U-Pb geochronology of detrital zircons from Caratas and Los Arroyos Formations, northeastern Venezuela

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Abstract
LA-MC-ICPMS U-Pb geochronology in detrital zircons was performed in two Tertiary turbidite sequences from Northeastern Venezuela to contribute to the understanding of the Cenozoic history of the northern South America plate. The age results of detrital zircons from the Eocene Caratas Formation show a range of Late Archean to Middle Proterozoic ages, suggesting a unique source from a drainage coming from the southern Guayana Shield. The Middle-Miocene turbidite of Los Arroyos Formation displays a detrital zircon age signature from Paleoproterozoic to Silurian which is significantly similar to an Early Cretaceous passive margin unit. The Guayana Shield has long been interpreted as the source of siliciclastic detritus within the Cretaceous passive margin and Tertiary strata of northern Venezuela; these ideas are compatible with our results that confirm previous models of Caratas and Los Arroyos formations as deposited in marine intracontinental basins with no influence of rock units from the Caribbean realm.

Key words: Turbidites, Barranquín Formation, Guyana Shield, Vidoño Trough.

Introducción

The provenance of sandstones as determined by LA-MC-ICPMS U-Pb detrital zircon (DZ) geochronology has become a widely used tool in geological interpretations. In 2007 a project was started to work with DZ in Northern Venezuela, sampling Cretaceous Passive Margin and Tertiary turbidite formations (NOGUERA 2009, NOGUERA *et al.* 2010). Earlier works in Venezuela in this field are those of GOLDSTEIN *et al.* (1997) and XIE (2010).

Separation of North and South America during the breakup of western Pangea created the Proto-Caribbean seaway and during the Triassic and Jurassic, continental breakup led to formation of numerous rift basins that were filled with continental red beds and associated volcanic rocks. The Triassic-Jurassic rifting phase was followed by the development of an Early Cretaceous passive margin dominated by siliciclastic sedimentation above a regional transgressive peneplain. Regional transgression onto the subsiding passive margin led to onlap of continental to shallow marine facies followed by deeper water facies, which reached a maximum in the Late Cretaceous (Turonian - Coniacian) and is reflected in the Cretaceous stratigraphic record by a gradual change from siliciclastic dominated sedimentation in the Early Cretaceous to more pelagic shale and carbonate sedimentation in the Late Cretaceous. Eastern Venezuela remained a continental passive margin until the gradual arrival of the peripheral bulge by Late Eocene time and the Caribbean foredeep by Oligocene time. Additionally, PINDELL *et al.* (2005) interpreted a trough, referred to as the Vidoño Trough**,** approximately oriented SW-NE, and separated from the open ocean by a flexural bulge. The Vidoño Trough is interpreted to have been fed mostly by shield-derived sand and to a lesser degree by sediments derived from the exposed passive margin rocks at the bulge. At the margins of the Guayana Shield and in the outer areas of the peripheral forebulge was deposited the Eocene Caratas Formation**,** marking the end of the continental passive margin stage in Northeastern Venezuela**.** The deposition of Los Arroyos Formation in Miocene times was probably contemporaneous with the uplifting of the Eastern Serranía del Interior.
To test this model, U-Pb detrital zircon geochronology was carried out to interpret the provenance of the Paleogene Caratas Formation and the Neogene Los Arroyos Formation (Fig. 1).

Materials

Caratas Formation (Early – Middle Eocene). The Caratas Formation is composed by a sequence of shale and fine-grained quartz-rich sandstone, topped by a thick carbonate sequence. The sandstones are also

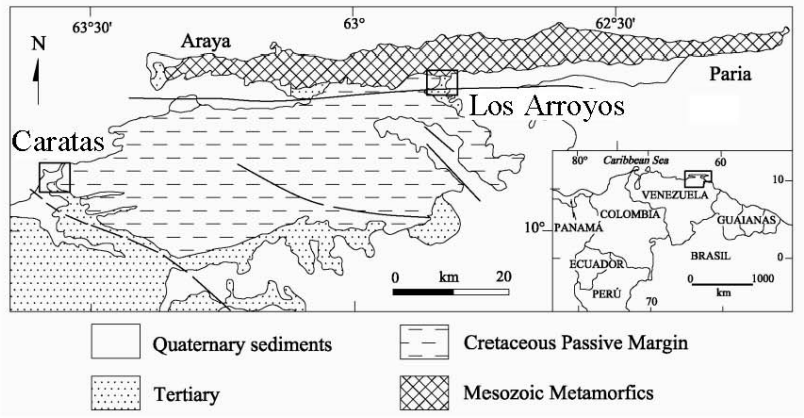

Figure 1. Geologic map of northeastern Venezuela showing the sampling locations.

frequently glauconitic and carbonate-rich. The Caratas Formation lays conformably over the shale of Late Cretaceous Vidoño Formation. Its upper contact with the shale of Oligocene-age Jabillos Formation is erosional and marks a regional hiatus, indicated by the absence of Late Eocene fauna. The sample of Caratas Formation used in this work was collected in the surroundings of Barcelona city. It is a medium to fine grain lithic graywake sandstone. Monocrystalline quartz is the most abundant mineral. Feldspars are present in variable concentrations as microcline and plagioclases. Glauconite grains are common in the sands of the Caratas Formation. Accessory minerals are rutile, zircon, tourmaline, muscovite and biotite. The lithic fraction displays fragments of chert and biotite-phyllite. Advanced substitution by calcite, dolomite, and clay masked some lithic fragments, making their identification difficult.

Los Arroyos Formation (Middle Miocene). The Los Arroyos Formation is a terrigenous-carbonate turbidite unit which includes conglomerate, shale, siltstone, lithic arenite and limestone (ÁLVAREZ *et al.* 1985). The lower section is composed of conglomerate with metamorphic pebbles. The middle section is dominated by shale. The upper section is represented by a typical turbidite sequence with structures also suggesting gravitational collapse. Our sample comes from this upper turbiditic section. The unit is poor in fauna; however, Middle Miocene ages were reported from the scarce foraminifera content. Distal platform environments have been interpreted from planktonic foraminifera and gastropods (ÁLVAREZ *et al.* 1985). The lower contact of the Los Arroyos Formation is defined as an angular unconformity over the pelitic metasediments of Tunapuy Formation of Cretaceous age of the Paria Península. Its upper contact is erosional and covered with Pleistocene-age gravels. The sample used for DZ geochronology is a medium to coarse grained graywake sandstone. Quartz represents the coarse fraction of the grains; monocrystalline quartz is dominant over the polycrystalline varieties in these rocks. Feldspars are absent. Accessory minerals include biotite, muscovite, zircon, tourmaline, apatite, titanite, detrital calcite and detrital glauconite. Biotite phyllite, quartz muscovite schist, and quartzite are present, along with fragments of chert, limestone, and sandstone. Most of the lithic grains are usually rounded to well rounded, contrasting with the sub-angular mineral grains.

Analytical Methods.

U-Pb geochronology was conducted by laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) at the University of Arizona LaserChron Center (GEHRELS *et al.* 2006). We obtained 93 U-Pb detrital zircon ages derived from one sample of each, Caratas and Los Arroyos formations (NOGUERA 2009).

Results and Discussions.

In **Caratas** Formation the DZ ages range between Late Archean (2916 ± 24.5 Ma) and Middle Proterozoic (1425 ± 23.7 Ma), showing a signature that match sources of the Guayana Shield. The ages show four broad peaks (Fig. 2) that in order of frequency are: a) 1800-2200 Ma, matching the age range of the felsic volcanics and plutonics of the Cuchivero Suite, while a small peak at 1850 Ma may come from to the Avanadero mafic intrusions in the Roraima Supergroup. b) The 2400-2500 Ma ages fit with the Pastora Province and the plutons of the pre-Transamazonian cycle. c) The 2800-2900 Ma ages represent the Archean rocks of the Imataca Complex. d) The grains in the range of 1400-1500 Ma probably originated in the Parguaza granitic batholith.

The DZ ages of **Los Arroyos** Formation span from Early Proterozoic (2292.8±34.3 Ma) to Ordovician (499.1±9.4 Ma). Since our sample displays an age pattern very similar to the Early Cretaceous passive margin Barranquín Formation of NOGUERA *et al.* (2011) (Fig. 2), a Kolmogorov-Smirnoff test was carried out to compare the cumulative age probability

plots of both formations. The resultant high p value shows that it is unlikely that the two samples are from different populations. The results show that Los Arroyos Formatin did not see the Caribbean Plate.

Conclusions.

The DZ ages of the Eocene **Caratas** Formation suggest source rocks solely from the Guayana Shield and supports the model of PINDELL *et al.* (2005) that such unit was deposited in an intracontinental trough, with the Guayana Shield and a peripheral bulge as its southern and northern margins, respectively.

The results of **Los Arroyos** Formation are more complex. The variety of lithic fragments as seen by petrography may suggest the following formations as sources: the metamorphic Tunapuy and Güinimita formations (quartz-mica phyllite/schist and quartzite) and the Cretaceous passive margin units as San Antonio Formation (chert), El Cantil and/or Querecual formations (limestone) and Barranquín Formation (sandstone). This petrographic information agrees with the DZ ages that display a strong similarity with the data of passive margin Barranquín Formation (NOGUERA *et al.* 2011).

In a similar way as in Las Mercedes and Las Brisas metamorphic units of Central Venezuela, the Araya and Paria penínsulas pelitic and psamitic low grade metasediments have been interpreted as part of the Late Jurassic – Late Cretaceous passive margin of Northern South America (GONZÁLEZ DE JUANA *et al.* 1980). The sources of these passive margin units probably were a combination from the Guayana Shield, El Baúl, the Mérida Arch and the Colombian cordilleras, to make possible the appearance of the conspicuous Grenville ages. The sediments were distributed by means of a Proto-Orinoco river system reaching as far as the deltaic deposits of the Cretaceous passive margin of eastern Venezuela (NOGUERA 2009). The protolith of the metasedimentary Tunapuy Formation was probably deposited by the same river system than the Barranquín Formation and we interpret that it probably has a similar DZ age distribution.

In Oligocene time, part of the sediments of the passive margin sequence were metamorphosed during the nappe piling event in Northeastern Venezuela (e.g.: PINDELL *et al.* 2009b: 332, fig. 18). Other major part of the passive margin units remained unaffected by metamorphism.

The continuation of the oblique Caribbean-South America interactions in Miocene time, generated dextral oblique thrusting that started the uplift of the Serranía del Interior. This allowed the juxtaposition of unmetamorphosed as well as metamorphosed passive margin units by means of the Chuparipal Thrust. By Middle-Miocene uplift and erosion continued. A small trough was generated and Los Arroyos Formation was deposited, with a load of lithic fragments of sedimentary and low grade metamorphic rocks. In Plio-Pleistocene times the area was further disrupted by the right-lateral El Pilar fault system. This geologic history is compatible with the DZ age data set of Los Arroyos Formation that shows statistically significant similarities to the Early Cretaceous passive margin Barranquín Formation.

The DZ age data of our samples are distinctive from other turbidite units in Central and Western Venezuela such as Guárico and Matatere formations (NOGUERA 2009) since no young ages (Middle Ordovician to Tertiary) were found in the detrital fraction of Caratas and Los Arroyos formations.

Since Los Arroyos Formation does not display any Caribbean ages, the Paria metasedimentary formations on which Los Arroyos rests upon were not part of the far travelled Caribbean orogen, but it supports the previous ideas that were deposited on the passive margin of South America and latter metamorphosed. On the other hand due the lack of a Barbados equivalent prism in the N-S cross sections through eastern Venezuela, we may consider that a Barbados-equivalent prism was thrust up the face of the margin, creating a trough between it and South America. It is either transposed out of the section, or it was overthrust and entirely eroded before the fomation of the localized Los Arroyos trough.

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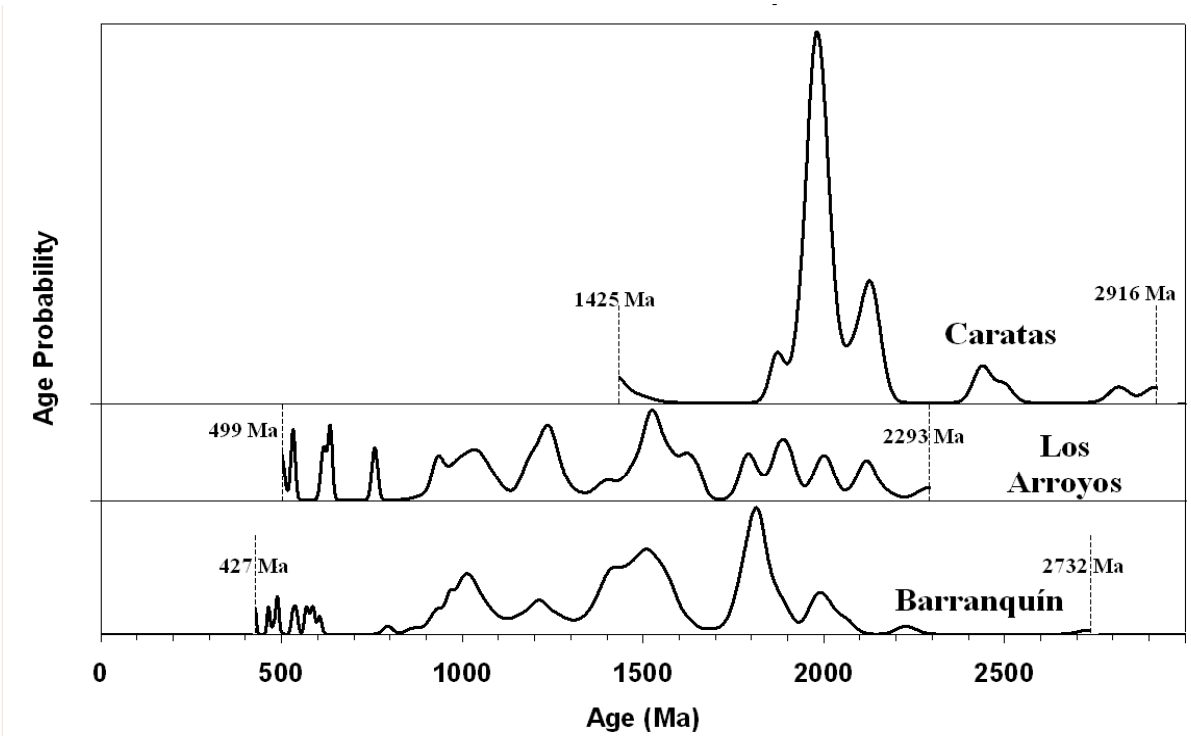

Figure 2. Probability density plot of U-Pb detrital zircon ages from Caratas (n=46) and Los Arroyos (n=47) formations. Barranquín Formation (n=189) data from NOGUERA *et al. (2011).*

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