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Controls on clay minerals assemblages in an early paleogene nonmarine succession: Implications for the volcanic and paleoclimatic record of extra-andean patagonia, Argentina

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A B S T R A C T

The distribution of the clay minerals of the Banco Negro Inferior-Río Chico Group succession (BNI-RC), a middle Danian–middle Eocene mainly continental epiclastic–pyroclastic succession exposed in the Golfo San Jorge Basin, extra-Andean Patagonia (~46° LS), is assessed in order to determine the possible origin of clay and specific non-clay minerals using X-ray diffraction and scanning electron microscopy analyses. The control over the clay mineralogy of the sedimentary settings, contemporary volcanism, paleoclimate and weathering conditions is considered. A paleoclimatic reconstruction is provided and correlated with the main global warming events that occurred during the early Paleogene.

Mineralogical analyses of BNI-RC demonstrate that smectite and kaolin minerals (kaolinite, halloysite and kaolinite/smectite mixed layers) are the main clay minerals, whereas silica polymorphs (volcanic glass and opal) are common non-clay minerals. Throughout the succession, smectite and kaolin minerals are arranged in different proportions in the three clay–mineral assemblages. These show a general vertical trend in which the smectite-dominated assemblage (S1) is replaced by the smectite-dominated assemblage associated with other clays (S2) and the kaolinite-dominated assemblage (K), and finally by S2 up-section. The detailed micromorphological analysis of the clay and non-clay minerals allows us to establish that the origins of these are by volcanic ash weathering, authigenic and pedogenic, and that different stages in the evolution of mineral transformations have occurred.

The supply of labile pyroclastic material from an active volcanic area located to the northwest of the study area could have acted as precursor of the authigenic and volcanogenic minerals of the analyzed succession. Diverse fine-grained lithological facies (muddy and tuffaceous facies) and sedimentary settings (coastal swamp and transitional environments, and different fluvial systems) together with variable climate and weathering conditions controlled the mineralogical transformations and the arrangement of clay–mineral assemblages. The paleoclimatic reconstruction suggests a general warm and humid climate. However, the temporal trend of the clay–mineral assemblages, the ratios between smectite and kaolinite and the micromorphological analysis of clay minerals contrasted with evidence from sedimentological analyses suggest a warm and seasonal climate for the basal part of the unit, a warm and humid climate with a relatively more perennial rainfall regime in the middle part of the unit, and a warm and less humid, probably subhumid, climate up-section. Such a reconstruction makes it possible to establish a correlation with some of the hyperthermal events of the Early Paleogene Global Warming (EPGW) and, consequently, constitute one of the most complete time records of the EPGW in South America.

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1. Introduction

Clay–mineral records in sedimentary terrestrial successions affected only by early diagenetic conditions constitute a powerful tool to provide insight regarding the interaction between main controls, such as the composition of the source area, depositional environments and paleoclimate (e.g. Velde, 1995; Chamley, 1989; Inglès and Ramos-Guerrero, 1995; Deconinck et al., 2000; Net et al., 2002; Sáez et al., 2003; Suresh et al., 2004; Gonçalves et al., 2006; Raigemborn et al., 2009; Rostási et al., 2011). In addition, explosive volcanic events contemporary with the sedimentation could produce a footprint on clay–mineral assemblages (Deconinck et al., 2000; Lindgreen and Surlyk, 2000; Do Campo et al., 2010), as they supply labile volcaniclastic material to the basin which could be easily transformed into clay and/or other minerals (Masuda et al., 1996; Marfil et al., 1998; McKinley et al., 2003). Besides, during subaerial exposure, clay mineralogy may be modified by soil-forming processes (e.g. Wilson, 1999), due to the fact that these minerals must have reached a state close to equilibrium with their environment in order to be representative of the climate prevailing during their formation in soil profiles (Thiry, 2000).

This study deals with the distribution of clay minerals into fine-grained samples of the BNI-RC succession, a middle Danian–middle Eocene mainly continental epiclastic and pyroclastic sequence exposed in the Golfo San Jorge Basin (Fig. 1A and B). In this area, the analyzed succession has undergone shallow burial (Raigemborn, 2006; Raigemborn et al., 2009), which is an essential condition for the preservation of original clay mineral record. Thus, the BNI-RC succession shows an excellent opportunity to integrate compositional and sedimentological information in order to evaluate changes in the mineralogical trends through time. Accordingly, in order to establish the influence of these controls on clay mineralogy throughout a continental succession, we carried out an integrated study using X-ray diffraction (XRD) and scanning electron microscopy (SEM) analyses, along with detailed sedimentary facies analysis. XRD is essential to qualify and semi-quantify clay and non-clay minerals in fine-grained samples, while SEM is indispensable to establish their micromorphology, recognize the mineralogical transformation and allocate a possible origin to clay minerals.

The clay mineralogy of the early Paleogene interval has received much attention worldwide as one of the most significant climatic changes of the Cenozoic age occurred in it (Gibson et al., 2000; Thiry, 2000; Egger et al., 2002; Arostegui et al., 2011; among others). This was a period characterized globally by high temperatures and no ice sheets, at least until the Middle Eocene, and it was the most recent period when a warm "greenhouse" climate prevailed on Earth (e.g. Zachos et al., 2001). Besides, the last 65 Ma

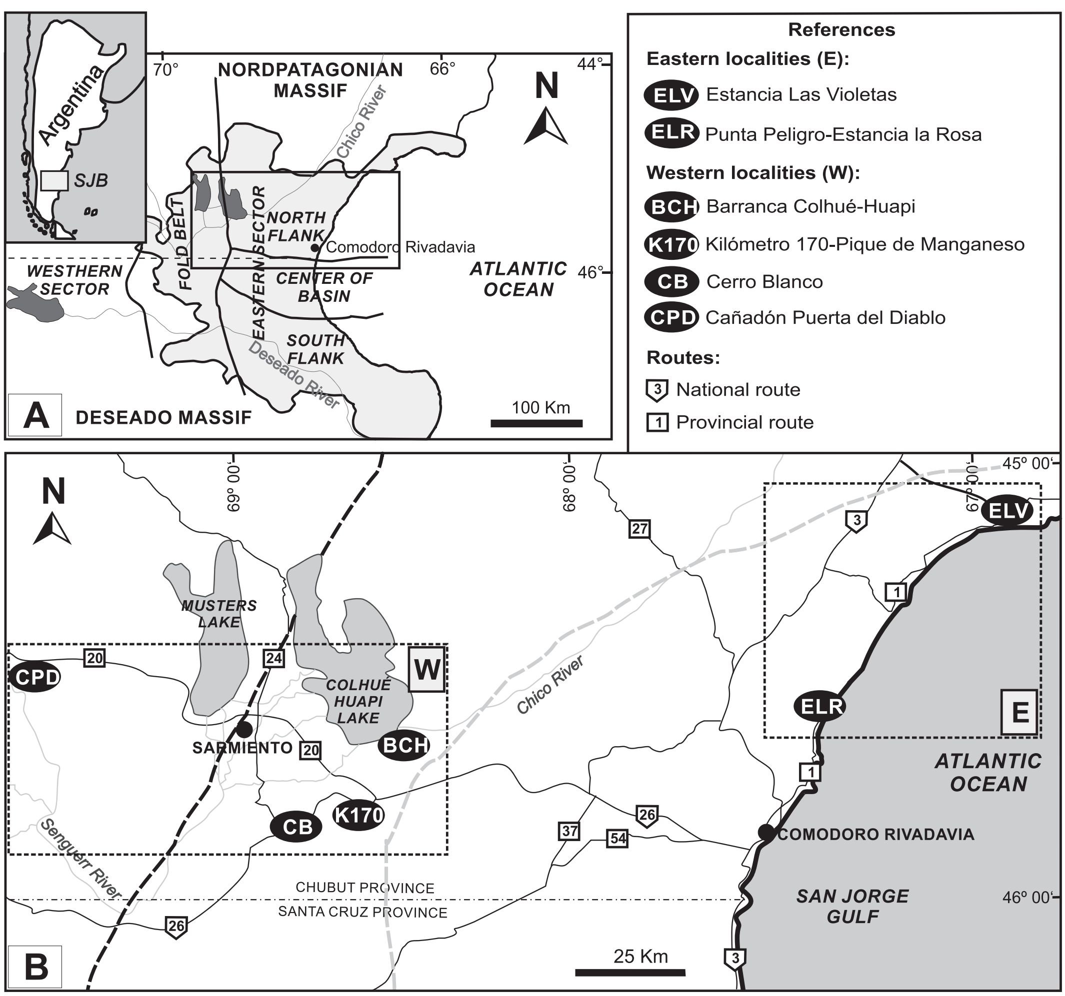

Fig. 1. (A) Map showing position and boundaries of the San Jorge Basin and the study area. (B) Map with the situation of the analyzed localities. The dashed black and gray lines indicate the outer boundary of the Banco Negro Inferior and the inner boundary of the Koluel-Kaike Formation, respectively (compiled from Uliana and Legarreta, 1999; Krause et al., 2010).