

Inherited Mantle and Crustal Zircons in Mantle Chromitites (E Cuba): Implications for the Evolution of Oceanic Lithosphere

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INTRODUCTION

Zircons are being increasingly found in chromitite bodies hosted in the upper mantle sections of ophiolites (e.g. Voikar-Syninsky ophiolite massif, Savaliev et al., 2006; Semail ophiolite, Robinson, 2011; Southern Tibet, Yamamoto et al., 2013). Here we present in-situ LA-(MC)-ICPMS U-Pb dating and Hf and O-isotope compositions for zircons from eastern Cuba chromitites that provide important constraints on the evolution of the Caribbean oceanic lithospheric mantle.

EASTERN CUBA OPHIOLITES AND ASSOCIATED CHROMITITES

The easternmost exposures of the Cuban Northern Ophiolite Belt are represented by the large massifs of Moa-Baracoa (MB) and Mayarí-Cristal (MC), which jointly form the "Mayarí-Baracoa Ophiolitic Belt" (MBOB, Proenza et al., 1999; Marchesi et al., 2006). The MB massif is made up of a ~2.2 km thick section of mantle tectonite harzburgite with subordinate dunite, and a Moho transition zone overlain by ~500 m thick layered gabbros of the lower oceanic crust. The MC massif is a > 5 km thick peridotite massif made up of highly serpentinized harzburgite tectonite hosting minor subconcordant dunite. The MBOB is a portion of MOR-like lithosphere modified in a supra-subduction zone related to the intra-oceanic Greater Antilles paleo-island arc developed during the Lower-Upper Cretaceous (130-70 Ma).

The MB massif contains bodies of

chromitite with high-Al chromite (Cr#=0.41-0.54) and variable TiO₂ (0.05-0.52 wt%). Chromitites with chromite of both high-Cr and high-Al varieties (Cr#=0.45-0.74) occur interspersed within the easternmost part of the Mayarí-Cristal Massif (Proenza et al. 1999; González-Jiménez et al. 2011). The zircon grains analysed in this study were separated from high-Al chromitites of Mercedita and Potosí deposits located near the mantle-crust transition exposed in the Moa-Baracoa massif, and from high-Cr chromitite of the Caridad deposit hosted in the deeper upper mantle tectonite of the Mayarí-Cristal massif.

SAMPLING AND ANALYTICAL PROCEDURES

Zircon grains were recovered using two different methods. Thirty-one zircons were obtained after processing 2.7 and 0.5 kg of chromitite from the Mercedita and Potosí deposits, respectively, using the innovative technique of hydroseparation (HS-11, Univ. Barcelona; Navarro-Ciurana et al., 2012). Another set of 10 zircons were recovered from the Caridad chromitite using the high-voltage electric pulsed SelFrag rock disaggregation facility at the Geochemical Analysis Unit, CCFS (GEMOC, Australia). Zircons were hand-picked under a Leica UV microscope, mounted in 25 mm epoxy resin discs and polished.

In general, the separated zircons are <100 µm, but they are suitable for laser ablation microprobe analysis. U-Pb ages were measured using an Agilent 7700

quadrupole ICP-MS instrument attached to a New Wave/Merchantek UP-213 laser ablation system (λ=213 nm), at GEMOC using a beam diameter of ca. 30 µm with 5 Hz repetition rate and energy of around 0.06 µJ and 8J/cm². The analytical procedures are described in detail by Belousova et al. (2009). Hf-isotope analyses were carried out in-situ using a New Wave/Merchantek UP-213 laser-ablation microprobe attached to a Nu Plasma multi-collector ICPMS at GEMOC (see Belousova et al., 2009, for details).

RESULTS

Zircon grains are prismatic to rounded, about 20-300 µm across. Euhedral zircon crystals with (bi)pyramidal shape show a clear oscillatory zonation in BSE and CL images (Fig. 1). In addition, sector zoning and lack of obvious zonation are locally observed. SEM-EDS and micro-Raman analyses revealed that zircon grains host inclusions of apatite, monazite, quartz, orthoclase, titanite, rutile and ilmenite. Typical mantle minerals (olivine, orthopyroxene, clinopyroxene, Cr-spinel) were not found within the zircons.

U-Pb age dating

U-Pb analyses on 4 zircons from the Mercedita chromitite deposit show ages clustering around the Carboniferous-Permian boundary (289 ± 9 Ma to 310 ± 10 Ma, 2σ uncertainty; Fig. 1). Analyses on 17 grains from the Potosí chromitite yield a significant range in age, scattering from Cretaceous (99 ± 21 Ma) to Neo-Archean (2750 ± 60 Ma),

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clustering around two main peaks at 293 ± 5 Ma ($n = 9$) and 713 ± 9.4 Ma ($n = 3$). The analysed zircons ($n = 5$) from the Caridad chromitite are Neo-Proterozoic (554 ± 29 Ma) and mainly Paleo-Proterozoic (1867 ± 58 Ma to 2130 ± 36 Ma).

Zircon Hf and O-isotope compositions

Lu-Hf analyses on the zircons of Mercedita yield depleted mantle Hf model age (TDM) from 1.08 to 1.18 Ga, with corresponding $\epsilon_{\text{Hf}}(t)$ between -3.67 and -6.44. The grains analysed from Potosí yield a TDM age from 0.22 to 3.06 Ga and corresponding $\epsilon_{\text{Hf}}(t)$ ranges between -9 and 13.5. Caridad zircons have TDM values of 2.14 to 2.62, with $\epsilon_{\text{Hf}}(t)$ values of -26.5 to 0.9. The analyses of oxygen isotopes on the Proterozoic zircons of Caridad show that four of these zircons have range of $\delta^{18}\text{O}$ between $6.01 \pm 0.34\text{‰}$ and $7.87 \pm 0.35\text{‰}$.

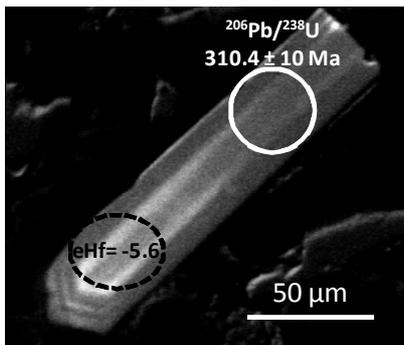


fig 1. BSE image of a ca. 310 Ma zircon grain from the Mercedita chromitite deposit. All zircons in the Mercedita deposit yielded negative ϵ_{Hf} values ranging from -5.6 to -3.7.

DISCUSSION AND CONCLUSIONS

Two zircon grains from Potosí are essentially of the same age (99 to 118 Ma) as that of the ophiolite formation (90-120 Ma). These zircon ages of ~110 Ma can be related to the timing of mantle melting and creation of new lithosphere, in agreement with their positive ϵ_{Hf} of 13.5. These processes were very likely associated with the opening of a back-arc basin behind the intra-oceanic Greater Antilles paleo-island arc developed during the Lower-Upper Cretaceous (130-70 Ma).

In contrast, most zircons from eastern Cuba chromitites are older than early Cretaceous and, hence, are considered inherited. BSE and CL images, wide range of ages and ϵ_{Hf} values suggests that these zircons were derived from multiple sources. Most values of $^{176}\text{Hf}/^{177}\text{Hf}$ ($\epsilon_{\text{Hf}} < 0$) indicate continental crustal origin which suggests reworking of old continental crust or detrital

sediments significantly involved in the evolution of the Caribbean oceanic lithospheric mantle. In fact, inclusions of quartz and K-feldspar and the high $\delta^{18}\text{O}$ of the Proterozoic zircons of Caridad (6.01 to 7.87), higher than typical value of $5.3 \pm 0.3\text{‰}$ of mantle zircons (Valley, 2003), clearly indicate that these zircons crystallized from intermediate-acid magmas evolved from supracrustal sources.

The Permian (~290 Ma) to Neo-Archean (2750 Ma) ages of the eastern Cuba zircons with $\epsilon_{\text{Hf}} < 0$, and $\delta^{18}\text{O} > 6\text{‰}$ indicate the incorporation of pre-existing (inherited) zircons of continental crustal origin to the mantle melts that formed the chromitite bodies 100-90 Ma ago. The preservation of crustal zircons in the mantle can be partly explained by their occurrence as inclusions in chromitite grains. These zircons document continental crust contamination of the suprasubduction mantle. They resided in the mantle peridotite for a long time, and underwent no significant resetting of their U-Pb ages despite the high T of the mantle before being entrained into the chromitites. We propose that subduction of continental crust-derived detrital zircon-bearing sediments deposited over oceanic lithosphere is the most likely process that contaminated the suprasubduction mantle.

On the other hand, the Potosí chromitites also contain inherited zircon grains with peaks at $\sim 713 \pm 9.4$ Ma and $\epsilon_{\text{Hf}}(t) = 4.5-13.5$ suggesting derivation from a juvenile mantle source region. These grains provide support for the hypothesis that residual domains of ancient subcontinental lithosphere mantle (SCLM, Pangea-derived) are present within the Caribbean lithospheric mantle. Relics of old SCLM have been found entrained in Phanerozoic ophiolites in the form of highly depleted mantle domains, similar to those found in the Mayarí-Baracoa Ophiolitic Belt.

We conclude that the origin of old zircons in eastern Cuban chromitites can be explained by two mechanisms:

- i) Incorporation of ancient continental crustal-derived zircons hosted in oceanic sediments (e.g. Caribbeana; García-Casco et al., 2008) into the upper mantle during subduction of the Proto-Caribbean (Central Atlantic-related) basin beneath the Caribbean (Pacific-related) plate in the Early Cretaceous.
- ii) Incorporation of ancient mantle-derived zircons hosted in fragments of

subcontinental lithosphere mantle into the Pacific-derived Caribbean basin during continental breakup of Pangea.

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