

Clay mineral assemblages and analcime formation in a Palaeogene fluvial–lacustrine sequence (Maíz Gordo Formation Palaeogen) from northwestern Argentina

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Abstract

The Palaeogene Maíz Gordo Formation is one of the main lacustrine events recorded in northwestern Argentina. It consists of sandstone, mudstone, and limestone beds 200 m thick, deposited in a brackish–alkaline lake and braided alluvial systems. The Maíz Gordo Lake evolved mainly as a closed system, with brief periods as an open one. X-ray diffraction (XRD) and scanning electron microscopy (SEM) were used to study samples from seven sites, corresponding respectively to proximal, intermediate, and transitional positions of the fluvial environment and marginal and inner-lake environment, focusing on the clay mineralogy and analcime formation. The basinward zonation of diagenetic minerals identified in the Maíz Gordo Lake was: mordenite → analcime → K-feldspar. Although not a typical zonation of saline–alkaline lakes, it does indicate an increase in salinity and alkalinity towards the centre.

In proximal fluvial settings, smectite predominates at the base of the sequence, with scarce kaolinite. Towards the top, a striking increase in kaolinite content suggests a change from a relatively arid climate with alternating humid and dry seasons, towards a warm and humid climate. Kaolinite content clearly decreases in a basinward direction. Such a variation is attributable to changes in hydro-geochemistry, denoting the progressive influence of the brackish and alkaline lake water on interstitial pores. SEM images of intermediate fluvial samples reveal authigenesis of illite at the expense of kaolinite booklets.

In littoral and inner-lake settings the clay fraction is composed of muscovite, sometimes with subordinate smectite. Analcime occurs in variable amounts in all sedimentary facies, in rock pores or filling veins. It forms subhedral square to hexagonal, or anhedral rounded crystals, denoting that they coarsened at low to moderate degrees of supersaturation. Although the mordenite identified in a fluvial level would have been the precursor of analcime in the Maíz Gordo Basin, no textural evidence of analcime formation through replacement of mordenite or other precursor zeolite was found. Hence it is more probable that analcime formation took place by direct authigenic precipitation or through the reaction between interstitial brines and clay minerals or plagioclase.

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1. Introduction

Considerable attention has been paid in recent years to mineralogical studies of Cenozoic and Recent lacustrine sediments. Particular notice has been given to clay minerals and zeolites, as these minerals represent important keys to deducing changes in source area, palaeoclimate, and sedimentary environments (see, for example, Mayayo et al., 1996; Inglès et al., 1998; English, 2001; Sáez et al., 2003). While many studies have examined the mineralogy of lacustrine sediments, less commonly have such studies considered the composition of both alluvial and lacustrine sediments, and the lateral changes occurring between the two environments.

The Maíz Gordo Formation constitutes, due to its thickness, extension, and time span, one of the main Palaeogene lacustrine events recorded in northwestern Argentina (del Papa, 1999). However, although many stratigraphic and sedimentological studies have focussed on this unit, detailed mineralogical studies are still lacking. Previous works, centering on the carbonate rocks (Matheos and del Papa, 2003), indicated the occurrence of analcime, which, in fact, is common in many Palaeogene lakes of northwestern Argentina (del Papa and Menegatti, 1993; del Papa et al., 2002; Novara, unpublication).

In this paper we analyse the mineralogy of representative alluvial and lacustrine samples of the Maíz Gordo Formation to study the relationship between depositional environments, climate, and mineral composition. In addition, we examine changes in the clay mineralogy between alluvial and lacustrine sediments, with the aim of establishing the influence of hydrogeochemical changes on these minerals. We also explore in detail the alkaline–brackish lake sediments of the Maíz Gordo Formation to determine possible mechanisms in analcime authigenesis.

Analcime is a widespread mineral in all lacustrine facies of the Maíz Gordo Formation. This occurrence has mineralogical importance as, in general, analcime is considered to form from precursor zeolites derived from volcanic glass altered in saline alkaline-lake water (Hay, 1966; Sheppard and Gude, 1969). However, in this particular area, volcanoclastic material is scarce and analcime is almost the sole zeolite identified, making it clear that analcime must have a different origin in this case.

Despite analcime being common in lacustrine sediments, literature on the physico-chemical requirements for its formation from non-volcanic precursors is nonetheless scarce. Recently, English (2001) pointed out the importance of saline groundwater and its time of residence in sediments for analcime precipitation.

Additionally, he identified a siliceous gel as a precursor of zeolite formation.

The aim of this contribution is to discuss how changes in climate and sedimentary setting control hydrogeochemistry and consequently rule the transformation of clay minerals from alluvial to lake settings. We also analyse the conditions of analcime authigenesis in sediments devoid of volcanoclastic material.

2. Geological setting

The Maíz Gordo Formation is the middle unit of the Santa Bárbara Subgroup of the Salta Group (Turner, 1959) (Fig. 1a). The Salta Group was deposited in an intracontinental rift (Galliski and Viramonte, 1988) that evolved from the lower Cretaceous to the middle Palaeogene. The deposits are mainly composed of continental sediments with minor interbedded marine levels (Salfity, 1982). In the synrift stage (lower Cretaceous–Maastrichtian), a thick succession of red conglomerates and sandy facies accumulated near the faulted blocks. The post-rift stage (Maastrichtian–Eocene) is characterised by widespread marine transgression and fluvial–lacustrine environments (Marquillas et al., 2005). Lakes characterised both the synrift and post-rift stages, but it was during the late post-rift stage (Palaeocene–Eocene) that thick lacustrine successions were produced.

2.1. Maíz Gordo Formation

In order to consider the sedimentary setting and its control on the origin and transformation of the clay minerals in the Maíz Gordo Formation, we present an overview of the environment and subenvironments recognized. For a detailed description of lacustrine facies and their sedimentary interpretation see del Papa (1999).

The Maíz Gordo Formation consists of 200 m of sandstone, mudstone, and limestone beds deposited in a braided plain and in a brackish (slightly saline) and alkaline lake. The lake evolved mainly as a closed system, but for short periods became open. Its sedimentary facies and palaeogeographic reconstruction indicate a lake with a ramp-type margin with alternating periods of low and high energy (del Papa, 1999).

Regional studies attest that the Maíz Gordo basin developed during a period of tectonic calm characterized by a low subsidence rate (Gómez Omil et al., 1989; Salfity and Marquillas, 1994).

Coarse-to-fine sandy fluvial systems surrounded the lake, especially to the west and southwest of the basin (Fig. 1b and c), where excellent outcrops allow reliable

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