Metamorphic P-T constraints for non-coaxial ductile flow of Jurassic pyroclastic deposits: Key evidence for the closure of the Rocas Verdes Basin in Southern Chile

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Introduction

Discontinuous exposures of mafic igneous complexes and hemipelagic sedimentary successions along the Pacific margin of southern South America and in the island of South Georgia, southern Atlantic ocean (51°-55°S), have been considered as the remnants of the Late Jurassic to Early Cretaceous Rocas Verdes basin (RVB; Dalziel, 1981; Stern and de Wit, 2003, and references therein). The formation of the RVB is thought to be preceded (Bruhn et al., 1978; Mukasa and Dalziel, 1996) and accompanied (Fuenzalida and Covacevich,1988; Calderón et al., 2003; Calderón, 2004) by Jurassic crustal anatexis and explosive silicic volcanism in a volcano-tectonic rift setting, leading to the deposition of the Tobífera Formation uncorformably over polydeformed Palaeozoic metasedimentary rocks. The basin evolved later to mid-ocean-ridge-type spreading centers until Late Cretaceous times (Stern and de Wit, 2003). Their components are thought to be obducted in mid-Cretaceous times (Dalziel, 1981).

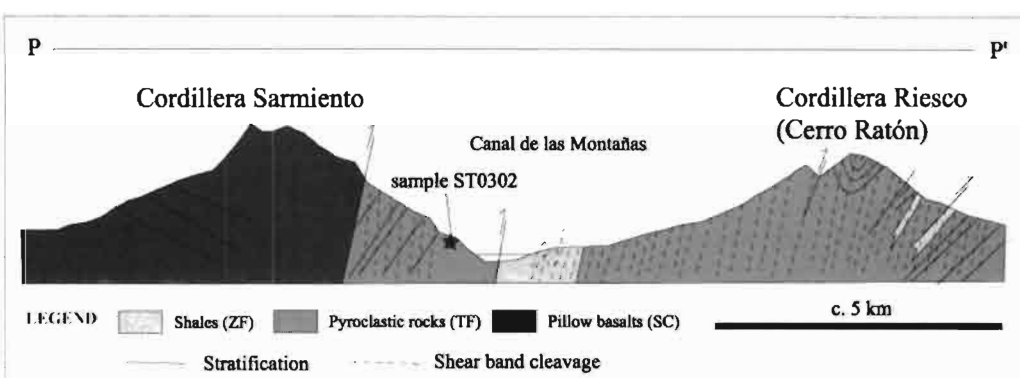

Figure 1. Geological cross-section at ca. 52°S.

The northernmost remnant of the RVB, the Sarmiento Complex (SC), is exposed in two imbricated thrust sheets in a N-S trending and subvertical- to east-verging fold and thrust belt. All components show variable deformative or no metamorphic overprint. The SC is flanked on the west by plutonic rocks of the Patagonian batholith and on the east by foliated volcanosedimentary successions assiggned to the Tobífera Formation (TF). The studied portion of the foliated TF is located to the east of the N-S trending Cordillera Sarmiento, along both shores of the Canal de las Montañas and at the eastern flank of the Cordillera Riesco (Cerro Ratón; Fig.1). The TF pseudostratigraphy consists of a thick pile of intercalated lapilli and fine tuffs, welded tuff and quartz-bearing siltstones at the top of the succession (Galaz, 2005). The syndeformational metamorphism and its tectonic significance is the aim of this report.

Structures and microstructures

Foliated rocks in the studied area show a regular N-S trending and east-vergent to subvertical anastomosed millimetre- to centimetre-sized main foliation (Sp) with steep stretching lineation. The stratification at the Cerro Ratón (Fig.1) is N-S trending and dips to west with variable inclination between 45° and 60°. Metre-sized asymmetric and tight folds in layers of fine tuffs show axial surfaces subparallel to Sp. Boudinage and disruption of competent material occur within metre-sized layers with heterogeneous components. Beds of siltstones show a slaty cleavage sub-parallel to axial surfaces of centimetre-sized isoclinal and tight asymmetric folds. Sheath folds in these rocks were also observed. Brittle structures are centimetre-sized tension gashes filled with quartz and a discrete but regular E-W trending and subvertical kink cleavage.

Under the microscope, the anastomossing and/or composite Sp at Canal de las Montañas shows mylonitic S-C'-type microstructures with a small angle (of ca. 20°, and commonly least than 30°) between both components. At Cerro Ratón S-C-type microstructures were recognised (Galaz, 2005). Therefore, the shear band cleavage formed under high-strain conditions with comparative lower strain rates in the eastern side of the studied area. In oriented thin sections, σ- and δ- type microstructures, quarter mats, mica fishes, strain shadows and crystal boudinage indicate a bulk reverse sense of shearing. Later and minor S-C" -type antithetic microstructures apparently dips gently to the east.

Metamorphic mineralogy and P-T constraints

Metamorphic assemblages in mylonites consist of quartz, K-feldspar, phengite and lesser amounts of albite with variable proportions of stilpnomelane, epidote, chlorite, actinolite and titanite in the foliated pseudomatrix and cleavage domains. Prehnite, albite and pumpellyite occur in quartz-veins. Some mafic rocks show actinolite in strain fringes formed along pyrite edges. These features indicate non-coaxial deformation operating under greenschist facies conditions of metamorphism, probably at temperatures between 300 and 400°C. This T interval is compatible with the observed mineral assemblages.

Syntectonic assemblages of quartz, phengitic mica, stilpnomelane, chlorite in quartzofeldspathic mylonites are useful to combine geothermometric and barometric constrains. For instance, Currie and van Staal (1999) have elaborated a geothermobarometer (implemented in their STILPNO2.EXE program) considering the equilibria:

1) daphnite + Fe-celadonite + quartz ⇔ stilpnomelane + muscovite; and
2) amesite + Mg-celadonite ⇔ clinochlore + muscovite.

The composition of syntectonic phengite, stilpnomelane and chlorite in sample ST0302 (Table1) yield mean P-T conditions (with 8 combinations) of ca. 7.0±0.8 kbar and 440±30°C. However, small compositional differences in chlorite have a significant effect on the temperature calculations. Higher temperatures are obtained with chlorite with higher Si and Al contents and lower Mg content. Instead, the Si content in phengite has an effect on the pressure estimates (e.g. Massonne and Szpurka, 1997). Calculation with phengite with higher Si contents yield higher pressure condition of metamorphism.

Table1. Analysed minerals in sample ST0302 (Canal de las Montañas).

	Phengite		Stilpnomelane		Chlorite	
Spot No	5	7	1	14	10	11
SiO2	49.3	49.3	45.5	46.0	26.2	25.8
TiO2	0.0	0.0	0.0	0.0	0.0	0.0
Al2O3	27.6	26.4	6.0	6.0	17.3	18.2
Cr2O3	0.0	0.0	0.0	0.0	0.1	0.1
Fe2O3						
FeO	6.3	6.9	28.8	28.8	33.3	33.6
MnO	0.0	0.1	0.9	0.8	0.4	0.4
MgO	2.6	2.6	5.5	5.5	10.6	9.6
CaO	0.1	0.0	0.2	0.2	0.0	0.0
Na2O	0.1	0.1	0.2	0.1	0.0	0.0
K2O	10.3	10.9	1.0	0.8	0.1	0.0
Total	96.3	96.4	88.1	88.3	88.2	87.7

The P-T estimates are consistent with those calculated by Galaz (2005) (with mean values of 6.4±1.1 kbar and 400±64°C). They are al so consistent with the ca. 7 kbar and 350°C peak metamorphic conditions calculated by Hervé et al. (2004) for metarhyolites located ca. 200 km to the north. However, we think that temperatures between 350 and 450°C are most likely because the upper thermal stability of stilpnomelane (<400°C at P <10 kbar according to Massonne and Szpurka, 1997).

Conclusions

This study reports the existence of a kilometre-wide N-S trending and subvertical to east-vergent shear zone developed within Late Jurassic pyroclastic rocks. Dynamic recrystallisation is characterised by the development of S-C'-type and S-C-type structures and microstructures coeval with folding and thrusting. Kinematic analysis indicates reverse sense of shearing. Upper greenschist facies conditions during syndeformational metamorphism are constrained, which are close to the transitional field of rocks formed in continental orogenic belts and those formed in a subduction zone (cf. Spear, 1993). Foliated quartzofeldspathic rocks represent the low-grade mylonitic sole of the Sarmiento Complex, tectonically juxtaposed probably in Early Cretaceous times.

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