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High-precision U–Pb zircon age from the Anfiteatro de Ticó Formation: Implications for the timing of the early angiosperm diversification in Patagonia

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ABSTRACT

The Baqueró Group is one of the most relevant units regarding the study of the early diversification of angiosperms in South America. Whereas the age of the upper part of the Group, namely the Punta del Barco Formation, has been recently dated at 114.67 ± 0.18 Ma, the rest of the unit still lacks precise dating. In this contribution a CA-TIMS U–Pb zircon age of 118.23 ± 0.09 Ma for a tuff interlayered with fossiliferous rocks of the Anfiteatro de Ticó Formation (lower part of the Baqueró Group) is reported. This age constrains the duration of deposition of the Baqueró Group to approximately 4 Ma and provides new evidence for the age interpretation of the previously described angiosperm flora and associated pollen assemblages from this unit, until now interpreted as early Aptian or possibly Barremian in age. The Aptian age of the Baqueró Group allows a better comparison between the paleofloras from this southernmost region.

1. Introduction

One of the most complete and diverse continental paleofloras developed during the Early Cretaceous is recorded in the Patagonian deposits of the Baqueró Group. Megascopic remains, as well as palynological assemblages, were recovered from the three lithostratigraphic units that compose the Group (Anfiteatro de Ticó, Bajo Tigre and Punta del Barco formations). Although these deposits have been studied since early in the last Century new fossil localities and specimens are still being found (Archangelsky and Villar de Seoane, 2005; Del Fueyo and Archangelsky, 2005; Passalia et al., 2010; Carrizo et al., 2011; Del Fueyo et al., 2012, 2013; Vera and Cesari, 2012; among others). The abundant paleobotanical and palynological content, which includes representatives of most of the major groups of plants, was summarized in the works of Archangelsky (2003), Del Fueyo et al. (2007), and Limarino et al. (2012).

Among the most relevant findings made on Baquero Group strata are some of the oldest records of angiosperm pollen and megafloristic remains for Argentina, representing a glimpse of the earliest stages of the flowering plants evolution. Archangelsky and Gamerro (1967) made the first mention of angiosperm pollen (*Clavatipollenites hughesii* Couper) from the Baqueró Group. Afterward, Archangelsky and Taylor (1993) studied in detail a small anther from the Anfiteatro de Ticó Formation which contained *Clavatipollenites* pollen masses. The younger unit of the Group (i.e., the Punta del Barco Formation) also contains angiosperm pollen grains, which were first described by Llorens (2003, 2005). Megascopic angiosperm remains from Baqueró Group were first described by Romero and Archangelsky (1986), who studied five angiosperm leaves collected from Anfiteatro de Ticó Formation outcrops at Estancia Bajo Tigre. Later, Passalia et al. (2003) reported

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a new form of angiosperm leaf from the same unit. In accordance with these results, Limarino et al. (2012) recognized the presence of angiosperm pollen grains throughout the Baqueró Group. Recently, Archangelsky and Archangelsky (2013) made a detailed systematic study of angiosperm pollen grains recovered from the Anfiteatro de Ticó Formation.

The emergence and rapid radiation of angiosperms during the Early Cretaceous is one of the most important events that occurred in the history of the terrestrial ecosystems. The origin and the different stages in the diversification of flowering plants have been the subject of many studies in southern South America since the late nineteenth Century (Passalia et al., 2001; Llorens, 2003; Cúneo and Gandolfo, 2005; Barreda and Archangelsky, 2006; Iglesias et al., 2007; Passalia, 2007; Archangelsky et al., 2009; Vallati, 2010; Perez Loinaze et al., 2012; Archangelsky and Archangelsky, 2013). However, one of the most important problems in the analysis and comparison between different sequences containing angiosperm pollen and megafloristic remains is the poor absolute dating (Hochuli et al., 2006). Integration of high-precision geochronology with the fossil record would address fundamental key-topics in the evolution of the modern ecosystems (Bowring and Schmitz, 2003).

In this work, a new absolute date obtained from a tuff recovered from the lower section of the Anfiteatro de Ticó Formation is presented. Also, the megafloristic content of the dated level, and palynological assemblages recovered from the levels immediately above and below the dated tuff, are given.

2. Geological setting and previous geochronology

The Baqueró Group is a continental – essentially fluvial and lacustrine – succession, which crops out in the central area of the Deseado Massif, and it is mostly composed of clastic and pyroclastic rocks (Cladera et al., 2002). This unit was originally defined as the Baqueró Formation with two members (Archangelsky, 1967). Cladera et al. (2002) proposed a different stratigraphic scheme, where these continental deposits were assigned to a new unit, the Baqueró Group, divided in three formations: Anfiteatro de Ticó, equivalent to the lower member of Archangelsky (1967), and Bajo Tigre and Punta del Barco, corresponding to the upper member of Archangelsky (1967). Recently, Limarino et al. (2012) presented a schematic stratigraphic section for the Baqueró Group (see Fig. 2), and recognized three Depositional Sequences and eight Facies Associations. The Anfiteatro de Ticó Formation, which is the focus of this work, consists of conglomerates, cross-bedded sandstones, fine-grained sandstones, and thin interbedded tuffs (Limarino et al., 2012).

The first paleontological studies in the area were made by Berry (1924) who, based on megafloristic remains collected from the eastern section of the Meseta Baqueró, suggested an Early Cretaceous age for the Baqueró sequence. Later, Feruglio (1937a, b, 1949) correlated these strata with those of a previously recognized unit (i.e., the "Complejo Porfírico de la Patagonia extra-andina") and, as a consequence, assigned an Upper Jurassic-Early Cretaceous age. In 1967, Archangelsky formally defined the Baqueró Formation, and based on their megafloristic content suggested a Barremian-Aptian age to this unit. Corbella (2001) dated by $^{40}Ar/^{39}Ar$, rocks from the middle section of Punta del Barco (119.65 ± 0.45 Ma) and Anfiteatro de Ticó (118.56 ± 1.40 Ma) formations, restricting the age of the Baqueró Group to the Aptian. Later, Corbella (2005) presented additional ages for the Anfiteatro de Ticó and Punta del Barco formations. The results obtained for the older unit were somewhat comparable to the ones previously reported by Corbella (2001), being 118.56 ± 1.40 Ma with the $^{40}Ar/^{39}Ar$, and 111.80 ± 7.40 Ma by fission track techniques. The age estimation for the Punta del Barco Formation, also made using the fission track technique, had an important degree of uncertainty, with ages ranging from 173 to c. 80 Ma (Corbella, 2005). Recently, Césari et al. (2011) published a CA-TIMS U–Pb zircon age of 114.67 ± 0.18 Ma for an interbedded tuff from the Punta del Barco Formation.

3. Methodology

3.1. Isotopic dating

The dated sample was collected from a tuff level from the lower part of the Anfiteatro de Ticó Formation, cropping out at the Anfiteatro de Ticó locality (48° 30′ 35.24″ S, 69° 14′ 11.47″ W, Fig. 1). The tuff is located approximately 40 m above the contact with the underlying Bajo Grande Formation (Fig. 2). It is a tabular bank, 0.8 m in thickness, containing abundant accretionary lapilli. This deposit covers an irregular surface, interpreted by Limarino et al. (2012) as a low-relief incision carved into lacustrine deposits. The sampled level corresponds to the Stratigraphic Level 5 of the Depositional Sequence 1, as recently proposed by Limarino et al. (2012).

Abundant megafloristic remains and silicified trunks have been recovered from this tuff (Limarino et al., 2012; Vera and Cesari, 2012), which add to the palynological assemblages obtained from the levels immediately above and below, composed by dark gray fine-grained sandstones, rich in organic matter, deposited in a lacustrine environment.

U–Pb dating was done at the Pacific Centre for Isotopic and Geochemical Research housed in the Department of Earth and Ocean Sciences (EOS) at the University of British Columbia. The technique used is a modification of CA-TIMS procedures outlined in Mundil et al. (2004), Mattinson (2005) and Scoates and Friedman (2008). Uncertainties in age are reported at the 95% level of confidence.

3.2. Palynology

Palynological analysis from Anfiteatro de Ticó Formation was carried out on one sample above the level dated (BA Pal 6227) and five samples below this level (BA Pal 6217, 6222–6225). The samples were treated by means of standard techniques for extraction and concentration of palynomorphs. Observations were made with an Olympus BX-51 microscope equipped with a Nikon DS-Fi1 digital camera for photomicrography. Coordinates of the illustrated specimens are cited as England Finder references. The slides are deposited in the Palynological Collection of the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (BA Pal).

4. Results

4.1. U–Pb dating

Six zircons from the tuff sample from the lower levels of the Anfiteatro de Ticó Formation were individually analyzed, with U–Pb data listed in Table 1. An age of 118.23 ± 0.09 Ma is based on the weighted average of $^{206}Pb/^{238}U$ dates for the six concordant and overlapping analyses (MSWD = 0.68; Fig. 3; Table 1). Based on this result, the Anfiteatro de Ticó Formation can be assigned to the late Aptian, according to the current Geologic Time Scale (International Chonostratigraphic Chart, 2012).

4.2. Palynological and megafloristic content

Abundant megafloristic remains were recovered from the same dated tuffaceous strata. Megafossils include the fern fronds *Koallipteris* sp. (="*Gleichenites*" sp.) and "*Phlebopteris–Matonidium–*