisms in of these rocks is very likely considering the K1 homogeneity.

K1 and K3 axis for the Prieto Granodiorite show a more complex distribution than the Donosa Granite rocks. Nevertheless, some systematic differences can be appreciated among the different facii. The equigranular facies is characterized by subhorizontal lineations mostly directed towards E, and minor W to NW directions. Most of the K3 poles cluster around subhorizontal to moderate dips indicating a northward direction. Several sites, located at the outer limits of the facies, Z11, Z13 and Z273 show subhorizontal dipping angles (subvertical foliation planes) variably directed but parallel to the limits with the Donosa Granite (fig. 1). Therefore, the Equigranular facies seems to be controlled by border conditions, as observed in most sites of the equigranular facies located along the northern, western and southwestern outcrops of the main body of the Donosa Granite. The Inequigranular and Porphyritic facies show a less well defined cluster for K1: A very systematic alignment of K1 axes trending NW with moderate plunges are shown by westernmost

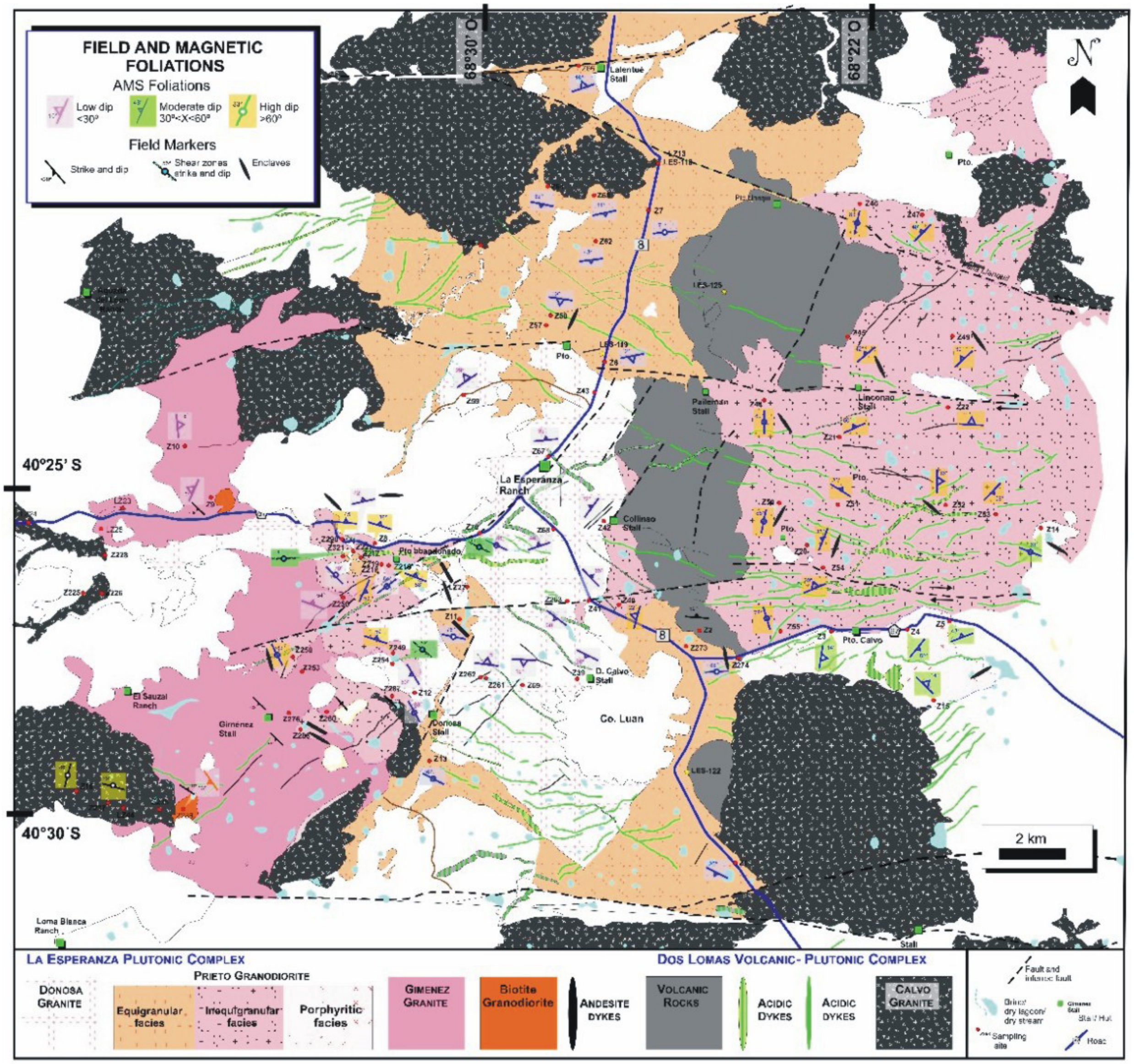

Figure 1. Field distribution of Permian to Triassic main units: La Esperanza Plutonic Complex and Dos Lomas Volcanic- Plutonic Complex. AMS and field foliations are shown.

rocks whereas the easternmost rocks a mostly subhorizontal dipping NW, N and SE plunges were found. In the latter area, moderate dipping northward directed lineations were found for several sites located nearby the volcanic rocks spreading center (sites Z44, Z46, Z47, Z50 and Z21). K3 shows a moderately dipping and random distribution, independently of the considered area. An exception is found in the N/NNW- S/SSE aligned sites Z44, Z46, Z50 and Z56, where foliation planes are nearly vertical, and consistently N-S directed (Figure 1). Wherever it was possible to measure, mostly oblate enclave preferred orientation as well as hornblende or plagioclase alignments resulted somewhat parallel to the preferred NW – SE magnetic lineations.

Two out of the three sites from the Gimenez Granite (Z9, Z10) show a very well defined subhorizontal foliations as well as NW lineations. These fabrics were parallel to the magmatic flow planes marked by macroscopic schlierens and channeled flow measured in the field. The sites obtained from the remnants units are not enough to constrain the behavior of the units.

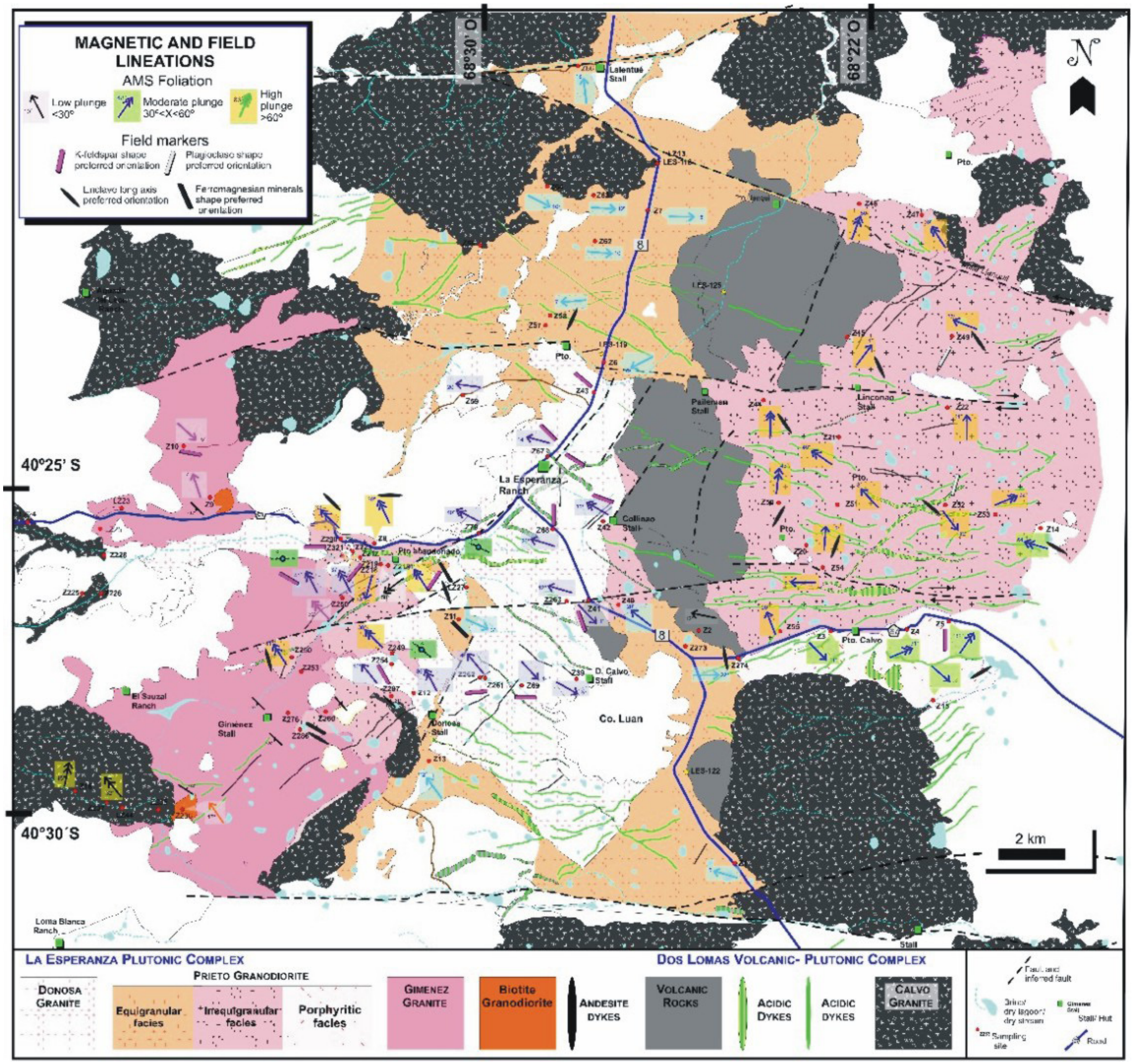

Figure 2. Field distribution of Permian to Triassic main units: La Esperanza Plutonic Complex and Dos Lomas Volcanic- Plutonic Complex. AMS and field lineations are shown.

Discussion

According to the available geochronological set, we envisage a three step model:

Stage 1) Donosa Granite crystallized as the first magmatic pulse of the LEPC, previous to the Prieto Granodiorite (273 ± 2Ma, crystallization of the Equigranular facies) and could have been emplaced confined (and triggered) by the NE-SW transtensional fault system.

Stage 2) The Prieto Granodiorite took emplacement as discrete pulses (and geochemically related to a different magmatic source respect of the Donosa Granite) that in its first stage might have found its space around the borders (Equigranular facies). Prieto Granodiorite Equigranular facies exhibit clear vertical planar magnetic fabrics (oblate ellipsoids) nearby the western border of Donosa (sites Z11 and Z13), which might suggest feeder channels for magma transport parallel to the borders with Donosa Granite. Therefore its fabrics could also imitate the borders and as they exhibit higher dipping angles they might have been

controlled by the previous geometry contour.
Stage 3) A subsequent stage of magma intrusion (more mingled magma, less hybrid) may have built the floor of the caldera system (Inequigranular facies, contemporary to the volcanic) after 265Ma. This facies may have found space around the Dos Lomas volcanics main spreading center, to east of the fault system. No further control, except the development of an internal structure due to the magmatic flux was found in the area. Moreover, a NNE-SSW feeding system was probably found nearby the volcanic axis. Little far from this spreading center, the shape and distribution of the magma (at least not in the area of study) is broadly concentric and may have not been influenced by any previously imposed field stress, developing this domic shape. However, in the westernmost area, Prieto Granodiorite and Gimenez Granite emplacement may have been controlled by the previous scattered spaced left by Donosa Granite as shown by the moderate dips in lineation and foliation planes. There, crosscutting relations are sharp between the Donosa Granite and Prieto Granodiorite. In any place, the control during magma emplacement is weak, consistent with an ongoing heat input into fragile crust level.
However, the NE-SW sigma-1 stress could not have ruled out the emplacement of the Prieto Granodiorite but also could not have finished (or been reactivated) after its emplacement since several andesitic and cross cutting microgranite dykes were also controlled by this stress system. Stage 4) in this scenario, by 250 Ma, the Calvo Granite will have been emplaced as subcircular to N-S elongated bodies consistent with a E-W sigma-1 stress system. Its emplacement as well as its alkaline tendency would mark the calderic collapse. Its emplacement would favor the extrusion thoughout hydraulic fracturing of the acidic and rhyolite dykes. Therefore, we propose a change in sigma-1 stress field from NW-SE since pre-280 Ma (as maximum) until ~ 260 Ma (minimum) and a sigma-1 stress field from E-W since ~ 260 Ma to 246 Ma (minimum).

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