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Comparative evolution of the Lower Cretaceous pluto-volcanic arc and back-arc from the Atacama Region, Chile

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INTRODUCTION

The Andean margin is a typical convergent oceanic/continental plate boundary zone, submitted to continuous subduction, since at least Mesozoic time. In central and northern Chile, major features of this plate margin are: (1) the emplacement of voluminous magmatic arc plutonic rocks giving rise to trench-parallel plutonic suites (batholiths) and volcanic sequences (magmatic arc); and (2) the inboard deposition of several thousands of marine calcareous and/or volcaniclastic deposits (back-arc). Modifications of the architecture of these margin elements both in time and in space have been linked with major changes in the basic subduction parameters like the obliquity of the subducting plate and/or relative rates of roll-back velocity and trench ward velocity of the overriding plate (Jaillard *et al.,* 1990; Scheuber & González, 1999; Grocott & Taylor, 2002).

Over the last 10 years the application in the Atacama Coastal Cordillera (northern Chile) of modern concepts on pluton emplacement and detailed structural geology, both accompanied with high precision geochronology made possible to relate the Mesozoic pluto-volcanic arc activity and the prevalent subduction regimes (Dallmeyer *et al.,* 1996; Grocott & Taylor, 2002; Arévalo *et al.*, 2003). However, since the back-arc areas are still poorly studied and understood, large scale subduction inferences remain uncompleted and somehow still speculative.

In this contribution we present preliminary results obtained mainly along one section across the back-arc sequences and integrate these observations with those obtained in the pluto-volcanic arc. On going research will allow a integrated arc/back-arc dynamic models making possible more realistic inferences with respect to the subduction regime prevalent during the Mesozoic.

THE PLUTO-VOLCANIC ARC IN THE COPIAPÓ-VALLENAR REGION

In the Coastal Cordillera of the Copiapó-Vallenar region Early Cretaceous plutonic rocks are exposed continuously and six main younging eastward plutonic belts have been defined indicating successive discrete phases of magmatic activity at 146-137 Ma, 130-128 Ma, 126-125 Ma, 123-120 Ma, 115-114 Ma, and 111 Ma y 92 Ma (Dallmeyer *et al.*, 1996; Arévalo *et al.*, 2003; Cruden *et al.*, 2004; Arévalo, 2005). The magmatic belts are separated by volcanic, volcaniclastic and/or calcareous screens of country rocks. These panels represent remains of overlying roof, underlying floors or lateral walls which contain a record of emplacement-related and/or pre- and post-plutonic regional deformation. Careful examination of these structures has been helpful to determine the emplacement mechanisms of the magma batches and, more importantly, has allowed inferences about the overall tectonic deformation prevalent in the arc at the moment of the magmatism. In fact, it has been determined that synplutonic extensional to transtensional faults were all utilised by the magmas to be emplaced at these different stages: 130-128 Ma (Late Hauterivian-Early Barremian), 126-125 Ma (Late Barremian), 123-

120 Ma (Early Aptian), 115-114 Ma (Late Aptian), and 111 Ma (Early Albian) giving a main extensional overall setting for the Early Cretaceous in the pluto-volcanic arc (age of stages are taken from Gradstein *et al.*, 2004). Additionally, brittle-ductile to brittle structures that are superimposed and/or rework extensional pre-existing structures have also allowed to interpret a series of left lateral transpressive stages. Although not all of them exhibit satisfactory constrains in age, the available database suggest that these phases were active at: ca. 125 Ma (Los Colorados FTB, Arévalo *et al.*, 2003), ca. 116 (main displacement of the Atacama Fault System at this latitude, Arévalo, 2005) and in the range 90-80 Ma (Paipote FTB; Arévalo, 1999; Grocott & Taylor, 2002).

THE BACK-ARC

Time equivalent rocks to the east, at similar latitude, are mainly calcareous with minor volcanic and volcaniclastics sediments, which have been grouped under the Chañarcillo Group that includes four different units: Abundancia, Nantoco, Totoralillo and Pabellón formations. These rocks represent deposition in a back-arc basin which has been generically denominated as Atacama Basin (Cisternas & Díaz, 1990; Mourgues, 2004). These deposits overlie Jurassic-Early Cretaceous volcanic rocks (Punta del Cobre Formation) and are covered eastwards by a thick subaerial volcaniclactic sequence ascribed to the Albian (?)-Turonian (Cerrillos Formation). In progress studies by the authors including detailed revaluation of old and recently collected paleontological material, facial interpretation of the sedimentary successions and sequence stratigraphy analysis confirm the existence of continuous deposition since the Lower Valanginian up to the Upper Aptian. They also show the prevalence of synsedimentary tectonics documented by major forced regressions, existence of olistolithes and olistostromes, tilting of shelves and synsedimentary normal faults all the way through the sedimentation. This demonstrate that the back-arc was a tectonically active region in the same way than the pluto-volcanic arc.

According to a section in Quebrada Melendez the evolution of the Atacama basin comprises three main cycles:

(1) The first cycle is formed by three sequences. The lowest one (Abundancia Fm, Upper Valanginian) records upward deepening up to hemipelagic outer shelf marls and limestones and a subsequent shallowing evolution toward bioturbated laminated litharenites and bioturbated fossiliferous limestones. The middle sequence (Lower Mb of Nantoco Fm, Lower Hauterivian) begins with retrogradational facies that culminate in hemipelagic, belemnite-bearing stratified limestones and continue with a new shallowing trend that ends in laminated silicified limestones of tidal environment. A third sequence which begins with trangressive deposits and culminates with hemipelagic marls and limestones is interrupted by a tectonic, forced regression, which leads to deposition of evaporites and shallow shelf limestones (Upper Mb of Nantoco Fm, Late Hauterivian). Tectonics then dominated, triggering the deformation, emergence and karstification of the limestones, which commonly appears as a "breccia". Preliminary observations point out, at least locally, to a compressional regime although evidence in the arc indicate the activity of extensional faults at the end of the Hauterivian (130–128 Ma). The kinematic compatibility between these two regimes both in the back-arc and arc is a matter of further research.

(2) The second cycle is compounded by two sequences. The first sequence (Totoralillo Fm, Early Barremian-early Late Barremian) starts with transgressive, laminated black marls and limestones of hemipelagic, anoxic environment and follows with a monotonous, thickening- and shallowing upward succession of marls and limestones. The second sequence begins with silicified limestones (Lower part of the Pabellón Fm), continues

with transgressive marls with abundant "*Parancyloceras*" *domeykanus* of Late Barremian age and ends with a prograding section with thin volcaniclastic interbeds and metric-scale slump structures, indicating an incipient tectonic activity. Upwards, volcaniclastic intercalations and slumps become thicker, larger and more abundant, while the partly silicified limestone beds contain more abundant phosphatic grains. The tectonic activity recorded by these facies seems to be documented by the sinistral transpressive phase at ca. 125 Ma (Late Barremian-Early Aptian) in the arc. The sequence ends up with a thin sequence of massive, cross bedded oolitic limestones of shallow shelf environment.

(3) The third cycle (middle and upper Pabellón Fm) begins with an unconformable, 70 m thick succession of tuffs, volcanic breccias and volcaniclastic debris flows and olistolith bearing lahars, expressing an explosive volcanic event. These rocks are overlain by a short-lived carbonate shelf represented by fossiliferous silicified limestones which are, in turn, covered by a ca. 150 m thick sequence of unconformable volcanic rocks (ocoites) and olistolith bearing, volcaniclastic debris flows and breccias. The section ends up in a new, transgressive short-lived carbonate shelf, marked by tixotropic calcareous breccias and abundant annelid bioherms overlain by inoceramid bearing silicified marls. The transition with the subaerial Cerrillos Formation is marked by a short lived lacustrine episode. Farther south (quebradas Carrizalillo and El Molle), the ocoitic rocks are transgressively overlain by a very shallow water, carbonate shelf sequence with corals, bryozoans (Carrizalillo) or sponges (El Molle), which is covered by volcanic flows and coarse-grained volcaniclastic mass flows bounded by synsedimentary normal faults that mark a major tectonic-volcanic event during the mid to Late Aptian. This stage correlate either with the left-lateral, transpressive phase of the Atacama Fault System at ca. 116 Ma or with the transtensional stage at ca. 115-114 in the arc domain (Grocott & Wilson 1997; Arévalo, 2005). Overlying shallow marine limestones are again covered by alluvial fan, volcaniclastic deposits which grade upward into fossiliferous (rudists, oysters, pectinids) sandy limestones overlain by the volcaniclastic deposits of the Cerrillos Formation. The last carbonate beds yield *Parahoplites* gr. *nutfieldensis* of Late Aptian age (Quebrada El Molle; Pérez *et al.*, 1990). Although not apparent in the field, the lack of the uppermost facies in the north indicates the existence of an erosional unconformity at the base of the Cerrillos Formation which would mark the generalized regression of the carbonate sequences during the Late Aptian-Lower Albian. This stage is correlated with the transtensional stage documented at ca. 111 Ma in the Coastal Cordillera-Copiapó Precordillera boundary (Arévalo, 1999).

CONCLUSIONS AND FUTURE WORK

The comparative analysis of the Early Cretaceous evolution of the pluto-volcanic arc and the back-arc allows to correlate at least four main deformation stages present in both provinces:

(1) a Late Hauterivian-Early Barremian phase expresed as the activity of extensional faults, in the arc (130-128 Ma), and a tectonic forced, probably contractional, regression in the back-arc.

(2) a Late Barremian-Early Aptian stage recorded as sinistral transpressive displacements in the arc (ca. 125 Ma) and as the supply of important volcaniclastic sediments to the back-arc calcareous platforms and the subsequent generalised slumping of the shelf deposits.

(3) a mid to Late Aptian stage represented by left-lateral, transpressive displacements of the Atacama Fault System (ca. 116 Ma) or transtensional faulting (ca. 115-114), in the arc domain, and by the interruption of

carbonate shelf deposition by the ingress of volcanic flows, coarse-grained volcaniclastic mass flows and the offset of synsedimentary normal faults, in the back-arc.

(4) a Late Aptian-Lower Albian phase marked in the arc by a transtensional stage (ca. 111 Ma) and by the generalized regression of the carbonate deposition and ingress of the subaerial Cerrillos Formation deposits, in the back-arc.

Future work will be focused on the structural characterisation of the synsedimentary structures recorded in the back-arc sequences, on the improvement of their relative ages, on the determination of their kinematic compatibility with contemporary structures in the pluto-volcanic arc and, ultimately, on the updating of current models regarding interaction between the overriding and the subducting plates during the Mesozoic.

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