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Thermal evolution of inverted basins: Constraints from apatite fission track thermochronology in the Cuyo Basin, Argentine Precordillera

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Abstract

Apatite fission track thermochronology (AFTT) was applied to derive the thermal history of formation and inversion of the oil-bearing Triassic–Cretaceous Cuyo Basin, Argentine Precordillera. The obtained central fission track ages range from 13 to 163 Ma, and the mean track lengths from 8.2 to 13.1 µm. Based on the integration of AFTT, stratigraphic and structural data, five evolutionary phases are here proposed for the studied area: I—Late Permian cooling related to the extrusion of basement volcanics, and initial extensional regime responsible for the Cuyo Basin formation, II—Triassic–Jurassic heating linked with the filling, and consequent burial, of the Cuyo Basin, III—Jurassic–Paleogene tectonic stabilization, IV—Early Miocene heating related to the load of foreland sedimentation, V—Late Miocene rapid cooling related to the Cuyo Basin inversion. During the Late Miocene, rock units formed in different crustal levels were juxtaposed through thrust, reverse and normal faulting, resulting in contrasting old and very young central fission track ages in closely spaced samples.

Keywords: Thermochronology; Rift basin; Foreland basin; Precordillera; Andes; Inversion; Triassic; Miocene

1. Introduction

The evaluation of tectonic and thermal histories in inverted sedimentary basins is complex since uplift and denudation affect such areas on a regional scale. These processes, along with thrusting and anticline formation, cause both the loss of stratigraphic pile and the lack of lateral continuity of strata between different outcrop sectors (Green et al., 1995).

The tectonic setting of the south-central Andes during the Phanerozoic is highly variable and marked by several events (Ramos, 1999), including the inception, filling and deformation of sedimentary basins. The oil-bearing Triassic–Cretaceous Cuyo Basin is one of the best examples of rift basins inverted during the Andean compressive evolution. The formation of this basin was controlled by inherited Paleozoic sutures, and its development was closely related to the tectonic styles of the Andes.

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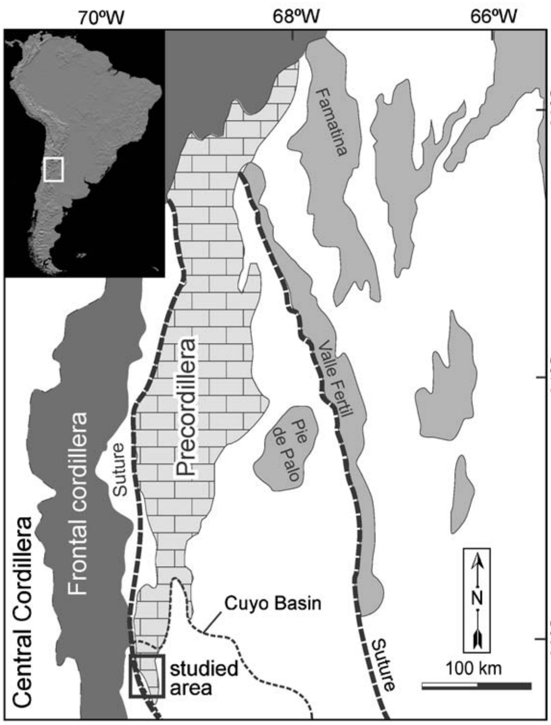

Fig. 1. Simplified tectonic map of the south-central Andes showing the main terranes (from west to east: Central Cordillera, Frontal Cordillera, Precordillera and Sierras Pampeanas) and Paleozoic sutures with indication of the studied area. Dotted lines represent the subsurface limit of the Cuyo Basin. White areas correspond to intermontane basins (modified from Astini et al., 1995).

Apatite fission track thermochronology (AFTT) is a powerful tool in reconstructing the cooling history of rocks as they are exposed in the surface, as a result of erosive and tectonic processes, representing an ideal method for studying the morphotectonic effects of deformation. Furthermore, since cooling below AFTT temperature range (60–110 °C) typically marks the cessation of hydrocarbon generation, the application of this methodology has important implications for the evaluation of hydrocarbon potential in sedimentary basins.

The aim of this paper is to present the results of the application of AFTT to 10 outcrop samples of the Triassic–Cretaceous Cuyo Basin and its basement in the Southern Argentine Precordillera (Fig. 1). The results allowed the proposition of a thermal and tectonic history for the analyzed samples with implications for hydrocarbon research and exploration in the Cuyo Basin.

2. Geological setting

The Triassic–Cretaceous Cuyo Basin, located in the Andean foreland, is largely a subsurface feature (Rolleri and Criado Roqué, 1968). It lies beneath a 2000–3000 m thick Cenozoic clastic cover, enclosed in a regionally little deformed piece of the Andean foreland. This basin is characterized by a series of spaced elongate folds, locally broken by reverse faults displaying eastward or westward vergence (Dellapé and Hegedus, 1995). These structures are aligned along two NNW-striking structural trends. These linear trends developed due to a regional extension, nucleated on a major crustal discontinuity along the Chilenia–Precordillera terrane boundary (Ramos and Kay, 1991). The eastern limit of this basin coincides with an important suture generated in the Silurian through the amalgamation of the Cuyania Terrane to the southwestern margin of Gondwana. On the other hand, the western border is a structure that represents the Devonian accretion zone of the Chilenia and Cuyania terranes (Ramos and Kay, 1991).

Zerfass et al. (2004) suggested that the extensional basins of Western Argentina could be generated by transtension related to the regional sinistral shearing with reactivation of ancient crustal sutures. According to Mpodozis and Kay (1990), the extensional tectonic setting of the southwestern Gondwana at the Permian–Triassic boundary is related to processes of crustal thinning, which occurred after the end of the Paleozoic collisional phenomena as already mentioned. This extensional event was responsible for an extensive acidic–intermediate volcanism, characterized by andesites, rhyolites and breccias (Choiyoi Group of Rolleri and Criado Roqué, 1968). The inception of the Cuyo Basin, whose sediments were unconformably deposited upon Choiyoi volcanics and Paleozoic sediments, is also a result of this generalized extensional setting (Ramos and Kay, 1991).

During the early rift phase (Lower Triassic) the active margins of the Cuyo Basin were controlled by tectonic processes that directly influenced the subsidence rate, quantity and type of material from source areas (Ávila et al., 2003). Close to the active margins, a thick conglomerate package crops out (Rio Mendoza Formation, Borrello, 1962), encompassing coarse-grained alluvial fans (sheetflood and debris-flow deposits) and pyroclastic flow deposits. Distally and stratigraphically above, fluvial and lacustrine deposits (Potrerillos and Cacheuta formations, Truempy and Lhez, 1937) with expressive volcaniclastic contribution replace the coarse alluvial fan deposits. Lacustrine black shales (Cacheuta Formation) have high organic matter and constitute the principal source rocks for the hydrocarbon accumulations in this basin (Chebli et al., 2001).

The transition from black (Cacheuta Formation) to reddish (Rio Blanco Formation, Fossa-Mancini, 1937) siltstones and shales marked the onset of a progradational trend. This prograding section began with the establishment of oxidizing conditions and continued with the progressively increased sedimentary influx to the basin depocenters by means of lacustrine, deltaic and high sinuosity fluvial deposits. This phase (Upper Triassic to Lower Jurassic) is associated with thermal subsidence, corresponding to a “sag” basin (Kokogian et al., 1993). During the “sag” stage