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SHORT NOTE

Early Miocene detrital zircon age from fluvial deposits of La Marcelina Formation in the Deseado Massif, Southern Patagonia, Argentina

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Early Miocene detrital zircon age from fluvial deposits of La Marcelina Formation in the Deseado Massif, Southern Patagonia, Argentina

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ABSTRACT

The La Marcelina Formation (LMF) in the southern Deseado Massif area (c. 47° 55′ S) represents a 23 m thick sedimentary succession deposited within a low-energy fluvial paleoenvironment. The age of this unit, formerly considered as Eocene due to its palynological assemblage, is adjusted by zircon U-Pb Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) from a sandstone bed at the middle part of the unit. The results reveal a maximum depositional age of ~20 Ma (Early Miocene, Burdigalian). The detrital zircon provenance analysis indicates zircon grains originated mostly in the Jurassic, with limited contributions from the Cretaceous, Permian, and Paleocene. The new age for LMF allows correlating these beds to the upper section of the continental Río Leona Formation in the southern Austral-Magallanes Basin.

Key words: Burdigalian, Maximum Depositional Age, Zircon Provenance, Patagonia

INTRODUCTION

The Deseado Massif is a prominent morphostructure located in northern Santa Cruz Province in central-southern Patagonia (Panza *et al.*, 2001; Navarrete *et al.*, 2023; Fig. 1). It is dominated by igneous and metamorphic rocks of Precambrian, Paleozoic, and Mesozoic ages (Navarrete *et al.*, 2023; Pérez Frasette *et al.*, 2024, and references therein). The Deseado Massif behaved as a positive relief throughout the geologic time resulting in sedimentary records confined to intracratonic basins.

Miocene deposits are scarce and restricted to the margins of the Deseado Massif. This study is focused on Miocene deposits from the southwestern margin of the massif (47° 55' S, 70° 12' W), represented by the La Marcelina Formation (LMF). This unit lies unconformably over the Jurassic Bahía Laura Volcanic Complex (BLVC) and was previously assigned to the Eocene based on palynological associations (Noetinger *et al.*, 2023). The LMF is unconformably overlain by Miocene marine deposits of the Centinela Formation (Malumián and Náñez, 2011). Equivalent Miocene marine deposits, known as the Monte León, El Chacay, and Estancia 25 de Mayo formations, are constrained between 18 and 22 Ma (Parras *et al.*, 2012; Cuitiño *et al.*, 2012, 2015; Parras and Cuitiño, 2021; Genge *et al.*, 2022; Aramendía *et al.*, 2023). The fluvial deposits of the Miocene Santa Cruz Formation transitionally overlie the Centinela Formation (Panza *et al.*, 2001).

Detrital zircon U-Pb geochronology is a widely used technique for estimating the maximum depositional age (MDA) of sedimentary beds and interpreting sedimentary provenance (Fedo *et al.*, 2003; Gehrels, 2012; Fosdick *et al.*, 2020). The objective of this short note is to analyze the age of the detrital zircons of the poorly studied LMF and to provide a temporal depositional framework, as well as to understand the provenance of the sediments and the implications of the new age for the Early Miocene palynology and regional stratigraphy in southern Patagonia.

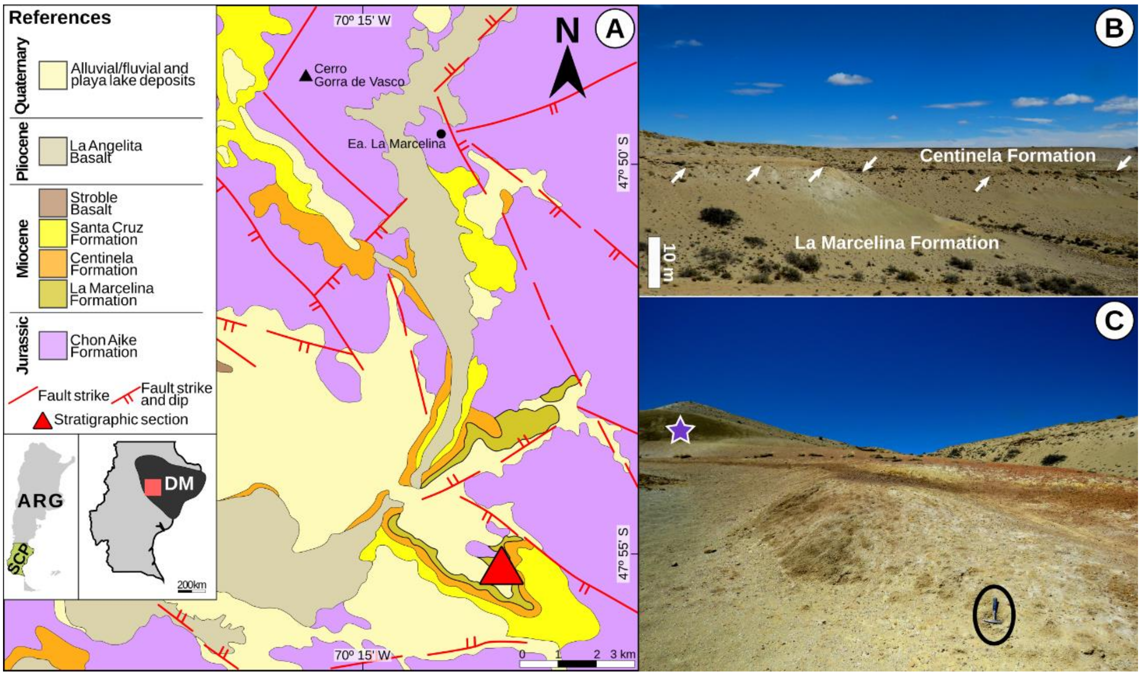

Figure. 1. a) Location of the studied deposits in the Deseado Massif (DM). The red square shows the location of the geological map to the right. The location of the studied stratigraphic section is depicted with a red triangle (modified from Noetinger *et al.*, 2023). SCP=Santa Cruz Province; ARG=Argentina. **b)** Outcrop view of the Lower Miocene sedimentary units. Note the sharp contact between the marine deposits of the Centinela Formation overlying the low-energy fluvial deposits of La Marcelina Formation. White arrows indicate the boundary between La Marcelina and Centinela formations. **c)** Outcrop view of the studied stratigraphic section with the location of the detrital zircon U-Pb sample analyzed for this work (purple star). Hummer for scale.

STUDY AREA AND METHODS

Fieldwork in the southwestern region of the DM was conducted during the summer season of 2019. The LMF in the study area is 23 m thick, with the base covered and a sharp contact with the overlying Centinela Formation (Panza *et al.*, 2001; Noetinger *et al.*, 2023). The LMF consists of an aggradational succession of fine- to very fine-grained tabular sandstone beds with sparse intercalations of mudstones (Fig. 2a). The sandstones are mostly massive, occasionally exhibiting horizontal lamination, while the mudstones are massive. These sedimentary characteristics, along with the palynological records (Noetinger *et al.*, 2023), likely indicate a low-energy fluvial system lacking channelized bodies, dominated by flooding events that facilitated the accumulation of fossil remains such as palynomorphs and coal (Noetinger *et al.*, 2023). The analyzed detrital zircon sample (LM-160) corresponds to a fine-grained sandstone bed that is located in the lower portion of the LMF section (Fig. 2a and b) and is intercalated between the palynological samples from Noetinger *et al.* (2023). Zircons were collected from c. 5 kg of sample using standard crushing, sieving, and heavy mineral concentration procedures. Final zircon concentrates were selected under a microscope, mounted on tape in epoxy resin and polished to expose the grain interiors. One hundred and two zircons were randomly analyzed from a linear swath of grains across the epoxy mount. Interpreted U-Pb ages use the 204Pb-corrected 206Pb/238U ratio for <1.0 Ga grains and the 204Pb-corrected 206Pb/207Pb ratio for >1.0 Ga grains. Analyses that were >20% normally discordant or >5% reverse discordant were excluded. Negative ages and results with a high standard deviation were removed. Weighted means and kernel density estimation (KDE) were generated using the routines in Isoplot (Vermeesch, 2018). Detailed geochronological data are available in the Supplementary Material. U-Pb detrital zircon geochronology was conducted by laser-ablation inductively coupled plasma mass-spectrometry (LA-ICP-MS) at the University of South Carolina's Center for Elemental Mass Spectrometry using a high-resolution single-collector Thermo Element 2 mass-spectrometer attached to a PhotonMachines G2 Analyte 193 nm ArF exciplex laser using a 25 μm circular spot.

The sample yielded young age groups that represent reliable maximum depositional age (MDA). For MDA determination the youngest age peaks defined by two or more overlapping zircon ages (within 2σ and <5% discordance) were used. For the error weighted mean, a value of 2σ was used. For older detrital zircon age groups, we used the graphical peaks from the KDE plots.

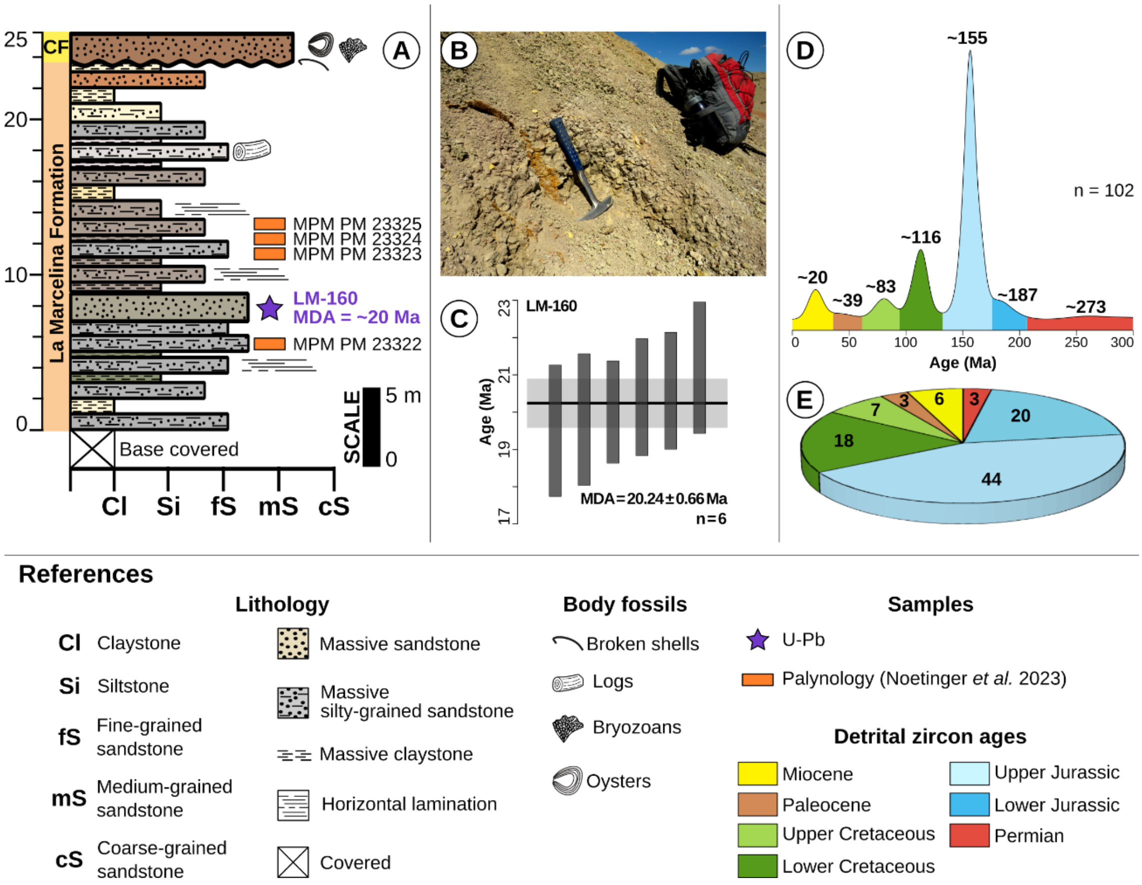

Figure 2. a) Stratigraphic section of the La Marcelina Formation with the location of the detrital zircon U-Pb sample studied for this research. **b)** Fine-grained sandstone outcrop where the sample was extracted for the analysis. **c)** Weighted mean plot showing U-Pb maximum depositional ages (MDA) for LM-160 sandstone sample. The dark-gray vertical bars show the individual ages of zircon grains used to calculate the MDA, the solid black line shows the MDA, and the light-gray band shows the 2σ uncertainty for the MDA. **d)** Kernel density estimation (KDE) plot for the detrital zircon U-Pb geochronology. n: total grains for provenance description. **e)** Pie chart with percentage values detailing the contributing ages during deposition of the La Marcelina Formation.

RESULTS

Detrital zircon U-Pb ages from sample LM-160 range from ~20 to 297 Ma and are characterized by well-defined Permian, Early Jurassic, Late Jurassic, Early Cretaceous, Late Cretaceous, Paleocene, and Miocene age peaks at c. 273, c. 187, c. 155, c. 116, c. 83, c. 39 and c. 20 Ma, respectively. Overall, nearly 65% of measured U-Pb ages fall between 155 and 187 Ma, with most dates clustered near 155 Ma (Fig. 2d and e). Cretaceous (66–145 Ma) zircon grains constitute an additional c. 25% of the distribution. Paleocene and Permian zircons constitute 5 % each. Using the 6 youngest overlapping zircon ages we constrained the MDA for this sample to 20.24 ± 0.66 Ma (Burdigalian; Fig. 2c). A full description of the zircon ages is provided in the Supplementary Material.

DISCUSSION AND CONCLUSIONS

Detrital zircon age analysis constrains the MDA of the LMF at ~20 Ma (Burdigalian; Lower Miocene). The LMF was first assigned to the Eocene based on an unpublished short list of palynomorphs (Panza *et al.*, 2001). Recently, Noetinger *et al*. (2023) described a palynological assemblage from the LMF comprising mostly forms with long stratigraphic distributions and few species with restricted biochrons that helped discard an older age than Eocene (*e.g.*, Polypodiisporites inangahuensis, Myrtaceidites verrucosus, Podocarpidites magnus). Moreover, the absence of modern forms and the low proportion of Nothofagaceae was suggestive of an early Eocene age. Multivariate analysis showed a closer affinity of the LMF flora to those of Eocene age. It was speculated that the resemblance between floras deposited in essentially terrestrial environments would reinforce a correlation between them (Noetinger *et al.*, 2023). This new age result aligns the LMF with Río Leona Formation to the southwestern of the Austral-Magallanes Basin (Panza *et al.*, 2001). The LMF temporally correlates to the upper section of the fluvial Río Leona Formation, which crops out near Río Turbio and Lago Argentino regions in Santa Cruz Province, dated to an age of 20.2–19.0 Ma (Albano *et al.*, 2023). Similarly to that of the LMF, the Río Leona Formation flora is composed of Cenozoic common families such as Podocarpaceae, Araucariaceae, Nothofagaceae, Proteaceae, and Myrtaceae, with poor stratigraphic resolution (Barreda *et al.*, 2009). Nonetheless, besides their similar depositional history with the LMF, the Río Leona Formation accounts with occurrences of known Neogene taxa (*e.g.*, Asteraceae, Poaceae), absent in the former.

The detrital zircon analysis reveals a dominant contribution from Jurassic rocks (c. 187 and c. 155 Ma peaks; Fig. 2d), mainly stemming from the Chon-Aike Silicic Large Igneous Province prevalent across the Deseado Massif named Bahía Laura Volcanic Complex (Kay *et al.*, 1989; Navarrete et al., 2023). Comparatively, Cretaceous elements are less prominent (c. 116 and c. 83 Ma peaks; Fig. 2d), probably linked to the Bajo Grande Formation or the Chubut and Baqueró groups (Navarrete *et al.*, 2023; Pérez Frasette *et al.*, 2024). Contributions from Permian-aged units (c. 273 Ma peak) and Paleocene-aged units (c. 39 Ma peak) are the least represented and may be associated with outcrops of the La Golondrina Formation and the Cerro del Doce basalt, respectively (Panza *et al.*, 2001; Navarrete *et al.*, 2023).

In summary, the Lower Miocene age (~20 Ma) places the fluvial deposits of LMF as predating the Patagonian marine transgression typified by El Chacay and Centinela formations. The new age for these continental beds establishes that the Patagonian marine deposits are younger than 20 Ma in this area as is noticed by the studies on the Río Leona Formation. Notably, the sediment's primary origins can be traced back to Late Jurassic sources.

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