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U-Pb geochronology of detrital zircon crystals 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.

Keywords: turbidites, Barranquín Formation, Guyana Shield, Vidoño Trough.

Geocronología U-Pb de cristales de zircón detríticos de las formaciones Caratas y Los Arroyos, Venezuela nororiental

Resumen

La geocronología U-Pb en zircones detríticos se realizó en dos secuencias de turbiditas terciarias del noreste de Venezuela, para contribuir a la comprensión de la historia geológica cenozoica del norte de la placa Suramericana. Los resultados de las edades de los zircones detríticos de la Formación Caratas del Eoceno, muestran un rango entre el Arqueano Tardío al Mesoproterozoico, lo que sugiere una fuente proveniente del sur del Escudo de Guayana. Las turbiditas de la Formación Los Arroyos del Mioceno Medio muestran edades desde el Paleoproterozoico al Silúrico, que resultan similares y en forma altamente significativa con una unidad cretácica de margen pasivo. El Escudo de Guayana ha sido interpretado como la fuente de detritos siliciclásticos dentro de las unidades de margen pasivo del Cretáceo y Terciario en Venezuela nororiental. Estas ideas de autores previos son compatibles con nuestros resultados que confirman los modelos anteriores que las formaciones Caratas y Los Arroyos se depositaron en cuencas marinas intracontinentales sin influencia de rocas del ámbito Caribeño.

Palabras clave: turbiditas, Formación Barranquín, Escudo de Guayana, Surco de Vidoño.

Introduction

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 [1, 2]. Earlier works in Venezuela in this field are those of Goldstein et al. [3], Bizzi [4] and Xie [5].

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 [6].

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 [7].

Additionally, Pindell et al. [8] 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 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 sedimentation 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 from Northeastern Venezuela (Figure 1).

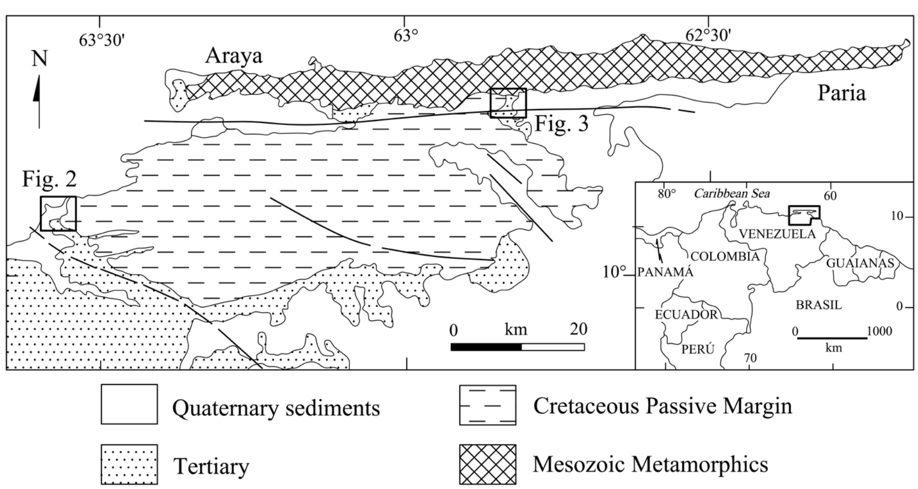

Figure 1. Geologic map of northeastern Venezuela with rectangles showing the location of further detailed figures. Simplified after [9].

The turbidite samples

Caratas Formation (Early-Middle Eocene)

The Caratas Formation is composed of a sequence of shale and fine-grained quartz-rich sandstone, topped by a thick carbonate sequence (Tinajitas Member). The sandstones are also frequently glauconitic and carbonate-rich. The Caratas Formation (Figure 2) 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 [10]. Galea [11] indicated the depositional environment of the Caratas Formation as turbidite flows on a continental slope, as suggested by its sedimentary structures and foraminifera.

The Caratas Formation sample used in this work was collected in the surroundings of Barcelona city (Figure 2). It is a medium to fine grain lithic graywake sandstone (Table 1). 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 chert and biotite-phyllite fragments. Advanced substitution by calcite, dolomite, and clay masked some lithic fragments, making their identification difficult.

Los Arroyos Formation (Middle Miocene)

Los Arroyos Formation is a terrigenous-carbonate turbidite unit which includes conglomerate, shale, siltstone, lithic arenite and limestone [13]. 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 was deposited in distal platform environments poor in fauna; however a middle Miocene age is accepted from the scarce plank-

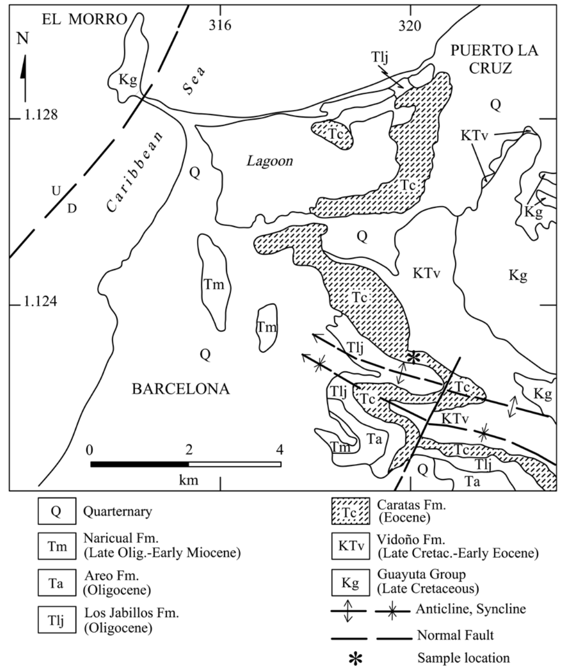

Figure 2. Geologic map of Barcelona-Puerto La Cruz area showing the location of Caratas Formation sample. UTM Coordinates zone 20 ($\times 10^{-3}$) datum La Canoa. After Keller [12].

tonic foraminifera and gastropods [13]. The lower contact of the Los Arroyos Formation is defined as an angular unconformity over the pelitic metasediments of the Cretaceous Tunapuy Formation of Paria Península (Figure 3). 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 (Table 1). 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, quartzite, chert, limestone, and sandstone fragments are present. 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

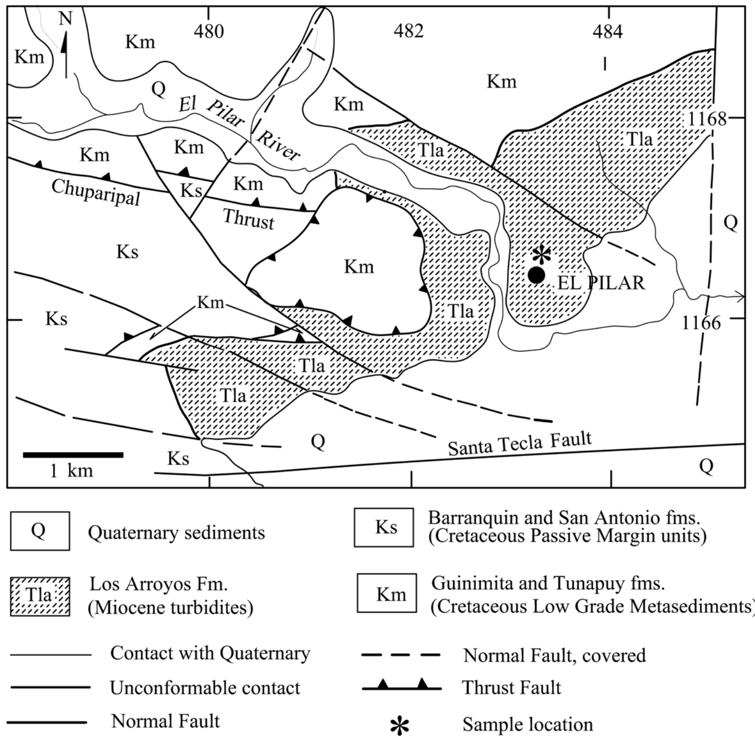

Figure 3. Geologic map of the El Pilar area with sample location of Los Arroyos Formation [25].

Table 1
General composition of samples (values are in vol. %)

Unit		Caratas	Los Arroyos
Sample ID		VMN-31	VMN-43
Framework grains	Quartz	45	44
	Plagioclase	1	0
	K-Feldspar	2	0
	Micas	1	1
	Heavy minerals	2	3
	Sedimentary lithics	0	6
	Metamorphic lithics	1	6
	Volcanic lithics	0	4
	Alteration products	9	0
	Fossils	1	1
	Glauconite	7	0
Whole rock	Grains	69	65
	Cement	25	10
	Matrix	5	20
	Porosity	1	5

plasma mass spectrometry (LA-MC-ICPMS) at the University of Arizona Laser Chron Center. Details of the analytical protocols can be found in Gehrels et al. [14] and Gehrels [15], while data processing was done using the Excel® Macros of Gehrels [16].

We obtained 93 U-Pb detrital zircon ages derived from one sample of each, Caratas and Los Arroyos formations (Table 2).

Results and discussions

The **Caratas** Formation DZ ages show four broad peaks (Figures 4 and 5) that range between Late Archean (2916 ± 24.5 Ma) and Middle Proterozoic (1425 ± 23.7 Ma), showing the signature of the Guayana Shield (Figure 6). In order of frequency they are: a) 1800-2200 Ma, matching the age of the Cuchivero Suite, while a small peak at 1850 Ma may come from to the Avananero mafic intrusions in the Roraima Supergroup [17]. b) The 2400-2500 Ma ages fit with the Pastora Province and plutons of the pre-Transamazonian cycle [18]. c) The 2800-2900 Ma ages agree with the Archean rocks of the Imataca Complex [19]. d) The grains in the range of 1400-1500 Ma probably originated in the Parguaza batholith [18].

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

Table 2
U-Pb age of detrital zircon from Los Arroyos and Caratas formations

Los Arroyos		Caratas		Los Arroyos		Caratas	
Age (Ma)	1δ	Age (Ma)	1δ	Age (Ma)	1δ	Age (Ma)	1δ
499.1	9.4	1425.0	23.7	1514.6	18.9	1995.2	30.8
532.5	6.2	1464.5	46.4	1527.3	33.0	1996.2	24.4
617.1	8.7	1869.5	18.1	1531.4	18.9	1998.6	21.2
636.0	6.1	1873.3	22.0	1560.7	35.7	2001.2	40.2
758.4	8.6	1943.8	21.3	1563.8	37.7	2002.7	29.5
932.8	15.7	1944.7	51.7	1569.8	58.7	2011.8	33.0
968.5	49.5	1954.8	33.4	1578.1	33.0	2013.7	21.0
971.6	64.8	1957.8	40.7	1622.7	18.8	2018.2	54.8
987.8	28.5	1969.2	26.4	1651.1	18.6	2074.3	22.4
1035.4	53.4	1969.8	20.9	1782.3	24.1	2101.2	32.7
1037.9	24.1	1970.7	18.6	1789.3	19.2	2114.8	31.4
1043.3	46.2	1971.8	17.9	1821.8	24.4	2115.5	26.0
1077.8	31.9	1972.2	24.2	1871.1	22.9	2120.7	25.1
1183.3	22.0	1972.6	27.1	1875.8	19.7	2127.8	24.9
1212.8	30.7	1975.6	31.4	1904.0	18.2	2132.0	19.4
1223.2	47.7	1976.1	31.2	1907.6	23.2	2147.6	27.4
1239.8	20.4	1980.9	21.4	1994.0	30.1	2147.7	23.8
1243.9	26.3	1983.2	32.6	1994.6	28.4	2434.3	23.6
1246.4	39.2	1984.9	29.2	2009.4	24.3	2442.9	19.0
1260.4	53.2	1985.0	54.5	2101.0	30.1	2498.4	19.0
1399.5	28.5	1989.4	21.7	2119.2	21.2	2818.0	16.3
1458.4	114.4	1989.7	43.1	2152.3	36.9	2916.0	24.5
1477.1	25.4	1992.2	22.4	2292.8	34.2		
1487.0	45.0	1995.0	23.5				

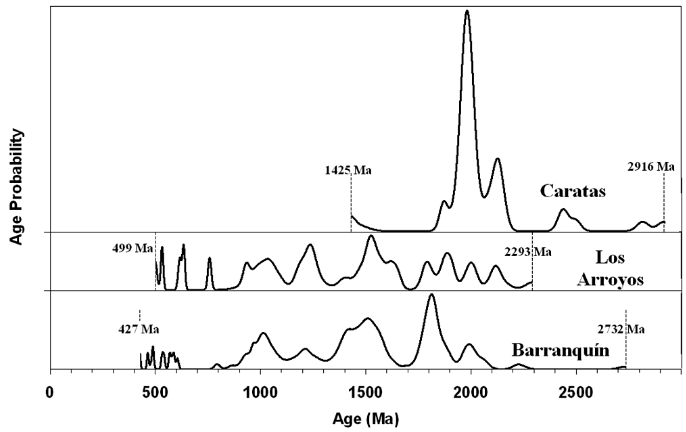

Figure 4. Probability density plot of U-Pb detrital zircon ages from Caratas (n=46) and Los Arroyos (n=47) formations. Barranquín Formation (n=189) data from Noguera et al. [20].

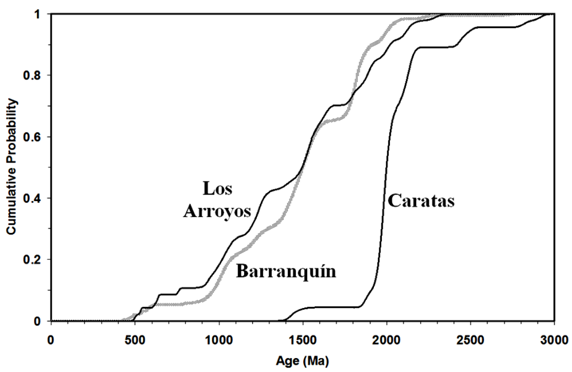

Figure 5. Cumulative Probability Density Plot of U-Pb zircon detrital zircon ages from Caratas, Los Arroyos and Barranquín formations.

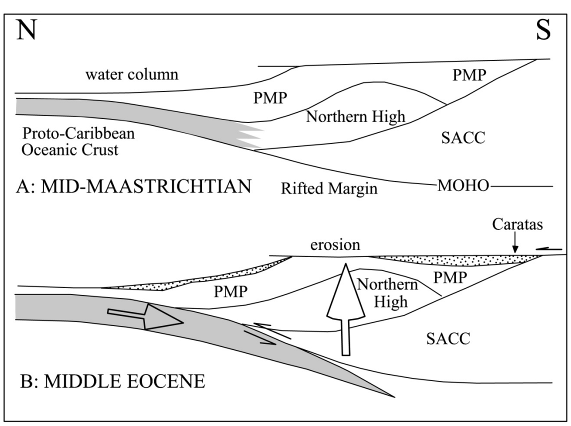

Figure 6. Geodynamic model of Pindell et al. [8] during Mid-Maastrichtian (A) and Middle Eocene (B) showing the position of the Caratas basin receiving sediments only from the Guayana Shield. PMP: Passive margin prism. SACC: South American Continental Crust.

displays an age pattern very similar to the Early Cretaceous passive margin Barranquín (Figure 7) Formation of Noguera et al. [20] (Figure 4), a Kolmogorov-Smirnoff test [21-27] was carried out to compare the cumulative age probability plots of both formations (Figure 5). The resultant high p value suggests that it is unlikely that the two samples are from different populations.

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., that the Caratas Formation was deposited in an intracontinental trough, with the Guayana Shield as its southern margin and separated from the open ocean by an outer high created by marginal inversion and several tens of kilometers of thrusting.

The results of **Los Arroyos** Formation are more complex. The variety of lithic fragments as seen by petrography may suggest the following units as source: the metamorphic Tunapuy and Güinimita formations (quartz-mica phyllite/schist and quartzite); 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 Early Cretaceous passive margin Barranquín Formation. In a similar way, Las Mercedes and Las Brisas units of central Venezuela, the Araya and Paria penín-

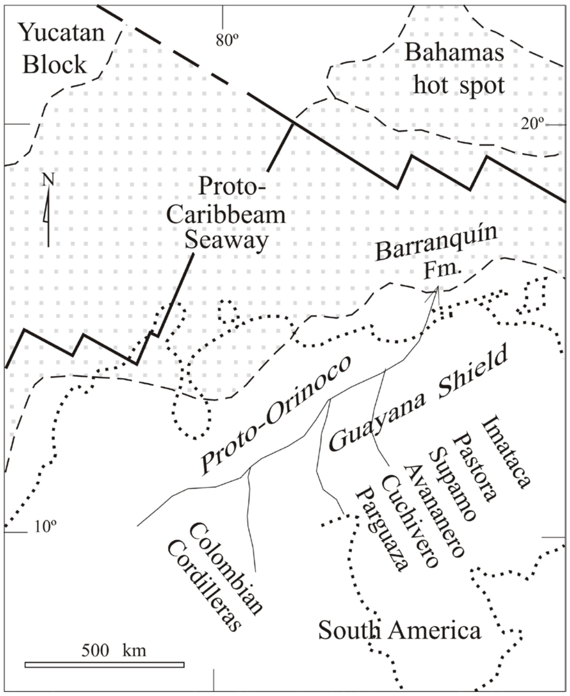

Figure 7. Paleogeography and global tectonic configuration for Early Cretaceous. The Barranquín Formation and the sediments of the Güinimita and Tunapuy formations were deposited in the passive margin of northern South America. Present day coastline is depicted for reference purposes only. Base map after Pindell et al. [27], proto-Orinoco after Noguera et al. [20].

sulas pelitic and psamitic units, all low grade metasediments, have been interpreted as part of the Late Jurassic-Late Cretaceous passive margin of Northern South America.

The source rocks of the deltaic deposits of the Cretaceous passive margin units of eastern Venezuela as the Barranquín Formation, probably were a combination of terranes from the proto-Colombian cordilleras (suplying Grenvillian and Paleozoic DZ), Mérida Arch, El Baúl, and the provinces and suites of the Guayana Shield as Imataca, Pastora, Avananero, Cuchivero, and Parguaza. The sediments could have been distributed by means of a proto-Orinoco river system -probably controlled by the subsurface Espino Graben tectonics. Even if latter metamorphosed, the sediments of the Tunapuy and Güinimita formations were probably deposited by the same river system than the Barranquín Formation and we interpret that they probably have a similar DZ age distribution.

In Oligocene-Miocene time, part of the sediments of the passive margin sequence were metamorphosed during the nappe piling event in Northeastern Venezuela. 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 mid-Miocene uplift and erosion continued. A small intracontinental 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 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 since no young ages (Middle Ordovician to Tertiary) were found in the detrital fraction of Caratas and Los Arroyos formations.

Since Los Arroyos Formation unconformably rests upon the Barranquín, Güinimita and Tunapuy units, and does not display any Cretaceous-Tertiary Caribbean ages, it supports the idea that the Paria metasedimentary units were deposited on the passive margin of South America and latter metamorphosed.

On the other hand due to the lack of a Barbados equivalent prism in the N-S cross sections through eastern Venezuela, we may consider that such prism was thrust up the face of the margin, creating a trough between it and South America. It was either transposed out of the section, or it was overthrusted and entirely eroded before the formation of the localized Los Arroyos trough.

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