Thermochronological data and denudation history along a transect between Chañaral and Pedernales (~26°S), North Chilean Andes: Orogenic implications

Thierry Nalpas (1,5), Gérard Hérail (1), Constantino Mpodozis (2), Rodrigo Riquelme (3), Jorge Clavero (4), & Marie-Pierre Dabard (5)

(1) IRD-LMTG, Román Díaz 264, Casilla 53390, Correo Central, Santiago, Chile, and Departamento de Geología, Facultad de Ciencias Físicas y Matemáticas de la Universidad de Chile. Santiago, Chile
(2) SIPETROL, Av. Vitacura 2736, Las Condes, Santiago de Chile, Chile
(3) Universidad Católica del Norte, Avenida Angamos 0610, Antofagasta, Chile
(4) SERNAGEOMIN, Av Santa María 0104, Providencia, Santiago, Chile
(5) Géosciences Rennes, Université de Rennes 1, Campus de Beaulieu, 35042 Rennes cedex, France

KEYWORDS: erosion, denudation, orogenesis, Andes, Chile

Introduction

The Chilean Andes along the southern Atacama Desert (26°-27°S) include into four main morphotectonic units: the Coastal Cordillera and the Central Valley, Precordillera (or Cordillera de Domeyko), Preandean depression (Pedernales-Maricunga basins) and Western Cordillera (Figure 1). Within the studied region, the second order Cordillera Claudio Gay separates the Western Cordillera from the Preandean depression.

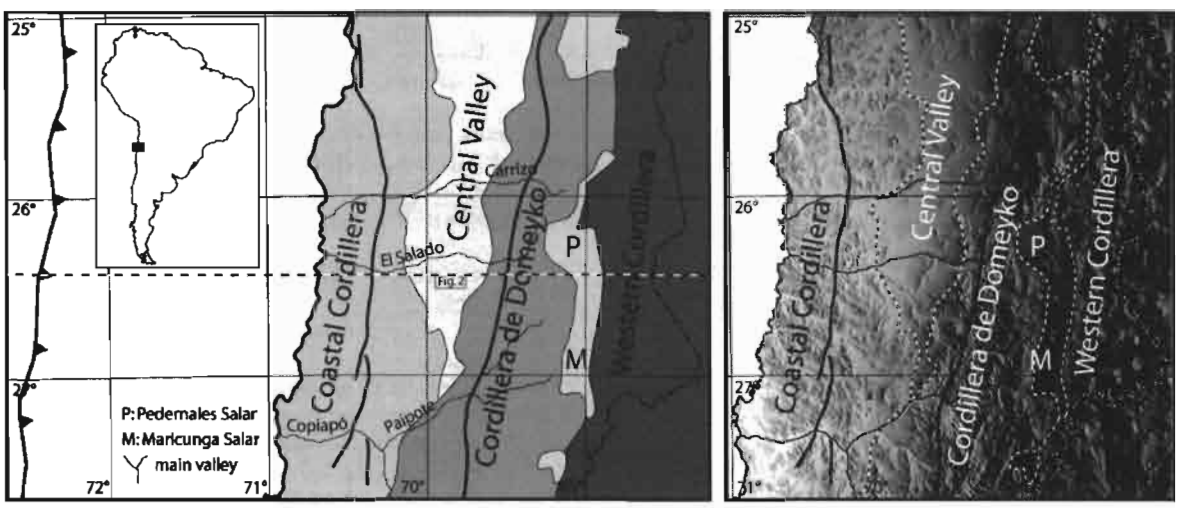

Figure 1: Localisation of the studied area (Salar de Pedernales P, y Maricunga M).

From the coast to the Maricunga-Pedernales basin topography raises from 0 to 35000m along a 150 km horizontal transect. Uplift and denudation should have produced a large amount of sediments during the Cenozoic but only in the Preandean depression (Pedernales basin) and the Argentine Puna further east thick sequences of Tertiary sediments has been preserved while in the Precordillera and Central Depression only a thin blanket of Miocene sediments (Atacama Gravels) forms the infill of a Tertiary paleovalley network (Sillitoe et al., 1968; Mortimer 1980; Riquelme, 2003; Gabalda et al., 2005). In this contribution we present a new set of thermochronologicals data that will allow us to establish the ages of main exhumation episodes, which can be tied to periods of erosion and Andean uplift along the western slope of the southern Central Andes.

Geological setting

The geology of northern Chile is dominated by a series of east-stepping magmatic Mesozoic and Cenozoic magmatic arcs (Mpodozis and Ramos, 1990). In the Chañaral-Pedernales region the, the Coastal Cordillera comprise the eroded remnants of Jurassic–early Cretaceous magmatic arc represented by large plutonic complexes, a Jurassic andesitic to basaltic volcanic sequence (La Negra Formation, Garcia, 1967), and Upper Jurassic–Early Cretaceous andesitic to dacitic lavas (Punta del Cobre Group Lara and Godoy, 1998). The main tectonic feature in the Coastal Cordillera is the Atacama Fault System (Salado Segment), which originated in the Jurassic as a "trench-linked" structural system along the axis of the early Andean magmatic arc (Fig. 1). Back-arc Jurassic-early Cretaceous marine and continental sedimentary units appear further east in the Precordillera overlying Late Paleozoic igneous basement units (Cornejo et al, 1993). Upper Cretaceous andesitic volcanic sequences (Llanta Formation, Cornejo et al., 1993) and Paleocene-Early Eocene volcanic complexes dominate the geology in the Central Valley. To the east, in the Precordillera, around El Salvador, the Mesozoic back-arc sediments are intruded by Eocene sub volcanic stocks and porphyries and deformed by the Eocene Sierra del Castillo-Agua Amarga fault and Potrerillos Fault and Thrust Belt (Tomlinson et al., 1994; Mpodozis et al., 1994; Tomlinson et al., 1999) which form part of the regionally important Domeyko Fault system (Figure 1). Younger volcanics of the Oligocene-Miocene Maricunga belt (Cornejo et al, 1993; Mpodozis et al, 1995) occur along the eastern edge of the Precordillera west of the Pedernales and Maricunga basins (Figure 1). Finally, The Cordillera Claudio Gay (Figure 2) is an uplifted basement block, covered by Eocene-Miocene sedimentary and volcanic sequences (Mpodozis and Clavero, 2002).

Above the "substratum" between the Coastal Cordillera and the Cordillera de Domeyko, a thin Neogene continental sedimentary sequence (Gravas de Atacama) is preserved in fluvial paleovalleys (Sillitoe et al. 1968; Mortimer, 1973; Riquelme 2003). These fluvial gravels, sands and clays are intercalated with ignimbrite layers allowing the dating.

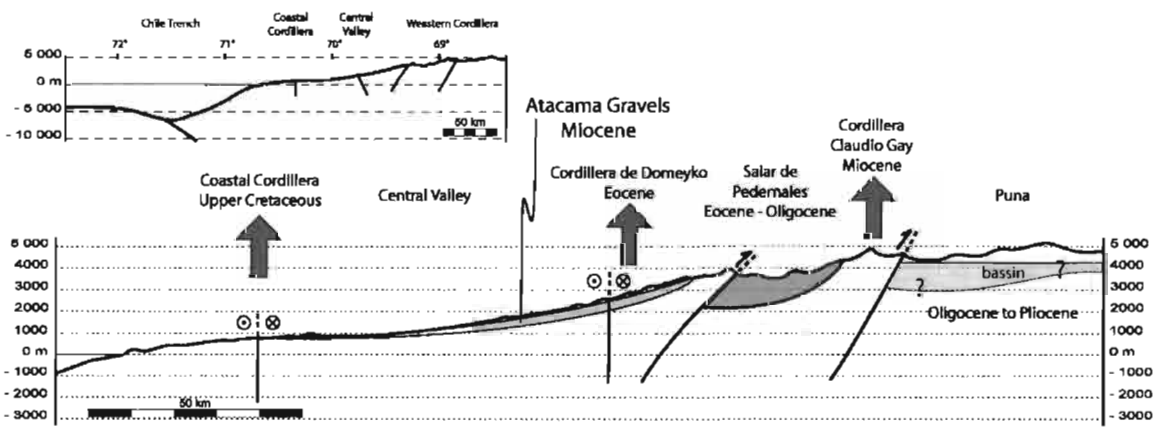

Figure 2: Simplified cross section of the studied area. The age of beginning of the exhumation, dark fleches, is indicated on each main morphological block).

Thermochronological data

In Figure 3 we present the results of 9 new apatite fission track 3 (U-Th)/He in zircon and 3 apatite He ages, for samples colleted along the transect from Chañaral to Cordillera Claudio Gay which were analyzed following the procedures described in Reiners et al. (2003) and Donelick et al (1999). Apatite He ages indicate the time of

cooling to below approximately 63-73 °C (approximately 2km considering a geothermal gradient of 33°C/km) apatite fission-track ages indicate the time of cooling below 110-120°C (3,5 - 4km) and Zircon He ages indicates the time of cooling below °C 180-200 (5,5 - 6km). The combined use of the three methods allow to determine variations in the denudation rates which can be compared with the tectonic history of the studied region, specially the evolution of regional deformation and uplift. Sampling was carried out in each of the representative structural blocks of the East-West transect (Fig 2).

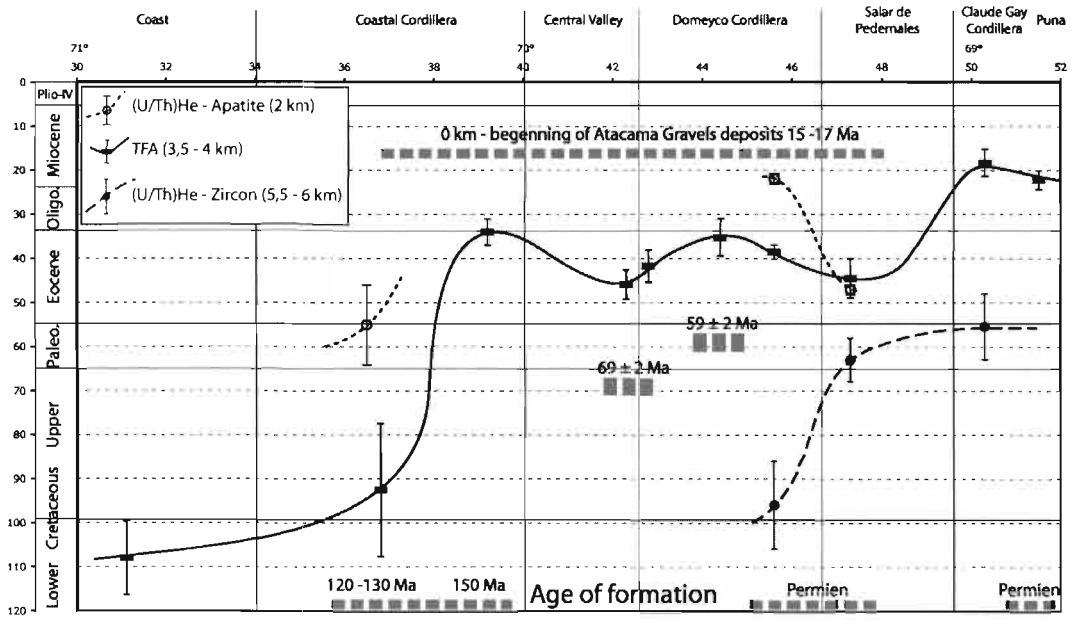

Figure 3: Plot of thermochronologic data vs. longitude along the Chañaral-Pedernales transect (Salar de Perdernales TFA data from Maksaev, V. and M. Zentilli, 1999).

Discussion and Conclusions

The data presented in Figure 3 show that regional exhumation occurred in three well defined steps along the Chañaral-Pedernales transect: Mid-Cretaceous to Paleocene on the Coastal Cordillera, Eocene from the Central Valley to the Pedernales Basin, and finally Oligo-Miocene at Cordillera Claudio Gay. Data clearly shows the eastwards propagation of the exhumation without significant tectonic reactivation of the landscape formed during previous denudation episodes and is interpreted as eastwards propagation of the deformation. Concerning the topic of mass transfer only sediments originated during the Eocene Oligocene events seem to have been preserved in the compressive pre-Andean Pedernales basin. At the same time, withdrawal of material towards the ocean prevailed along the western Precordillera (and Central Valley) as indicated by the paleovalley system sealed below the Atacama Gravels. These data and the observation of the paleofluvial network that contain the Atacama Gravels testify an episode of fluvial dissection. Mass transfer out of the Precordillera diminished during the Miocene as shown by the well-preserved Atacama Gravels sedimentary blanket. These considerations indicate that topography is not the major factor controlling the amount of mass transfer during Andean uplift as the adjustments in the volume of mass transferred out of the system seem to track climatic changes towards semiarid-hyper arid conditions during the Miocene.

References

Cornejo, P., Mpodozis, C., Ramirez, C.F., Tomlinson, A.J., 1993. Estudio Geológico de la Región de Potrerillos y El Salvador (26°–27° Lat.S). Servicio Nacional de Geología y Minería-CODELCO, Informe Registrado IR-93-01, 12 cuadrángulos escala 1:50.000 y texto. 258 p., Santiago, Chile.

Donelick, R.A., Ketcham, R.A., and Carlson, W.D., 1999. Variability of apatite fission track annealing kinetics II: Crystallographic orientation effects. American Mineralogist, v. 84, p. 1224-1234.

Gabalda G., Nalpas T. and Bonvalot S., 2005. Base of the Atacama Gravels Formation (26°S, Northern Chile): first results from gravity data. ISAG VI, Barcelona.

García, F., 1967. Geología del Norte Grande de Chile. In Simposium sobre el Geosinclinal Andino, No. 3, 1962. Sociedad Geológica de Chile, 138 p.

Lara, L., Godoy, E., 1998. Hoja Quebrada Salitrosa, Región de Atacama. Servicio Nacional de Geología y Minería, Mapas Geológicos N.4, 1 mapa, escala 1:100.000. Santiago, Chile.

Maksaev, V. and M. Zentilli,1999. Fission track Thermochronology of the Domeyko Cordillera, Northern Chile: Implications for Andean Tectonics and Porphyry Cooper Metallogenesis. Explor. Mining Geol. 8(1 y 2), p. 65-89.

Mortimer, C., 1973. The Cenozoic history of the southern Atacama Desert, Chile. J. Soc. Lond. 129, p. 505–526.

Mortimer, C., 1980, Drainage evolution of the Atacama Desert of northernmost Chile. Revista Geológica de Chile, no. 11, p. 3–28.

Mpodozis, C., and Ramos, V., 1990, The Andes of Chile and Argentina. Earth Science Series, Circum-Pacific Council Energy Mineral Resources, v. 11, p. 59–90.

Mpodozis C.; Tomlinson A. y Cornejo P., 1994. Acerca del control estructural de intrusivos eocenos y pórfidos en la región de Potrerillos, El Salvador. Congreso Geológico Chileno N°7, Actas, v. 2, p. 1596-1600.

Mpodozis, C., Cornejo, P., Kay, S.M., and Tittler, A., 1995, La Franja de Maricunga: Sintesis de la evolución del frente volcánico oligoceno-mioceno de la zona sur de los Andes Centrales. Revista Geológica de Chile, v. 22, p. 273–314.

Mpodozis, C, and Clavero, J., 2002. Tertiary tectonic evolution of the southwestern edge of the Puna Plateau: cordillera Claudio Gay (26°-27°), northern Chile. ISAG V, Toulouse.

Reiners Peter W. Zhou Zuyi, Todd A. Ehlers, Xu Changhai, Mark T. Brandon, Raymond A. Donelick, and Stefan Nicolescuet al., 2003. Post-orogenic evolution of the Dabie Shan, eastern China, from (U/Th)/He and fission-track thermochronology. American Journal of Science, v. 303, p. 489-518.

Riquelme, R., 2003, Evolution geomorphologique neogene de Andes Centrales du Desert d'Atacama (Chili): interaction tectonique-climat, Ph.D. Thesis, Université Paul Sabatier (Toulouse, France) and Universidad de Chile (Santiago, Chile), 258 p.

Riquelme, R., Martinod, J., Hérail, G., Darrozes, J. and Charrier, R., 2003. A geomorphological approach to determining the Neogene to Recent tectonic deformation in the Coastal Cordillera of northern Chile (Atacama). Tectonophysics 361, p. 255-275.

Sillitoe, R.H., Mortimer, C., and Clark, A.H., 1968, A chronology of landform evolution and supergene mineral alteration, southern Atacama Desert, Chile. Institute of Mining and Metallurgy Transactions, v. 77, p. B166-169.

Tomlinson, A., C. Mpodozis, P. Cornejo, C. F. Ramírez, and T. Dumitri, 1994. El sistema de Fallas Sierra de Castillo-Agua Amarga: Transpresión sinistral eocena en la precordillera de Potrerillos– El Salvador. In VII Congr. Geol. Chileno, Concepción, vol. II, p. 1459– 1463.