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The Sierra de Varas Pluton in Domeyko Cordillera, Northern Chile: Emplacement mechanism and host rock deformation from structural data and AMS

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1. Introduction

The Sierra de Varas Pluton (SVP) is an elliptical north-south oriented granitic body located in the Pre-cordillera of Norther Chile (Fig. 1A). The age of SVP has been determinated by U/Pb and K/Ar radiometric dating showing that the emplacement occurred during the Late Carboniferous (~ 300 Ma U/Pb; Smoje *et al*, 1994; Padilla, 1988). The interpretations of geological and geodynamic setting in the northern Chile during the Late Palaeozoic have been performed based in stratigraphic and petrological data. The most widespread interpretation is a subduction - related arc placed in the present continental margin during the Late Palaeozoic (Balhburg & Hervé, 1997; Brown, 1991). The origins of the intruded magmas during this stage have been extensively discussed. Some Late Palaeozoic plutonic rocks show I – type granite signature from magmatic-volcanic arc (Taltal – Chañaral complex, Brown, 1991; Precordilleran granites and Sierra de Varas Pluton; Marinovic *et al*, 1995). Nevertheless, Sr and Pb isotopic ratios from Sierra de Moreno have been interpreted as magma signatures originated from Early Palaeozoic recycled crust, maybe related to transpressive or transtensional strike-slip fault (Lucassen *et al.*, 1999).

2. Contacts

The SVP contacts can be classified in 3 segments according to the nature to the relationship between the pluton and the surrounding rock (Fig. 1B). (a) The western margin of the pluton is cut by the north-south trending Sierra de Varas Fault (Oligocene). (b) The north margin is NW – SE oriented showing tectonic or intrusive contacts. The intrusive contacts are parallel to the bedding of the host rock (Sierra de Varas Formation) dipping 45° to the north-east. This segment is showing that the intrusion was partially concordant with host rocks. (c) The east margin is the main intrusive contact between the SVP and the Sierra de Varas Formation and it is exposed along 7 Km. The general trend of this segment is NNE – SSW dipping westward since 90° at south end to 60° at the central and north part.

3. Magmatic units in SVP

The pluton is formed by three main lithologies: a) metric to decametric elliptical enclaves of gabbro included by the tonalite; these rocks are restricted to a zone close to the eastern contact. b) The hornblende Tonalite is located along the border of the SVP intruding the host rock. The hornblende is altered to pseudomorphic aggregated of ferric chlorite and titanite, Fe-oxides and calcic epidote. In some areas near to eastern margin the tonalite show evidence of solid state deformation with kink bands in biotite and chlorite,

dislocation creep in quartz and deformation twins in plagioclase c) The most widespread rock in the pluton is the biotite Granodiorite. The Granodiorite intrudes to previous outermost Tonalite and have a lower grade of alteration. There are microdioritic enclaves included by both the tonalite and the granodiorite. Some enclaves are asymmetry of the enclaves shows a "pluton up" flow direction. The contact between the tonalite

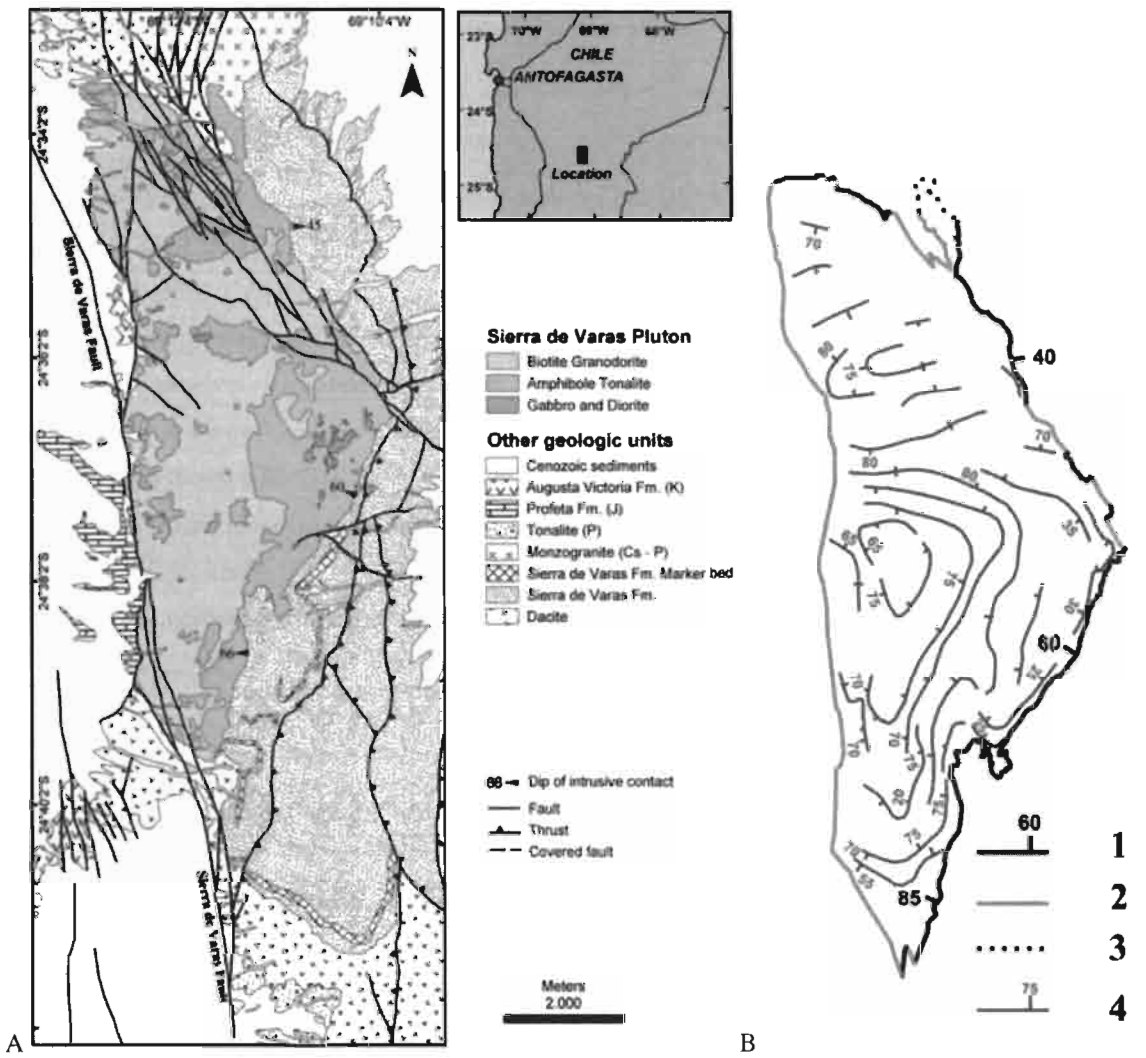
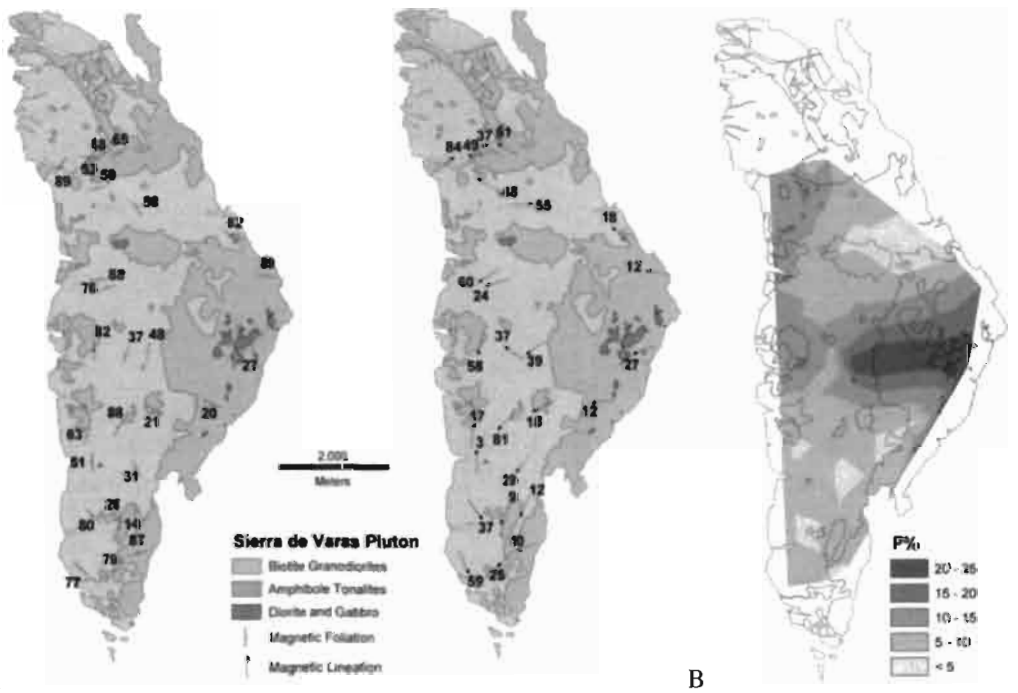


Figure 1. A. geologic map of north end of Sierra de Varas. B. interpretative foliation paths: 1) intrusive contact showing dip; 2) fault; 3) contact with younger granitic bodies; 4) foliation path showing dip.

and the granodiorite vary along the pluton. In the south end, the contact is banded showing a progressive pass from tonalite to granodiorite. The most of the contact between the granodiorite and tonalite is sharp with a unconformity between the foliation to both sides of the contact. In some place a leucocratic band is located in the granodiorite directly above the contact a showing a chemical interchange between the tonalite and granodiorite, both with different viscosities related to the crystal content.

4. Magmatic foliations and lineations

The magmatic foliation in the Sierra de Varas Pluton is geometrically related to shape of the intrusive contacts. The tonalite show a magmatic foliation defined by the preferred orientation of prismatic crystals of plagioclase and hornblende. The foliation in the granodiorite is defined by the preferred orientation of platy biotite crystals and plagioclase.The interpretative foliation paths show a concentric foliation pattern mainly dipping to the centre of the pluton and increasing the dip from the east to the center (Fig. 1B). The magmatic lineation is clear only in some outcrops near to the east margin and it dips to the centre of the pluton and to NW.



A B

Figure 2. A) Magnetic foliations and lineations in SVP. B) Distribution map of the anisotropy grade P%.

5. Magnetic fabric

161 core samples were drilled from 26 sampling site in the SVP for Anisotropia of Magnetic Susceptibility analysis (AMS). The bulk susceptibility varies between ~200 to 17.500 μSI at site scale. There is not a clear correlation between the paramagnetic or ferromagnetic zone with the lithology. The magnetic susceptibility in ferromagnetic sites is carried by the magnetite or illmenite content and by the biotite and hornblende in the paramagnetic sites. The magnetic foliation have the same trend showed by the macroscopic foliation, except near to the east margin where the ASM orientation parameter are controlled by the alteration of tonalite and the exsolution of illmenite in magnetite (Fig. 2A). The P and F parameters have a strong correlation, both with values higher than 15% coinciding with an E-W axis of change of the azimuth of foliation paths and areas where the alteration and deformation of tonalite is most developed (Fig. 1B and Fig. 2B). The low values of L in most of the SVP coincide with the oblate shape of the AMS ellipsoid showed by the T parameters. This is consistent with widespread magmatic foliation in all the pluton and the low development of the magmatic lineation.

6. Host rocks deformation

The host rock is formed by the hypabyssal Dacite (Carboniferous) and the volcanic-sedimentary sequence of Sierra de Varas Formation (Carboniferous). The sequence is formed by near 150 m of tuff, agglomerate, volcanic breccia, andesite and 30 m thick sedimentary rocks in the base of the formation. From the base, the sedimentary member is formed by conglomerates, sandstones and limestone with intercalations of chert. There are differences in the host rock deformation when is compared the Sierra de Varas Formation away or near to the SVP. 3km at south of the SVP, the Sierra de host rock is in homoclinal attitude; in addition, the cleavage is progressively less developed away to pluton. Close to the north and east intrusive contacts, the host rocks is folded, with the axial plane close to be parallel to the contacts. The cleavage is an axial plane

cleavage formed by pressure solution (Niemeyer *et al.* 2000). The limestone beds can be considered as deformation marker bed because their distinctive lithology and lateral continuity. Comparing the homoclynal attitude of the Sierra de Varas Formation away the SVP with the limestone near to the SVP, the marker bed is folded and deflected around the intrusive contact. The tertiary thrust affecting the host rock cuts and displaces the previous folding sedimentary rocks.

7. Discussion and conclusions

The magmatic foliation and lineation and specially the concentric foliation paths suggest that the inner structure of the Sierra de Varas Pluton was controlled by the shape and the magma forces during the emplacement. The actual erosion surface is showing a lower level of the pluton below the ecuatorial axial plane of the original body; this is evidenced by the dip direction of foliation to the centre of pluton. The successive intrusion of the two magma pulses (Tonalite and Granodiorite) folded and pushed to east the volcano-sedimentary host rock; this is showed by the host rock folding restricted around the PSV and the deflection of the calcareous marker beds near to the pluton. In addition to the folding and translation, is possible suggest that part of the necessary space for the magma emplacement was accommodated by the pressure solution in the axial plane cleavage. The north end of the pluton could be the only part where the pluton roof is exposed, showing a concordant relationship between the SVP and the host rock. The correlation between the solide state deformation and the anisotropy magnetic has been reported in many plutons (e.g. Saint-Blanquat et al., 2000; Román-Berdiel et al., 2004). In the case of SVP, the high magnetic anisotropy area is related to the tonalite deformation during the granodioritic magma input and next lateral expansion.

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