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The base of the Atacama Gravels Formation (26°S, Northern Chile): First results from gravity data

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Introduction

The Neogene Atacama Gravels Formation situated in the Atacama Desert, northern Chile, infills the Central Depression or Central Valley (Mortimer, 1973). In the region of El Salado valley (26°S), this formation corresponds to large coalescing alluvial fans, coming from the East (Precordillera) to the West (Coastal Cordillera). The base of the Atacama Gravels Formation (surface between gravels and andesitic basement) is visible in the Coastal Cordillera zone and the Precordillera area. In the Central Depression region, it is only visible in a few points by the way of the erosion of the present valley (e.g. El Salado). The maximum Neogene gravel formation thickness, observable from geological data, is estimated at about 500-600m in the Eastern part of the El Salado valley (Precordillera area). Within the Central Depression the geometry of the gravel infill is still poorly constrained. Obviously, a better knowledge of some geometrical parameters (gravel infill thickness, localisation of maximum infilling, shape of the contact between gravels sediments and basement...) might be helpful to discuss how the Atacama Gravels Formation is preserved. These parameters are also helpful to discuss the paleomorphology of the Central depression (irregular erosion or planar superficy) prior to the gravel deposits and therefore to better understand the erosion/deformation styles. This geometry of the base of the Atacama Gravels Formation between the East (Precordillera) to the West (Coastal Cordillera) is also important to determine if the preservation is related to deformation synkinematic or not. A step in the geometry of the base could be related to deformation.

According to the high value of the expected density contrast between the Atacama Gravel Formation infilling the central depression and the surrounding andesitic basement, gravity surveying techniques appear as an adequate method to determinate the geometry of the base of the Atacama Gravels Formation. In order to test such hypothesis and to give first order results, we conducted a first experiment of gravity surveying along an EW profile crossing the El Salado valley. Preliminary results of this gravity experiment and its tectonic implications are discussed here.

Geological setting

The Atacama Desert is divided into four main geological units parallel with the Pacific Ocean coast, which are from west to east: the Coastal Cordillera, the Central Depression, the Precordillera, and the Western Andean Cordillera (Fig. 1). In the study area the Precordillera is called Cordillera de Domeyko, and the Western Andean Cordillera, Cordillera Claudio Gay, between them is situated the Salar de Pedernales. In the Coastal Cordillera, the main tectonic structure is the Atacama Fault System (AFS), a N-S trending fault zone following, over 1000

km, the coast of northern Chile from Iquique (±20°S) to La Serena (±29°S). In the study area this fault system, between 26° to 28°S is called: El Salado segments (Thiele and Pincheira, 1987). The main tectonic structures in the Cordillera de Domeyko is the Sierra del Castillo fault and the overthrust belt de Potrerillos that limits in its Eastern part the Salar de Pedernales (Tomlinson et al., 1994; Mpodozis et al., 1994; Tomlinson et al., 1999).
The Andean structuration is characterized by an eastward migration through time of the magmatic arc towards the interior of the continent (Reutter and Scheuber, 1988).

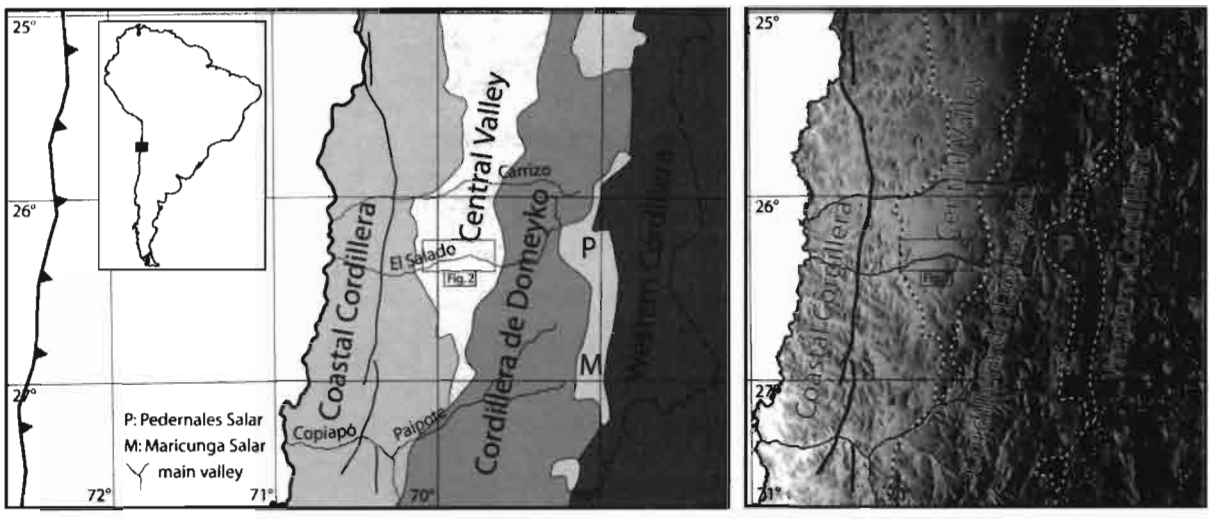

Figure 1: Localisation of the studied area.

In the study area, between the Coastal Cordillera to the Cordillera de Domeyko, the basement is roughly constituted of: (1) Jurassic–early Cretaceous magmatic arc including several north–south trending and elongated plutons, parallel to the AFS branches, (2) Jurassic andesitic volcanic sequence (La Negra Formation, Garcia, 1967), (3) Upper Jurassic–Early Cretaceous back-arc basin fill succession of andesitic lavas (The Punta del Cobre Group, Lara and Godoy, 1998), (4) Upper Cretaceous andesitic volcanic sequence (Llanta Formation, Cornejo et al., 1993), (5) Jurassic–early Cretaceous andesitic-basaltic volcanic sequence intercalated with marine chalk and continental sediments (Sierra Fraga Formation).
Above this "basement" a thin Neogene continental sedimentary sequence is preserved in the Pampa del Indio Muerto. The basal part, Lower to Middle Miocene, is called the Gravas de Atacama Formation sensus stricto (Mortimer, 1973) and the top, Upper Miocene to Pliocene, is constituted old alluvial fans (Mortimer, 1973). These gravels are intercalated with ignimbrite allowing the dating. They are constituted of fluvial deposits going from conglomerates (with fin to coarse rounded blocks) to sand, silt and clay deposit.

Gravity/GPS field data acquisition and processing

In order to test the feasibility of the gravity method for constraining the base of the Atacama Gravel Formation, we carried out a short field survey in 2004 to acquire precise gravity and GPS data on a key zone across the El Salado valley (Figure 2). The gravity measurements have been done along a 30km long profile using a Scintrex CG-3M microgravity meter (#9408267) from a central base station located in the El Salado valley. The gravity station coordinates have been determined by means of differential GPS measurements using full wavelength data (dual-frequency Ashtech Zxtreme receivers). The base station coordinates have been computed in respect to the ITRF2000 coordinate system using permanent GPS stations from the IGS network.

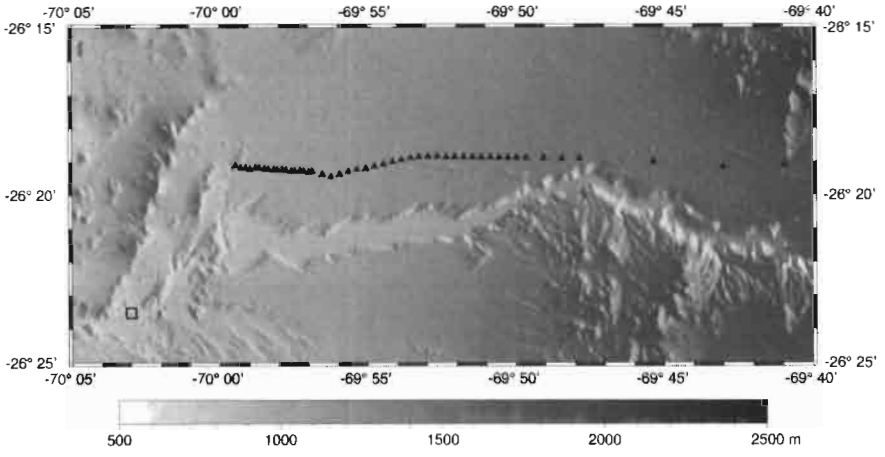

Figure 2: Localisation of measurement station, gravity and GPS (dark triangle), with reference GPS base station in Diego de Almagro (white square).

The gravity and GPS data processing has been done through CG3TOOL (Gabalda et al., 2003), GAMIT 10.1 (MIT) and Ashtech Solution 2.6 (Ashtech Ltd.) softwares. The final accuracy of the gravity and GPS measurements is estimated to be better than 20 microGal and 5 cm respectively. A gravity terrain correction has been applied through the Geosoft software (Xcceleration module) using the 90 m resolution SRTM Digital Elevation Model. The residual complete Bouguer anomaly profile (figure 3) is characterized by a gravity low with a relative maximum amplitude up to -5 mGal.

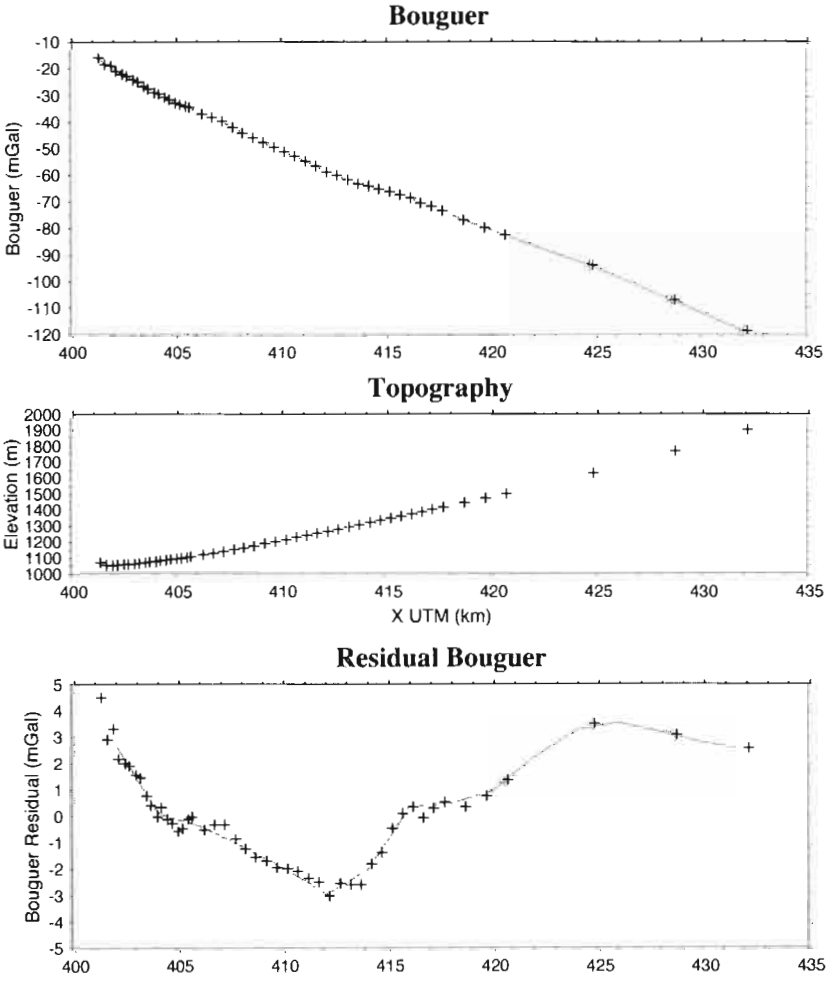

Figure 3: Gravity profile

Assuming that this residual gravity signal is mainly produced by the density contrast between a dense andesitic basement and a low density gravel infill (acceptable density contrast between -0.5 to -0.8), a 2.5-D gravity data

inversion has been performed to determine the profile of the base of the Atacama Gravel Formation. This modelling enhances (i) the irregular topography profile of the contact between the Atacama Gravel Formation and the andesitic basement and (ii) that the maximum gravel infill might be locally in order of 200 to 400 meter depth.

Discussion / Conclusion

The main objectives of the study were to quantify the thickness of the gravels preserved in the Central Valley and to better enhance the topography of the contact between the Neogene gravel sediments and the andesitic basement. Under the assumptions made for the gravity modelling, the proposed methodology seems appropriate and some results can be derived from this first experiment. (i) The maximum thickness of gravels, in function of the acceptable models, do not exceed 400 m for roughly 15 to 20 Ma, and generally it is around 150-200 m in the centre of the Central Valley. That means we are in a system with very low preservation and consequently low accommodation. (ii) The resulting gravity model shows an irregular geometry of the interface between the andesitic basement and the gravels sediments (base of the gravels is not plane). The deepening of the gravels base from the Coastal Cordillera, or from the Cordillera de Domeyko to the Central Valley is progressive. This geometry can be interpreted as an old surface of erosion, with relief variations comparable to those observed, at present time, in the eroded zones of the study area (Coastal Cordillera or Cordillera de Domeyko). This could indicate that before the sedimentation of the Neogene gravels, the hydrologic system was in erosion and connected to the Ocean through paleovalley of El Salado. The present morphology of the Central Valley, plane depression with 1-3% dip in direction to the Pacific Ocean, is only due to the preservation of hundred meters of gravels. This first experiment also confirmed that gravity data might be successfully used here to better resolve the geometry of the base of the Atacama Gravel Formation.

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