CENOZOIC TECTONO-STRATIGRAPHIC EVOLUTION OF THE ANDEAN FOREARC NORTHERN CHILE

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INTRODUCTION

It has been suggested that during the Cenozic the tectonic regime along the Pacific margin of South America was controlled by the angle and rate of convergence at the subduction zone (Pardo-Casas & Molnar, 1987). Periods of rapid convergence (>100 mm/a) correspond to phases of compressional deformation and periods of relatively slow convergence (<50 mm/a) correspond to intervals of tectonic quiescence. The angle of convergence is considered to have controlled the amount of strike-slip deformation, an increase in obliquity resulting in an increase in transpressional/transtensional deformation. A number of deformation phases have been determined for the Cenozoic of the Central Andes which have become relatively widely accepted in the literature (e.g. Jordan & Alonso 1987) these include: the Late Eocene Incaic, an Early Miocene phase, the Late Miocene Quechua and the Pliocene Diaguita phases. The Incaic and Quechua deformation phases correspond with periods of increased convergence (Pardo-Casas & Molnar, 1987). The Central Andean margin appears, therefore, to have been subject to a compressional tectonic regime throughout much of the Cenozoic, interspersed with periods of tectonic quiescence. However, the structural and sedimentological expression of these tectonic regimes varies considerably. Here we examine the Cenozoic structural and stratigraphic evolution of the north Chilean forearc using new and published data in a traverse across the forearc through the Coastal Cordillera, Central Depression, the Precordillera and the Preandean Depression. We suggest that compressional episodes were interspersed with periods of active transtensional basin formation and that Late Miocene extension of the Coastal Cordillera is related to crustal flexure and extensional collapse. In addition, much of the palaeomagnetically determined rotation which has affected the north Chilean forearc can be attributed to localised strike-slip deformation associated with these periods of deformation, and not oroclinal flexure.

TECTONO-STRATIGRAPHIC EVOLUTION

Following the Late Eocene Incaic Orogeny a period of 'tectonic quiescence' was associated with pluton emplacement and development of a regional pediplain across northern Chile. The post-Incaic evolution of the forearc is detailed for distinct morphotectonic zones.

Preandean Depression

Deposition in the Preandean Depression (Salar de Atacama) commenced in the Early Oligocene (30 Ma) following Incaic deformation at approximately 40 Ma. Sedimentation was continuous until at least the Early Miocene (19 Ma). In a southerly sub-basin, 800 m of sandflat, playa and sheetflood sediments were deposited between 30 and 24 Ma. At 24 Ma an abrupt influx in coarse grained detritus produced 600 m of alluvial fan sheetflood and debris flow deposits up to 19 Ma (Kape, 1996). In the northern sub-basin 500 m of distal sheetflood sediments were deposited before 24 Ma, prior to deformation and development of an unconformity between 24 and 15 Ma (Kape, 1996). Elsewhere, sedimentation did not commence until approximately 10 Ma when deposition of the 'Hollingworth gravels' took place unconformably over the Early Miocene succession at approximately 10 Ma (Naranjo et al., 1994). A thick sequence of ignimbrites and interbedded gravels were deposited between 10 and 4 Ma (San Bartolo Group) followed unconformably by deposition of Plio-Pleistocene sheetflood and lacustrine sediments (Vilama Formation) which in turn were locally deformed prior to the Holocene.

Precordillera

Sedimentation in the Precordillera took place within the Calama Basin. The basin forms a link between the Preandean and Central Depressions and is located within the Cordillera de Domeyko. Following Incaic deformation, sedimentation commenced in the ?Late Eocene to Early Oligocene with deposition of 500 m of alluvial fan deposits (?35-?28 Ma). Deformation in the Late Oligocene to early Miocene took place prior to deposition of 100 m of fluvial and playa deposits in the Early to Mid-Miocene (?21-?14 Ma). Deposition of 115 m of alluvial-lacustrine sediments (interrupted by localised deformation) took place in the Late Miocene (9-3 Ma) following Mid-Early Late Miocene deformation and non-deposition. Sedimentation recommenced in the Late Pliocene to Pleistocene with deposition of 30 m of fluvio-lacustrine sediments, minor deformation and incision.

Central Depression

Deposition within the Central depression followed Incaic deformation (after 42 Ma) in the Late Eocene to Early Oligocene (?35 Ma). Approximately 1000 m of alluvial fan and lacustrine sedimentation took place throughout the Oligocene and Miocene (the Sichal Formation) up to 11 Ma (Jensen et al. 1995)(although it should be noted that exposure is poor over this interval). A hiatus between 11 and 7 Ma was followed by deposition of volcanics (Ichuno Formation) and alluvial-lacustrine sediments of the Quillagua Formation up to the Late Miocene-?Early Pleistocene (Saez, 1995).

Coastal Cordillera

Up to 120 m of interbedded shallow marine and alluvial fan sediments were deposited along the western flank of the Coastal Cordillera from the Late Miocene onwards (La Portada and Mejillones formations). Sedimentation was largely conformable with localised unconformities developed adjacent to active faults, and has taken place in active half-grabens or topographic lows carved in Jurassic volcanics and granodiorites.

SYNTHESIS: BASIN FORMATION AND DEFORMATION

Comparison of the stratigraphic sections from the studied areas reveals the following sequence of events:

1) Commencement of alluvial fan and playa sedimentation across the area in the Late Eocene/Early Oligocene following regional deformation associated with the Incaic Orogeny. The Calama Basin and Preandean Depression almost certainly formed part of a single basin.
2) End Oligocene/Early Miocene deformation in the Calama Basin and northern part of the Salar de Atacama. Whether deformation took place in the Central Depression is difficult to ascertain due to the lack of detailed information.
3) Continuation of alluvial fan and playa sedimentation from the Early to Mid/Late Miocene.

4) Regional deformation associated with the Quechuan orogeny which affected the Central Depression, Calama Basin and Preandean Depression.
5) Commencement of sedimentation in the Late Miocene across the forearc with ignimbrite emplacement dominant in the Preandean Depression and alluvial-lacustrine sedimentation in the Calama Basin and Central Depression. The latter two basins were linked after localised deformation in the latest Miocene. Initiation of sedimentation on the western side of the Coastal Cordillera and development of extensional tilted fault blocks.
6) Localised Late Pliocene to Pleistocene deformation in the Calama Basin and Preandean Depression synchronous with localised sedimentation and incision.

DISCUSSION

It is suggested that following the Incaic deformation phase, the Oligocene period of tectonic quiescence was represented by transtensional basin formation recorded by virtually synchronous sedimentation in the Central Depression, Calama Basin and Preandean Depression. Changes in sediment thicknesses adjacent to large-scale faults (e.g. Precordilleran Fault system) suggest these faults were active (Jensen et al. 1995). The development of a transtensional tectonic regime could be due to extensional collapse of the Incaic Orogen following a decrease in convergence rate. A significant deformation phase took place at the end Oligocene/Early Miocene. The regional extent of this phase is difficult to constrain, however, the amount of deformation appears to have been greatest in the Calama Basin - a feature which suggests deformation associated with movement along the Precordilleran Fault System (May et al. this volume). Alluvial fan and playa sedimentation in transtensional basins continued up to the end of the Mid-Miocene across the study area prior to the regional Quechuan deformation phase. The full extent of sedimentation in the Preandean Depression during this time period is difficult to quantify due to post-depositional uplift and erosion associated with the Quechuan Orogeny.

A significant change in deposition took place from the Late Miocene to Late Pliocene. The products of the volcanic arc swamped the Preandean Depression, whilst diatomite and carbonate lacustrine sedimentation dominated over much of the Calama Basin and Central Depression. Interestingly, this lacustrine sedimentation is coincident with a change from a semi-arid to hyper-arid climate (Alpers & Brimhall, 1988). A series of localised deformation phases affected the forearc during the Late Pliocene and Pleistocene which may correspond to the Diaguita phase of deformation (Jordan & Alonso, 1987). Throughout much of the Tertiary it appears that the Central Andes were subject to periods of intense compressional-transpressional deformation interspersed with periods of fault-controlled subsidence. Subsidence is likely to have been related to a transtensional tectonic regime generated by periods of crustal collpase and stress relaxation. Localised deformation appears to have continued throughout much of the basin-fill and may be related to movement on individual faults. This cycle of compression and relaxation could account for much of the tectono-stratigraphic development of what is now the Andean forearc.

An extensional collapse process may also explain the Late Miocene development of the Coastal Cordillera. The leading edge of the South American Plate is represented by a series of extensional graben and half-graben (Moberly et al. 1982; Padilla & Elgueta, 1992) which have an inferred Miocene fill. It is proposed that stress relaxation following uplift associated with the Quechuan deformation phase has resulted in extensional collapse of the leading edge of the continental plate, possibly due to a decreased convergence rate and/or less effective coupling with the Nazca Plate. This process could explain why synchronous extensional and compressional deformation has affected the forearc.

A number of palaeomagnetic studies have been undertaken on rocks of different ages from throughout the north Chilean forearc. The studies have frequently found evidence for block rotation which is commonly interpreted in terms of Oroclinal bending. It is possible that many of the palaeomagnetically determined rotations simply reflect localised deformation associated with transpressional/transtensional fault movement.

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