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Syn- and post-sedimentary controls on clay mineral assemblages in a tectonically active basin, Andean Argentinean foreland

Margarita Do Campo [a,*], Fernando Nieto [b], Cecilia del Papa [c], Fernando Hongn [d]

[a] INGEIS (CONICET – Universidad de Buenos Aires) y FCEyN, U.B.A. Pabellón INGEIS, Ciudad Universitaria, 1428 Buenos Aires, Argentina
[b] Departamento de Mineralogía y Petrología and I.A.C.T., Universidad de Granada – CSIC, Avda. Fuentenueva s/n, 18002 Granada, Spain
[c] CICTERRA, CONICET – Universidad Nacional de Córdoba, Córdoba, Argentina
[d] IBIGEO (CONICET – Universidad Nacional de Salta), Avda. Bolivia 5150, 4400 Salta, Argentina

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ABSTRACT

In the northern part of the Calchaquí Valley (NW Argentina), Palaeogene Andean foreland sediments are represented by a 1400-metre-thick continental succession (QLC: Quebrada de Los Colorados Formation) consisting of claystones, siltstones, sandstones, and conglomerates representing sedimentation in fluvial-alluvial plains and alluvial fan settings. To understand the main syn- and postsedimentary variables controlling the clay mineral assemblages of this succession, we have studied the fine-grained clastic sediments by X-ray diffraction and electron microscopy, along with a detailed sedimentary facies analysis, for two representative sections. In the northern section, the whole succession was sampled and analysed by XRD, whereas in the second section, a control point 15 km to the south, only the basal levels were analysed. The XRD study revealed a strong contrast in clay mineral assemblages between these two sections as well as with sections in the central Calchaquí Valley studied previously. In the northernmost part of the study area, a complete evolution from smectite at the top to R3 illite/smectite mixed-layers plus authigenic kaolinite at the bottom, through R1-type mixed-layers in between, has been recognized, indicating the attainment of late diagenesis. In contrast, the clay mineral assemblages of equivalent foreland sediments cropping out only 15 km to the south contain abundant smectite and micas, subordinate kaolinite and chlorite, and no I/S mixed-layers to the bottom of the sequence. Early diagenetic conditions were also inferred in a previous study for equivalent sediments of the QLC Formation cropping out to the south, in the central Calchaquí Valley, as smectite occurs in basal strata. Burial depths of approximately 3000 m were estimated for the QLC Formation in the central and northern Calchaquí Valley; in addition, an intermediate to slightly low geothermal gradient can be considered likely for both areas as foreland basins are regarded as hypothermal basins. Consequently, the attainment of late diagenesis in the northernmost study area cannot be explained by significant differences in burial depth nor in geothermal gradient in relation to the section 15 km to the south nor with the central Calchaquí Valley. The formation of R3 mixed-layer I/S and authigenic kaolinite in the northern study area was most likely controlled by the circulation of hot, deep fluids along the reverse faults that bounded the Calchaquí valley. These faults were active during the Cenozoic, as evidenced by the syndepositional deformation features preserved in the studied sediments. Stress could also have been a driving force in burial diagenesis at the R3 mixed-layer I/S stage in these young continental sediments.

1. Introduction

Variations in the clay mineral assemblages of ancient deposits have been successfully employed to investigate long-term trends in provenance and palaeoclimate of a variety of sedimentary successions all over the world (Adatte et al., 2002; Fagel et al., 2003; Suresh et al., 2004; Dera et al., 2009). Depending on the interplay of several variables including climate, tectonics, source area lithology, and burial history, sediments can contain clay minerals of detrital or diagenetic (neoformed and/or transformed) origin. Detrital clay minerals are derived directly from the weathering of crystalline rocks in the basin and drainage areas, but can also be recycled from ancient sedimentary rocks. In successions that have not been buried deeply, variations in clay-mineral assemblages are frequently employed to reconstruct palaeoclimatic changes, based upon the premise that the other variables play a secondary role

* Corresponding author. Tel.: +54 114783 3021.
E-mail addresses: docampo@ingeis.uba.ar (M. Do Campo), nieto@ugr.es (F. Nieto), delpapacecilia@yahoo.com (C. del Papa), Fhongn@aol.com (F. Hongn).

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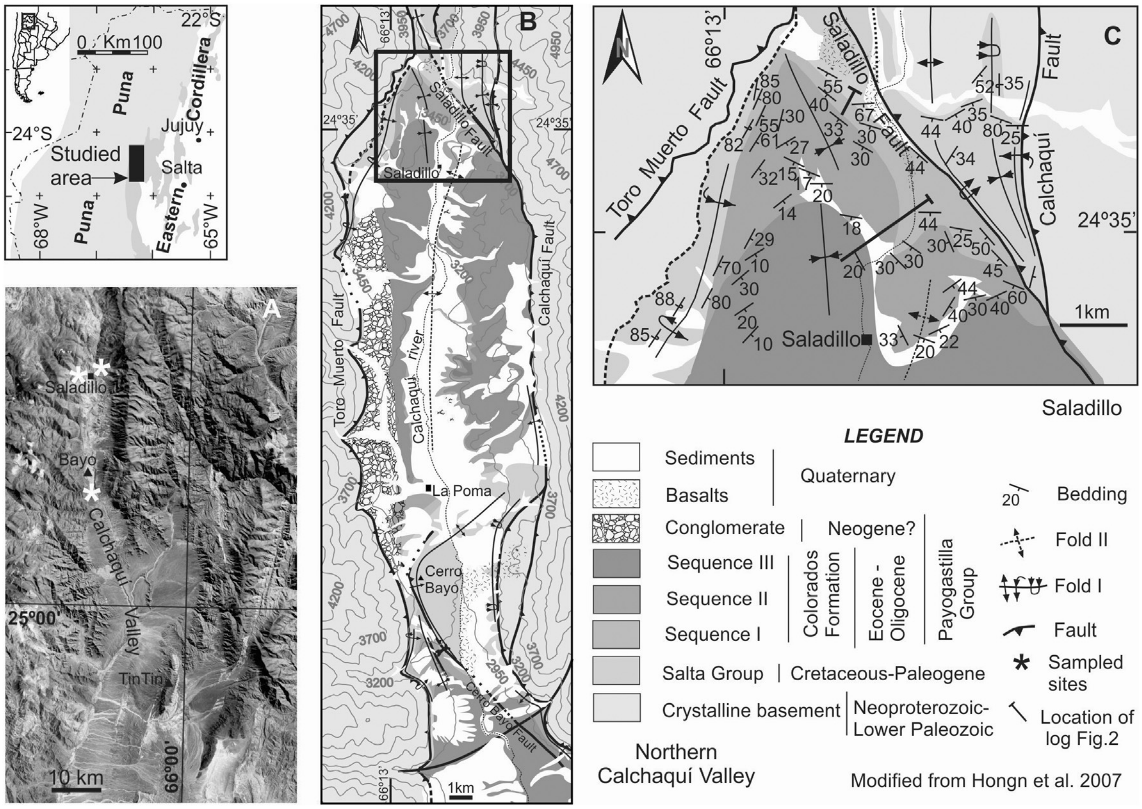

Fig. 1. A) Satellite image of the northern Calchaquí Valley, sampling sites (Saladillo and Cerro Bayo) are shown. The location of Tin Tin basin, previously studied by Do Campo et al. (2010), is also shown. B) Location and geological map of the northern Calchaquí Valley. C) Detailed geological map of the Saladillo area and location of stratigraphic log described in Fig. 2.

(Adatte et al., 2002; Saèz et al., 2003; Suresh et al., 2004; Fesharaki et al., 2007). In this context, Chamley (1989) proposed the kaolinite/muscovite ratio (Kln/Ms) as a palaeoclimatic indicator taking into account that fined-grained white mica represents a product of predominantly physical weathering typical of dry climates, whereas kaolinite formation is favoured by wet climates and requires a minimum temperature of 15 °C (Adatte et al., 2002). However, such approaches must be used with caution because clay minerals can only be used as a palaeoclimatic proxy when they derive from mature and mineralogically differentiated soils formed during the same sedimentary cycle (Thiry, 2000). Furthermore, in active settings, tectonism can change the dominant composition of the detritus carried to the basin since it can modify continental morphology and produce changes in source areas.

On the other hand, when the clay assemblages are modified by diagenetic reactions, clay minerals are useful to constrain a basin's thermal history (Dorsey et al., 1988; Arostegui et al., 2006; Collo et al., 2011). The transformation of smectite to illite through illite/smectite (I/S) mixed-layers is one of the main mineral reactions during the burial diagenesis of mudstones (Merriman and Peacor, 1999). This transformation has received considerable attention since the mid-seventies not only due to academic interest but also because it is closely associated with the initial steps of hydrocarbon generation and its subsequent migration (e.g. Pollastro, 1993). Consequently, numerous research papers have attempted to correlate the state of reaction progress of the smectite-I/S-illite series with burial temperature and also with organic indicators of basin maturity, such as vitrinite reflectance (Bevins et al., 1996; Arostegui et al., 2006).

Even though the study of clay mineral assemblages in conjunction with facies analysis has been established as a powerful tool in basin analysis, this approach has been little used so far to decipher the complex history of Andean foreland basins (Net et al., 2002; Do Campo et al., 2010; Collo et al., 2011). As foreland basins receive synorogenic sediments from fold-thrust belts, understanding their sedimentary and tectonic evolution could contribute to understanding the history of the orogen itself.

As part of an extensive study on the evolution of Palaeogene Andean foreland basins in NW Argentina, we have undertaken a study of clay-mineral assemblages applying XRD, SEM, and detailed sedimentary facies analysis for three representative sections in the northern (Saladillo and Cerro Bayo areas) and central Calchaquí Valley (Tin Tin basin, Fig. 1). The results of the mineralogical and sedimentological study of a 1400-metre-thick Palaeogene succession of the Tin Tin basin had been presented in a previous contribution (Do Campo et al., 2010). In that area, smectite occurs in the basal siltstones of the foreland sediments, thereby suggesting early diagenesis for the entire sequence, in agreement with the burial depths of ~3000 m estimated for the sediment column. In contrast, in the northernmost part of the Calchaquí Valley, a preliminary study evidenced I/S mixed-layers in the basal levels (Do Campo et al., 2008), indicative of late diagenesis. Moreover, the XRD study revealed a strong contrast in kaolinite abundances between the central and northern regions of the Calchaquí Valley. The present study has focused on the clay mineral assemblages of Palaeogene foreland sediments, the Quebrada de los Colorados Formation (QLC), cropping out in the northern Calchaquí Valley (NW Argentina, Fig. 1). This 1400-metre-thick continental succession constitutes the first filling of the Andean foreland basin, recently defined as a broken foreland (del Papa et al., 2013).

The main objectives of this study are twofold: 1) link the variations in clay mineral assemblages across a north-south transect