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Albian to Santonian tectonic closure of the Andean marginal basin at 28°S: Sedimentological, geochronological and structural evidences.

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Abstract. Albian to Santonian siliciclastic units outcrop from 22°S to 34°S in Chile, covering neocomian arc volcanic units and back-arc carbonate marine and continental clastic units. These sedimentary rocks represent a major paleogeographic configuration of the Andean margin, however little is known of their peleogeographical meaning. This study focuses on the Checo de Cobre Member, of the Cerrillos Formation, and the Pucalume Fm., both cropping out at 28°S. Through facies analysis, structural mapping and detrital zircon geochronology we interpret an estuarine environment for the Checo de Cobre Member and a tidal to fluvial environment for the Pucalume Fm. Detrital zircon shows an west to east sediment transport for the Checo de Cobre Mb. and a dominant east to west transport for the Pucalume Fm, hence, these units would represent the western and eastern margins , respectively, of a back-arc basin connected to the sea. Integration of these results with published data allows to identify two major tectonic uplift events taking place in the western margin of the Cretaceous Back-arc basin, a first compressive event around 110 Ma, triggering a major regression in the back-arc and the emergence of the arc, and a second event between 83 and 94 Ma, related to the final closure of the back-arc basin, and the establishment of the Santonian to Maastrichtian arc on the previous back arc basin.

Keywords: Aptian, Albian, Cerrillos, Chañarcillo, Tectonic inversion, Back-arc basin, Andes, Chile.

1 Introduction

The paleogeographic configuration of the Andean margin of northern Chile during the Early Cretaceous includes the development of a NS trending island arc, in the present Coastal Cordillera, whose volcanic products interfinger westward with marine limestones of a NS back-arc marine basin (Arévalo *et al.*, 2005a; 2005b) with continental facies along its eastern margin (Legarreta and Uliana, 1991; Mpodozis et al., 2005). Unconformably overlying both arc related volcanics and back-arc marine to continental deposits, hundreds of meters thick conglomeradic wedges outcrop discretely from 22°S to nearly 34°S (Puricaltis Fm., Cerrillos Fm., Las Chilcas Fm.).

These conglomeradic deposits represent a major change in the paleogeography of the continental margin. At 28°S some authors have interpreted these conglomerates as the final stage of and aborted marginal basin (Mpodozis and Allmendinger, 1993; Arévalo *et al*., 2005a; 2005b) while others propose to be the filling of a foreland basin related to the onset of a compressional regime in the arc (Maksaev *et al.*, 2009). Recent sedimentological studies, supported with U-Pb geochronology have proposed an alluvial to fluvial environment in a foreland setting for this conglomeratic units at 22°S (Purilactis Fm., Bascuñan et al., 2015) and at 33°S (Las Chilcas Fm.; Boyce, 2015), where these overlay continental back-arc deposits and arc related volcanics, respectively.

This study focuses on Albian to Santonian siliciclastic units cropping out at 28°S, Cerrillos Fm. In the Andean orogenic front, and Pucalume Fm. within the Frontal Cordillera (Del Carmen river). The first one overlies directly the limestones of a marine carbonate shelf of the marine back-arc basin (Chañarcillo Group; Mourgues, 2007) and could, therefore, better record base level fluctuations in the basin. The second one overlies late Valanginian volcanics (Algarrobal Fm.). The main object of this study is to evaluate the tectonic and sedimentation processes taking place within the marine back-arc basin during this major reconfiguration of the margin through sedimentology, structural mapping and U-Pb geochronology.

2 Local Geology

The study area is located on the western part of the Frontal Cordillera at 28°S, between two major regional NS west vergent reverse fault systems, the Las Cañas fault system to the west and the San Felix fault system to the east. Oldest units cropping out are the Punta del Cobre Fm. in the west, Late Jurassic to Early Cretaceous andesites to basaltic andesites with a few intercalations of limestone, and the Algarrobal Fm. in the del Carmen river, composed of andesitic to rhyolitic volcanics. The Punta del Cobre Fm. unit underlies the marine carbonate sequence of the Chañarcillo group, while westward, it interfingers laterally with the Chañarcillo Group, evidencing the diachronic nature of this lithostratigraphic unit, spanning from a Late Jurassic to Albian age in the east, and from Late Jurassic to Hauterivian age in the study area. The Chañarcillo Group is composed of a few hundred meters of limestones with good biostratigraphic control spanning in age from

Hauterivian to Aptian.

Covering the Chañarcillo Group, through an angular unconformity, is the Cerrillos Formation, which is composed of a lower conglomeratic member (Checo de Cobre Member) and an upper volcanic member. The Checo de Cobre Member is well exposed in the Algarrobal creek, eastward of the Domeyko locality, as an east dipping monocline, however it interfingers laterally, northward and southward, with the volcanic member. The Checo de Cobre Member is composed of conglomerates, sandstones and some limestone levels in its upper section. A U-Pb detrital zircon ages obtained immediately beneath the limestone levels gave a maximum depositional age of 94.5 Ma (fig.1). The U-Pb zircon age obtained by Creixell *et al*., (2013) from a intercalated tuff near the base of this unit allows to constrain its possible age range from Albian to Turonian. The volcanic member has been well dated by Creixell *et al*. (2013) with 3 U-Pb zircon ages between 111,5±1 and 93 Ma, and a 83 Ma age obtained in the base of the unconformably overlying Viñitas Fm.

In the east, in the Del Carmen valley, volcaniclastic deposits of the Algarrobal Fm. are onlapped by red sandstones and conglomerates of the Pucalume Fm., where Creixel *et al.* (2013) obtained a maximum depositional age of 91 Ma through detrital zircons (fig.1). This unit is also unconformably covered by the Viñitas Fm. volcanics, dated on U-Pb con zircons near this locality on 80 Ma (Creixel *et al*., 2013)

Hence, the Viñitas Formation overlies a major regional unconformity along the andean orogenic front, it is composed mainly of andesitic lavas and its age is constrained between 83 and 80 Ma (Creixell *et al*., 2013).

Structural mapping has unveiled an undocumented unconformity at the base of the Viñitas Fm., in the western part of the study area, sealing a west vergent reverse fault affecting the Checo de Cobre Member and constraining a compressional deformation event between 94 and 83 Ma.

3 Sedimentology

3.1 Facies Associations

Volcanics: Andesitic lava flows and pyroclastic breccias, locally peperitic. May contain irregular lenses of limestone and sandstone (fig.1).

Gravelly Channel Bed: This association is composed of amalgamated clast-supported, imbricated, rounded and sandy conglomerates, with erosive concave bases with lenses of coarse sandstone with concave bases and eroded upper contact (fig.1). This association is interpreted as gravel bars and sandy channels of a gravelly-sandy channel belt of a braided river (Bridge, 2006, Miall, 2006).

Flood Plain: This association is composed of intercalated medium to coarse grained sandstones, massive, poorly sorted with bioturbated mudstones with dissecation cracks and pedogenetic carbonatic concretions. The sandstones may contain mud-clasts and planar cross lamination (fig.1). These deposits are interpreted as tractive flows flooding the fluvial flood plain, with subsequent decantation of fines and of soil formation processes. This association also includes localized metric packages of rhythmically alternated centimetric levels of very coarse sandstone with granule poorly rounded conglomerates. The latter is interpreted as crevasse splays pouring on a fluvial flood plain.

Tidal flat: This association comprises tabular continuous layers of medium grained sandstone, moderately sorted, intercalated with planar laminated mudstones, sometimes bioturbated. The sandstones include abundant heterolithic associations (mud drapes, lenticular bedding and wavy lamination) and may be normally graded. The mudstones include irregular evaporitic lenses and load structures (fig.1). This association is typical for coastal environments with tidal influence (Nichols, 2009), hence is interpreted as a tidal flat environment.

Mouth bars: This association comprises metric layers of massive medium to coarse sandstone with a few centimeters thick lenses very coarse to pebble conglomerates and continuous centimetric levels of mudstones. The mudstone layers are typically disrupted to mudclasts in the sandstone, evidencing tractive transport. The conglomeratic lenses show erosive concave bases and normal gradation (fig.1). This association is interpreted as sandy bars distributary channels at a river mouth.

Low energy carbonate shelf. Rhythmic intercalations of millimeter to centimeter thick levels of dark limestone and light grainstone, a few metric levels of grainstone with red chertic nodules in places (fig.1), and one intercalation of an irregular white chert level. This association is interpreted as an open quiet-water depositional ramp or starved (drowned) shelf.

Alluvial Fan. Decimetric to metric layers of clast-supported, poorly sorted, subprismatic cobble conglomerates. They show planar stratification and imbricated clasts (fig.1). These are interpreted to have been deposited by tractive debris flows.

3.1 Depositional Environment and Detrital zircons

The arrangement of facies associations for the Checo de Cobre Member, as well as his lateral relation with the Volcanic Member of the Cerrillos Fm. indicates that this clastic wedge developed within an inland deflection of the shoreline in an estuarine environment. Detrital zircon data

obtained in the Checo de Cobre Member show four important peaks: 94 Ma, 100 Ma and 104 Ma. Most probable sources for such zircons are a series of plutons cropping out in the eastern flank of the Cordillera de la Costa, or their non-preserved volcanic counterparts, west of the study area, suggesting a west-to-east sediment transport. These results are consistent with a marine back-arc basin to the east during the Albian, as documented in Argentina (Lagarreta and Uliana, 1991).

The Pucalume Fm., on the other hand, shows littoral to continental environment (fig. 1). Detrital zircons obtained in the base of the tidal associations (fig 1) show peaks at ~282 Ma, ~144 Ma ~91 Ma. The Permian peak is most probably from the Chanchoquin Plutonic Complex (297-285 MA; Salazar *et al.* 2013), an extensive granitic complex cropping out in the hanging wall of the San Felix fault system to the east. The Late Jurassic peak is most likely from the Algarrobal Fm. which is the Formations basement and also covers extensively the Permian plutons to de east (Salazar *et al.*, 2013; Ortiz *et al.* in prep). The only known source for the ~91 Ma zircons is the plutonic and volcanic rocks of located to the west, interpreted as the volcanic arc (Creixell *et al.*, 2013). This data shows the pre-Turonian exhumation of Permian basement to the east, probably by the activity of the San Felix reverse fault system, and a simultaneous supply of sediment from the arc at the west.

4 On the Tectonic and Eustatic Evolution of the west margin of the Back-Arc Basin

Global show a progressive and sustained rise between the late Aptian through to the Turonian (Haq *et al.*, 1987). More locally, sequence stratigraphy results for base level fluctuations on the eastern margin of the back-arc basin, show a mid-Aptian transgression and a stable highstand throughout the Albian (Legarreta and Uliana, 1991), while our results show a major regression at the beginning of the Albian, along with an angular unconformity, suggesting tectonic uplift of the arc, possibly related to a compressional event. This uplift would have triggered the emergence of dryland, the onset of drainage systems and the suppression of the carbonate factory.

Global eustatic variation curves also show a global maximum around 91 Ma (Haq *et al.* 1987), which, given the U-Pb geochronology presented (fig 1) correlates perfectly with the drowning of the coast interpreted for Checo de Cobre Member. and onset of carbonate sedimentation. To the east it correlates with the drowning of raised lands and the onset of the tidal Flat environment interpreted in the Pucalume Formation (fig. 1)

The other compressional event documented here at the base of the Viñitas Fm. (i.e. between 94 and 83 Ma) is compatible with the various pulses of tectonic deformation defined as "Peruvian Phase" by Jaillard (1992) that has being recognized in northern Chile and Southern Peru.

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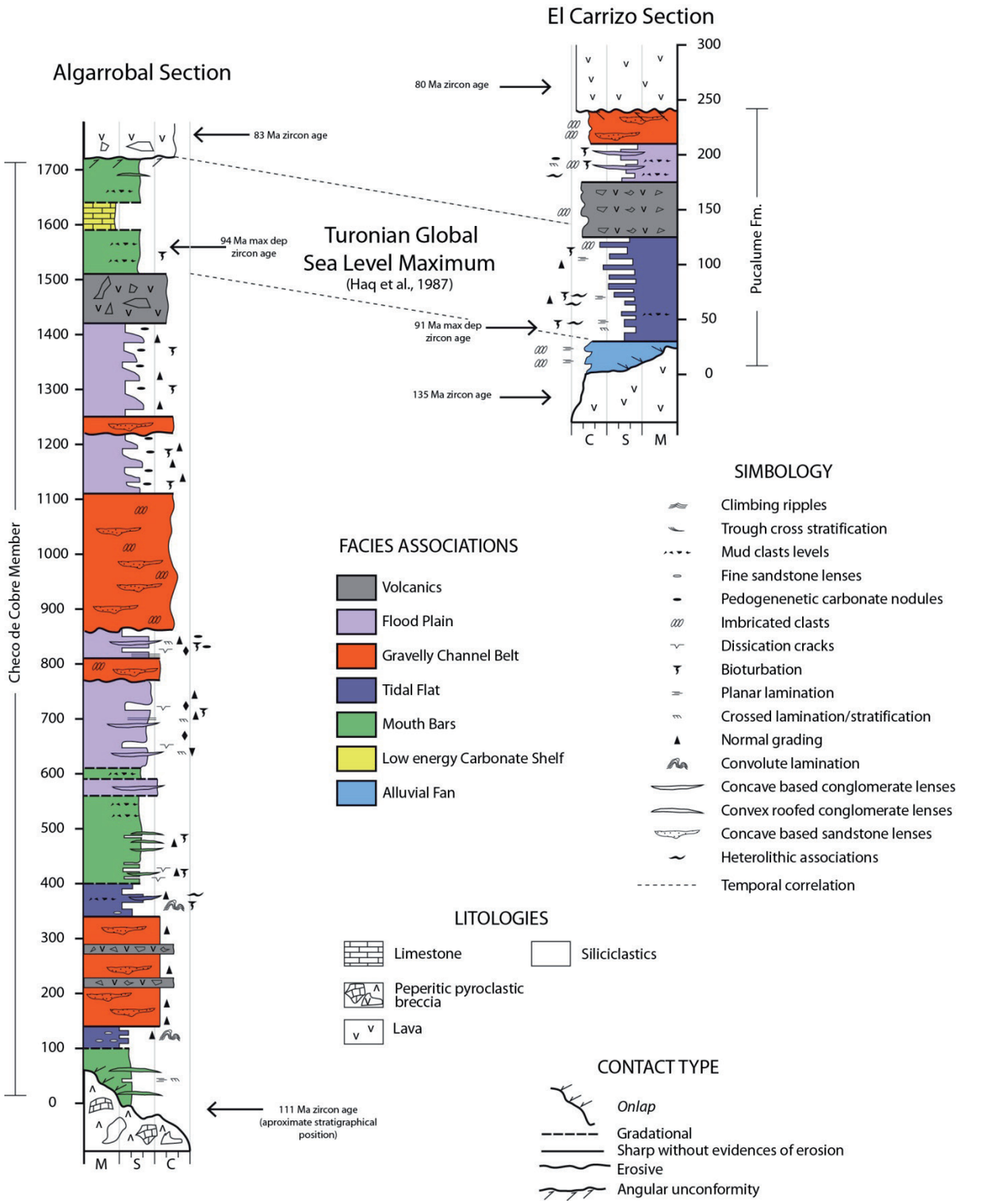

Figure 1. Synthetic stratigraphic sections of the Checo de Cobre Member and the Pucalume Fm. showing facies associations distribution and available zircon U-Pb ages.