SERVICIO NACIONAL
DE GEOLOGIA
Y MINERIA·CHILE

CONGRESO
GEOLOGICO
CHILENO
1·9·9·1

RESUMENES EXPANDIDOS
p. 640 - 644

GEODYNAMIC DEVELOPMENT OF THE SALAR DE ATACAMA BASIN, NORTHERN CHILE

S.Flint*, P. Turner**, A.J. Hartley° and E.J. Jolley**+

Abstract

The Salar de Atacama basin of northern Chile originated as part of an intracratonic regional rift system during Permian times, at the start of the Andean orogenic cycle. Triassic syn-rift continental red beds were deposited to a thickness of at least 2 km but no marine rocks were deposited and the area remained above depositional base level throughout the Jurassic/early Cretaceous. In the late Cretaceous-Paleocene the Salar basin accommodated some 4 km+ of continental detritus (Purilactis Group). Basin accommodation space at this time may have reflected an interplay between tectonic basin margin uplift, limited fluxural loading and thermal effects related to establishment of the Late Cretaceous volcanic arc adjacent to the western basin margin (arc-related, foreland-style basin stage). Late Eocene strike-slip faulting was succeeded by deposition of the Paciencia Group (intra-arc basin stage). The Miocene-Recent Salar basin is a continental forearc basin, comprising pyroclastics and continental sediments, thrust over Quaternary gravels in many places. The Salar de Atacama basin thus preserves the stratigraphic evidence for the development of the complete Andean cycle.

Introduction

Current models for sedimentary basins include rift, thermal sag, foreland and pull-apart types, which have generally accepted spatial and temporal geodynamic positions in orogenic cycles. In this paper we describe the history of the Salar de Atacama (Fig.1), a long-lived (Triassic-Recent) arc-related basin which, owing to the geodynamic development of the Central Andes, has evolved from a foreland rift, through complex 'arc-related' stages, to a Miocene-Recent forearc basin.

Stratigraphy of the Basin-Fill

The composite stratigraphy of the Salar de Atacama basin extends from the Permo-Triassic to the Recent, albeit with significant periods of non-deposition and erosion, associated with contractional and subsidiary strike-slip deformational episodes. Overall estimated stratigraphic thickness is some 8 km, based on the exposed strata on the inverted western basin margin. The main, unconformity-bounded depositional basin-fill units are shown in figure 2 and are dominated by continental red bed clastics and volcanics.

However, during the Late Cretaceous a further eastward jump of the Andean arc is apparent[15] to a basin margin position, coincident with the El Bordo Dorsal; this introduction of active intrusions is likely to have resulted in uplift of the eastern basin margin, which may be reflected in the overall coarsening upward nature of the Purilactis basin-fill[7]. The dominance of fresh boulders of granodiorite in the upper conglomeratic members of the Purilactis Group reflects the unroofing of the Cretaceous arc.

Late Eocene Transgression

Projected plate reconstructions for the Eocene indicate a period of oblique convergence (Fig. 4), implying right-lateral strike movement of the margin[1, 12]. NW-SE trending strike-slip faults have been mapped along part of the western Salar basin margin[6]. Their effect has been

* Department of Earth Sciences, University of Liverpool, P.O. Box 147, Liverpool, U.K.
** School of Earth Sciences, University of Birmingham, P.O. Box 363, Birmingham, U.K.
° Department of Geology, University of Wales College Cardiff, P.O. Box 914, Cardiff, U.K.
+ Present address: P.B. Petroleum Department Ltd., 301 St. Vincent St., Glasgow G2 5DD, U.K.

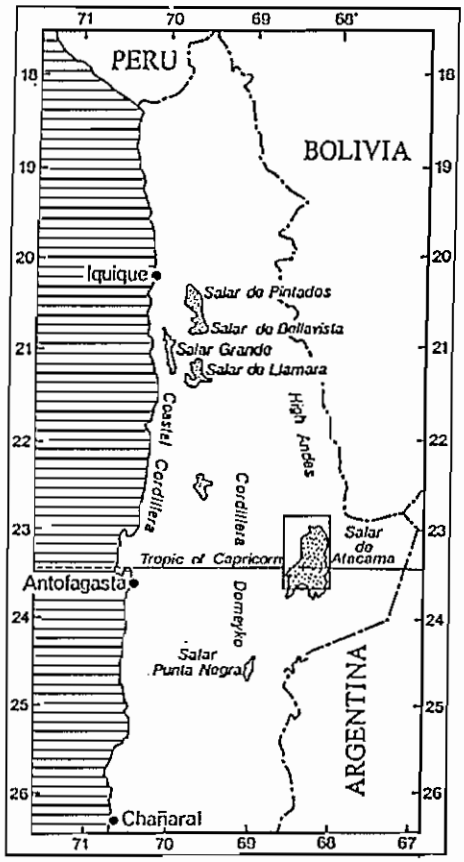

FIG. 1. Location of the Salar de Atacama basin within the present day morpho-tectonic framework of the north Chilean forearc. Boxed area shows position of figure 3.

to complicate part of the Purilactis Group stratigraphy and to produce intense folding[3], which is localised to a relatively local zone and preferentially developed in fine grained playa siltstones and evaporites of the lowermost Purilactis Group.

Oligocene-Early Miocene intra-arc basin stage

Accommodation space for deposition of the Paciencia Group may have resulted initially from the Incaic strike-slip faulting (pull-apart basin) and possible later thermal subsidence as the Eocene arc system cooled. The depositional architecture of the Paciencia Group is complicated by folding, thrust faulting and salt-related doming[6]. Nevertheless, westerly-derived clastic (sourced from the uplift Purilactis Group) eventually prograded right across the basin but the Paciencia Group shows less well-developed coarsening-upward cycles than the Purilactis Group. We intepret this to be a function of less synsedimentary tectonism; the facies architecture was controlled more by microclimatic fluctuations, as evidenced by the fluctuation between shallow but long-lived lacustrine environments and hyper-arid salt pan system.

Early-Middle Miocene Contraction

The Paciencia Group was folded prior to the deposition of the San Bartolo Group. This intra-Miocene deformation has been linked to the fragmentation of the Farallon plate into the Cocos and Nazca plates (Fig.4). By this time the Andean arc had fully established itself in its present day position to the east of the Salar basin.

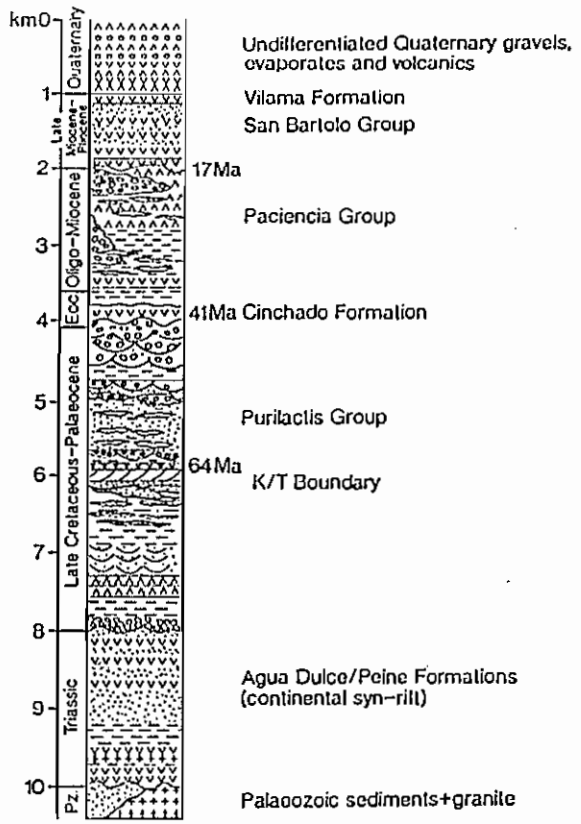

FIG. 2. Stratigraphy of the Salar de Atacama basin-fill as exposed in the inverted western margin.

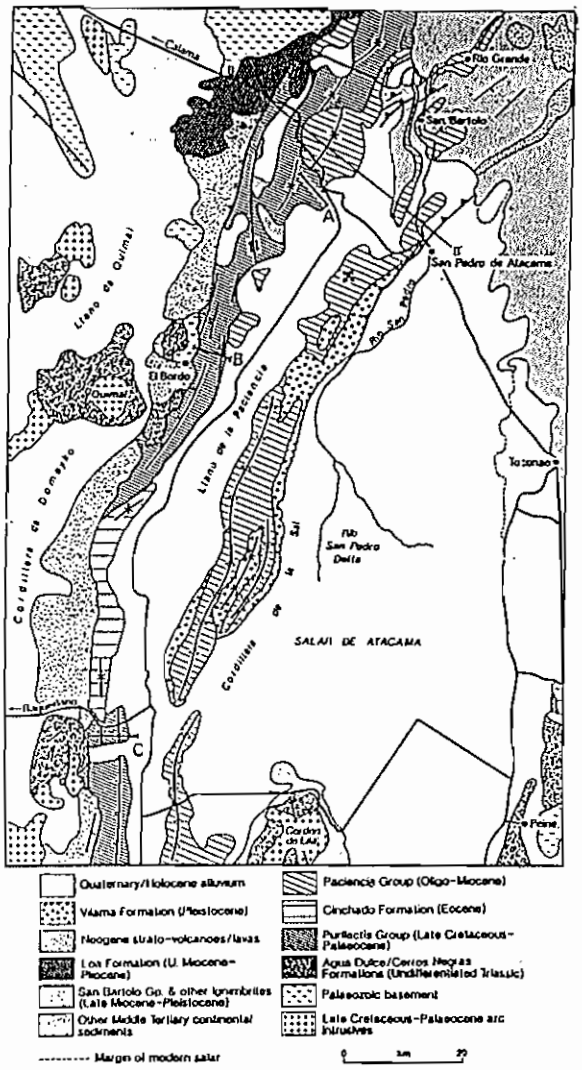

FIG. 3. Simplified geological map of the western Salar basin margin showing the outcrop pattern of the main tectono-sedimentary units. Simplified from Marinovic and Lasen[11] and Ramírez and Gardeweg[14].

Middle Miocene-Recent forearc basin stage

The Salar basin became an intermontane forearc basin from early Miocene to Recent times. Sedimentation over this period has been controlled by combination of volcanic activity and thin-skinned thrusting[9, 10]. During the Pleistocene, climatic cyclicity induced by glaciation resulted in pluvial periods, characterised by lacustrine deposition.

Stratigraphy of the Basin-Fill

The composite stratigraphy of the Salar de Atacama basin extends from the Permo-Triassic to the Recent, albeit with significant periods of non-deposition and erosion, associated with contractional and subsidiary strike-slip deformational episodes. Overall estimated stratigraphic thickness is some 8 km, based on the exposed strata on the inverted western basin margin. The main, unconformity-bounded depositional basin-fill units are shown in figure 2 and are dominated by continental red bed clastics and volcanics.

Controls on Stratigraphy Development

The stratigraphic architecture of the Salar de Atacama basin is dominantly a function of tectonic and magmatic (thermal) events. Figure 4 is a chronoestratigraphic diagram of the basin-fill, showing positions of the main hiatuses and depositional periods.

Triassic-Middle Jurassic rift basin stage

In the case of northern Chile early history of the Andean cycle is poorly understood. Breitkreuz *et al.*[2] postulate an intraplate origin for the whole Carboniferous-Triassic of northern Chile, based on a combination of igneous rocks geochemistry, stratigraphy and forearc-trench geometry. In the Salar and Domeyko basins we interpret the Agua Dulce/Peine sequence as early syn-rift deposits. The presence of a marine back-arc basin during the Late Triassic-early Cretaceous is well known through the length of South America; this basin clearly formed by continued extension of the Triassic rift system, now in a back-arc setting. However, the stratigraphy of the Salar basin indicates that no marine strata were deposited. We conclude that the El Bordo area represents a Paleozoic basement high, separating the easterly Salar failed rift western Domeyko successful rift. The Salar basin thus received some continental detritus during the late Triassic but had probably filled to depositional base level by Jurassic times.

Middle Cretaceous contraction and uplift

Opening of the South Atlantic ocean[13] resulted in the westward movement of the South American continent[5],

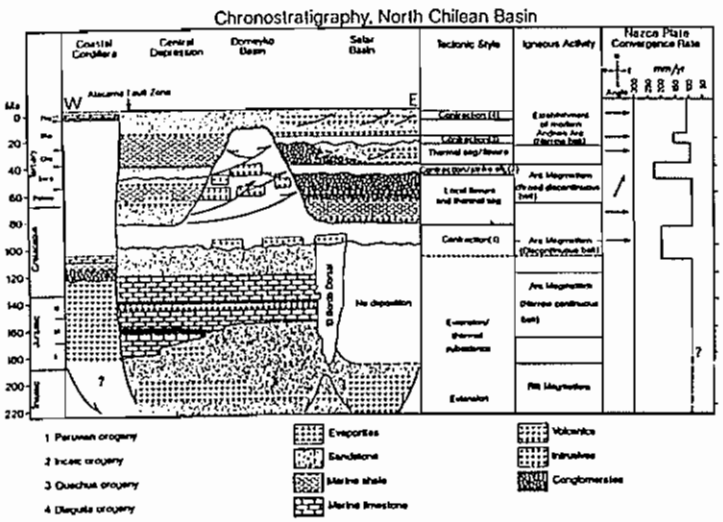

FIG. 4. Chronostratigraphic diagram for the Andean forearc, northern Chile, showing all phases of basin filling and inversion. Magmatic and tectonic activity are plotted alongside convergence rate/abgke data abd shiw a good correlation betweenplate dynamics and continental margin evolution.

[12]. This resulted in a middle Cretaceous period of regional contraction (Fig. 4), with the closure of the Domeyko back-arc basin and accretion of the Jurassic arc to the leading edge of the continent4. The net result was production of a basement-cored thrusted uplift (proto-Cordillera de Domeyko[16]). The other important aspect of this shortening was to produce an eastward movement of the arc to the Cordillera de Domeyko area[15].

Late Cretaceous-Eocene 'foreland style' basin stage

The Purilactis Group[3,14] represents and overall coarsening upward sequence but may be divided into a series of upward-coarsening mega sequences (200-500 m thick), themselves comprised of 2-5 m scale fining upward units. In foreland basins such megasequences have been interpreted as representing tectonically-related progradation of clastic systems, controlled by episodes of thrusting. It is possible to interpret such an origin for the Purilactis alluvial fan systems, which prograded from the west[8], during initial growth of the Cordillera de Domeyko. Evidence includes extensive palaeocurrent data and provenance studies which attest to the Jurassic late rift carbonate basin acting as a partial source area for this unit.

The local rise in depositional base level resulted in low gradient, high sinousity fluvial systems being established (Vilama Formation). During the Quaternary, the emergence of the intrabasinal Cordillera de la Sal as a function of thrust front propagation[10] resulted in the western quarter of the basin (Llano de la Paciencia) being effectively partitioned from the rest of the Salar as a thrust sheet-top basin (Fig. 3), thus trapping all coarse grained sediments in the Llano.

Conclusion

The Salar de Atacama basin preserves the stratigraphic evidence for the development of the complete Andean cycle. It has evolved from a foreland rift, through back-arc and intra-arc stages to a Neogene forearc basin. The sedimentological/structural response to these changing magmato-tectonic phenomena during the complex evolution of the Chilean crust is most completely preserved in the arc-related basin-fills. Further stratigraphic studies of arc-related basins should promote a greater understanding of the geodynamic development of the Andean margin.

References

1. Beck, M.E. Jr. 1988. Late Jurassic-Recent Palaeomagnetic data from active plate margins of South America. *Journal of South American Earth Sciences*, Vol. 1. p.39-52.
2. Breitkreutz C.; Bahlburg, H.; Zeil, W. 1988. The Paleozoic evolution of northern Chile: Geotectonic implications. *In* The southern Central Andes (Bahlburg, H.; Breitkreutz, C.; Giese, P.; editors). *Lectures Notes in Earth Sciences, Springer, Heidelberg*, No. 17, p. 87-102.
3. Charrier, R.; Reutter, K.J. 1990. The Purilactis Group of northern Chile: link between arc and backarc during Late Cretaceous and Palaeogene. *International Symposium Geodynamique Andine, Proceedings* , p. 249. (Abs). Grenoble.
4. Coira, B.; Davidson, J.; Mpodozis, C.; Ramos, B. 1982. Tectonic and magmatic evolution of the Andes of northern Argentina and Chile. *Earth Science Reviews*, Vol.18, p.303-332.

5. Daly, M.C. 1989. Correlations between Nazca/Farallon Plate kinematics and forearc basin evolution in Equador. *Tectonics,* Vol. 8, p. 769-790.
6. Dingman, R.J. 1967. Geology and groundwater resouces of the northern part of the Salar de Atacama, Antofagasta Province, Chile. *U.S. Geological Survey, Bulletin,* No. 1219, 49 p.
7. Flint, S.; Hartley, A.J.; Rex, D.C.; Guise, P.; Turner, P. 1989. Geochronology of the Purilactis Formation of northern Chile: implications for Early Tertiary basin dynamics in the Central Andes. *Revista Geológica de Chile,* Vol. 16, No. 2, p.241-246.
8. Hartley, A.J.; Flint, S.; Turner, P. 1988. Lithostratigraphy and sedimentology of the Cretaceous Purilactis Formation, Antofagasta Province, Chile. *In Congreso Geológico Chileno, No. 5,* Santiago.
9. Hooper, B.; Flint, S. 1987. Cenozoic tectonic evolution of the San Bartolo area of northern Chile. *Zentralblatt für Geologie und Palaontologie,* Teil 1, p. 945-957.
10. Jolley, E.J.; Turner, P.; Williams, G.D.; Hartley, A.J.; Flint, S. 1990. Sedimentological responses of an alluvial system to Neogene thrust tectonics, Atacama desert, northern Chile. *Journal of the Geological Society of London,* Vol.147, p. 769-784.
11. Marinovic N.; Lahsen, A. 1984. Hoja Calama. *Servicio Nacional de Geologia y Minerla, Carta Geológica de Chile,* No. 58, 140 p. Santiago.
12. Pilger, R.H. Jr. 1984. Cenozoic plate kinematics subduction and magmatism: South American Andes. *Journal of the Geological Society of London,* Vol.141, p.793-802.
13. Rabinowitz, P.D.; Labrecque, J. 1979. The Mesozoic South Atlantic ocean and evolution of its continental margin. *Journal of Geophysical Research,* Vol. 84, p. 5973-6002.
14. Ramírez, M.; Gardeweg, M. 1982. Hoja Toconao. *Servicio Nacional de Geologia y Minerla, Carta Geológica de Chile,* No. 54, 122 p.
15. Reutter, K.J.; Giese, P.; Gotze, H.J.; Scheubet, E.; Schwab, K.; Schwarz, G.; Wigger, O. 1988. Structures and crustal development of the Central Andes between 21° and 25°S. *In* The southern Central Andes (Bahlburg, H.; Breitkreutz, C.; Giese, P.; editors). *Lecture Notes in Earth Sciences, Springer, Heidelberg,* 17, p.231-261.
16. Turner, P.; Williams G.D.; Flint, S.; Hartley, A.J. 1990. Cretaceous to Recent basin evolution in northern Chile: and insight into the nature of the western margin of Gondwana. *7th International Gondwana Symposium, Proceedings.* Sao Paulo.