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A new U-Pb zircon age determination for the Lemaire Formation of Fuegian Andes, Tierra del Fuego, Argentina

PRISCILA FIORELLA PALOTTI (*),MARCO MENICHETTI (*), MARIA ELENA CERREDO (**) & ALEJANDRO TASSONE (°)

RIASSUNTO

Una nuova datazione U-Pb sugli zirconi della Formazione Lemaire delle Ande Fuegiane, Terra del Fuego, Argentina

Una nuova datazione U-Pb sugli zirconi che provengono da un campione riolitico dall'area delle terme di Rio Valdez permette integrare temporaneamente le rocce vulcaniche delle Andes Fueginos con la evoluzione del bacino di Rocas Verdes. Le età concordanti ottenute delle 11 zirconi analizzati danno un range compreso tra 155-170 Ma, posizionando la roccia nel Giurassico Medio a Superiore. Il resto dei risultati, discordanti, sono stati tracciati su un grafico di concordia, in cui la intercetta inferiore indica un età di cristallizzazione di 163.9 ± 3.6 Ma. In un contesto regionale, questa età conferma l'ipotesi di apertura da SE a NW del bacino marginale di Rocas Verdes, e potrebbe rappresentare un magmatismo precedente alla generazione di crosta *quasi*-oceanica. Inoltre, non e stata riconosciuta una relazione con la migrazione a SW del magmatismo acido Giurassico.

KEY WORDS: *Gondwana break-up, Jurassic magmatism, Rocas Verdes basin, Southermost South America.*

INTRODUCTION

Since the Middle Jurassic to Lower Cretaceous, southernmost South America was affected by an extensional regime resulted in the opening of the South Atlantic Ocean during the breakup of Gondwana (ULIANA & BIDDLE, 1987, 1988). The lithospheric thinning and continental rifting led to a large-scale silicic magmatism extending from Patagonia to the Antarctic Peninsula, and the development of the Rocas Verdes marginal basin along the southernmost Pacific margin. This basin appears as a belt of mafic rocks interpreted as part of *quasi*-oceanic crust that was obducted onto the continental crust during the Late Cretaceous (DALZIEL, 1981; ALLEN, 1983; STERN & DE WIT, 2003]. The formation of the Rocas Verdes basin is thought to have been preceded and accompanied by the production of siliceous crustal melts in a volcano-tectonic rift setting, with the deposition of the Lemaire (or Tobífera) Formation (BRUHN *et alii*, 1978; FUENZALIDA & COVACEVICH, 1988; MUKASA & DALZIEL, 1996). From the Late Cretaceous onwards, the Andean compression led to the closure, shortening and inversion of the basin, and was responsible for the main Cordillera formation.

Although geochronological data of the Jurassic magmatism in the region of Chile and Patagonia were published, in the area of Tierra del Fuego, Argentina, are scarce. Toward improving the understanding of the Rocas Verdes basin in this area, we present new U-Pb zircon ages from a rhyolitic rock of Lemaire Formation.

GEOLOGICAL SETTING

The Lemaire Formation, and its Chilean equivalent Tobífera Formation, are exposed in the Fuegian Andes hinterland thrust sheets, including those of Cordillera Darwin, but also occur in the stratigraphic record of Magallanes and Malvinas basins (BIDDLE *et alii*, 1986; WILSON, 1991; PANKHURST *et alii*, 2000). In the Central Tierra del Fuego, the Lemaire Formation is the oldest exposed unit (fig. 1a) and is mostly composed of lava flows, rhyolitic/dacitic tuffs, ignimbrites and interlayers of black shales, deposited in a deep marine environment. The primary magmatic/depositional textures and mineralogy were variably overprinted by sea-floor metamorphism (during the extensional stage) and later reworked by the Andean orogenesis. This episodic compressional event was responsible for the deformation and the very low- to low-grade metamorphism that affected the rocks, and is characterized by the Upper Cretaceous, Paleogene and Miocene emplacement of NE-verging thrust sheets. The thrust detachment levels are located between the Lower Cretaceous volcaniclastic and marine sedimentary succession of the Yahgán and Beauvoir Formations, and the Lemaire Formation (fig.1b). The area also was affected by a transcurrent regime with the development of left-lateral strike-slip faults, result of the expansion of the Weddell Sea and the formation of the small Scotia plate. The structures associated are mainly transtensional with extensional faults that intersect the previous structural arrangement.

(*) Dipartimento di Scienze della Terra, della Vita e dell'Ambiente, Università di Urbino "Carlo Bó", Italia.
(**) CONICET-Departamento de Ciencias Geológicas, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina.
(°) CONICET-INGEODAV, Departamento de Ciencias Geológicas, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina.
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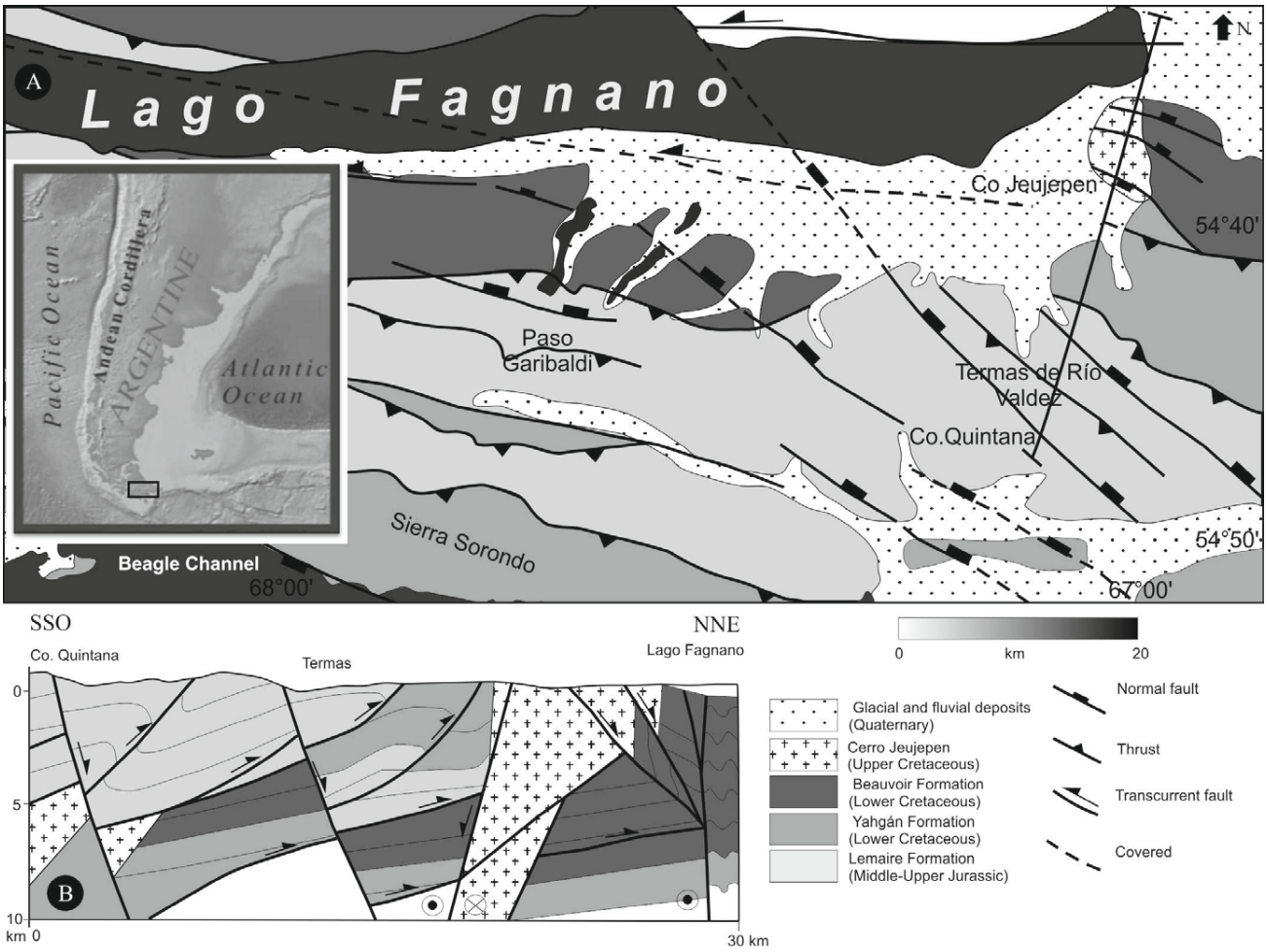

Fig. 1 – A) Geologic map of the study area. Geology was derived from different sources (Wilson, 1991; Fildani & Hessler, 2005; Olivero & Malumián, 2008; Barbeau et al. 2009) and field work conducted by the autors. B) geological cross section from Cerro Quintana to Fagnano Lake, including the Termas de Rio Valdez area.

PREVIOUS GEOCHRONOLOGY

Within the regional framework, in Jurassic times extra-Andean Patagonia along with the southernmost Andes and Antarctic Peninsula were the scenario of a large-scale silicic volcanic activity, this Large Igneous Province (LIP) evolved between and contemporaneously with the initial break-up of Gondwana in the east and a subduction zone in the west (FERAUD *et alii*, 1999; PANKRUST *et alii,* 2000). The time span of this acid magmatic event has been constrained by $^{40}Ar/^{39}Ar$ and SHRIMP U/Pb ages between 187-144 Ma (FERAUD *et alii*, 1999) or 188-153 Ma (PANKRUST *et alii,* 2000). As revealed by seismic profiles most of this volcanism in Patagonia was controlled by NNW-SSE half-grabens, with the thickest accumulations located within the grabens (ULIANA AND BIDDLE, 1988).

On the basis of paleontological content the Lemaire Formation strata at the northern shore of Lake Argentino (southern Patagonia) was early considered as Late Jurassic (FERUGLIO, 1949-1950). The biofacies associations in interlayered sedimentary rocks of Tobífera Fm. at the Brunswick Peninsula and Torres del Payne Chilean National Park, indicated Kimmeridgian-Tithonian times (FUENZALIDA & COVACEVICH, 1988).

In Cordillera Darwin (Chile) both SHRIMP (HERVÉ *et alii,* 2010; BARBEAU *et alii*; 2009; KLEPEIS *et alii*, 2010) and conventional (MUKASA & DALZIEL, 1996) U/Pb in zircon ages of Tobífera Formation cluster around 155-164 Ma. In the Magallanes foreland basin, SHRIMP U/Pb in zircon yielded somewhat older ages (~ 172 and 178 Ma, PANKRUST *et alii,* 2000).

In the northern tip of RVB (~ 51-52º SL), Tobífera Fm. rocks yielded youngest ages clustering in the 140-150 Ma range (SHRIMP U/Pb in zircon, CALDERÓN *et alii*, 2007).

Radiometric dating of the *quasi* oceanic crust of RVB in turn, provided more tightly constrained time-spans both in the northern areas as in the beagle channel area: ~ 149-150 Ma, shrimp U/Pb in zircon, (CALDERÓN *et alii*, 2007; MCATAMNEY *et al*., 2011) and in the Magallanes foreland basement (~ 158 ma, WR K/Ar age, S□LLNER *et alii*, 2000).

NEW RESULTS

The analyzed sample correspond to a rhyolitic composition volcanic rock of the Lemaire Formation, collected from an outcrop that extends more than 50 meters in the area of Río Valdez baths (*Termas de Río Valdez*), southeast of the Fagnano

Lake (fig.1a). This rock present a porphyric texture, with phenocrysts of quartz, K-feldspar, plagioclase and opaque minerals, immersed in a fine-grained quartz-feldspar groundmass. The rock has a slight alteration reflected in sericite flakes on feldspar crystals, and white mica filling fractures in plagioclase. The zircons and other accessory minerals such as monazite, allanite and titanite, were mostly recognized with Scanning Electron Microscope (SEM). With this instrument, the zircon crystals were analyzed and selected, reaching a total of 11 zircon crystals in 6 thin sections.

Cathodoluminescence (CL) images were first obtained on all the zircon grains and used to select specific areas for analysis within the grains. This reveals widespread oscillatory zoning (fig. 2) and an absence of metamorphic rims, indicating formation from a magma with negligible secondary growth. U-Pb zircon geochronology was conducted by laser ablation inductively coupled plasma-mass spectrometry (LA-ICP-MS), using a spot diameter of 10 mm because of the grain size.

The sample reported contain few concordant U-Pb ages, which range from ca. 155 to 170 Ma. Proterozoic ages were obtained in the core of two zircon grains (fig. 2), indicating that these components would have been inherited by the Jurassic volcanic rocks while in their magmatic stage. The remaining fractions are discordant, but form an array with a lower concordia intercept of 163.9 ± 3.6 Ma (fig. 3), interpreted as the crystallization age of the volcanic rock. The discordant U-Pb ages can be explained in terms of the "tectonic overprint" and/or due to the small size of the crystals.

DISCUSSION

Our new age extends the Middle Jurassic volcanic activity represented in Cordillera Darwin by Tobífera Fm. to central Tierra del Fuego, as indicated by the rhyolitic lava of Lemaire Formation. Therefore, a protracted magmatic activity during Jurassic times may be interpreted from the whole set of available ages for Tobífera/Lemaire formations, confirming regional time-pattern pointing to NW decreasing ages within the Rocas Verdes basin. The fact that the obtained age is older than those known of the *quasi* oceanic crust of RVB, and similar to ages of some rocks that represent a proto-marginal basin setting (MUKASA & DALZIEL, 1996), could mean that the magmatism that led to the formation of the studied volcanic rocks preceded the formation of the basin.

A displacement in time of volcanism and rifting to the SW within the Chon-Aike LIP, from northern extrandean Patagonia to the Southernmost Andes (Pankhurst et al., 2000) is not evident by recent geochronologic data.

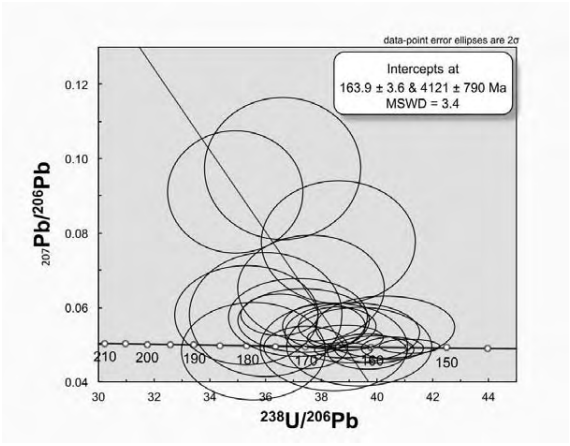

Fig. 3– U-Pb Concordia diagram for a rhyolite of the Lemaire Formation from Río Valdez baths (*Termas de Río Valdez*).

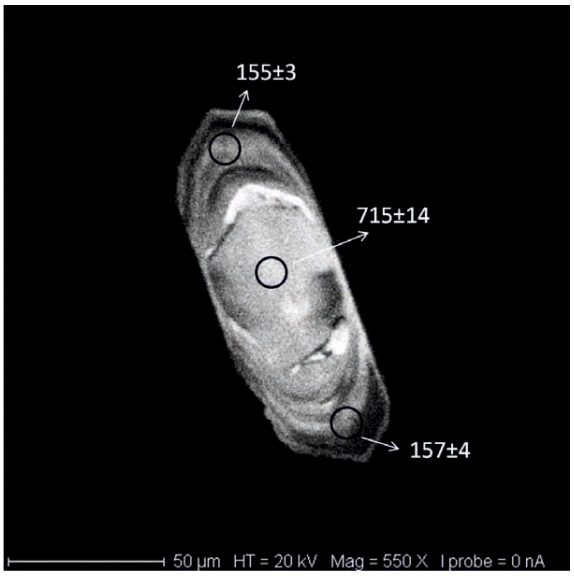

Fig. 2– Cathodoluminiscence (CL) image of one zircon from the studied sample. Oscillatory zoning and Proterozoic core are shown.

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