GEOCHEMICAL AND GEOCHRONOLOGICAL DATA ON THE PROVENANCE OF THE DEVONIAN CABANILLAS GROUP IN THE WESTERN AND COASTAL CORDILLERAS OF SOUTHERN PERU

Authors:

Cornelia Reimann[1*], Heinrich Bahlburg[1]
Ellen Koijmann[2], Jasper Berndt[2]
Victor Carlotto[3]

[1]Westfaelische Wilhelms Universitaet Muenster, Geologisch-Palaeontologisches Institut, Corrensstrasse 24, 48149 Muenster, Germany
[2]Westfaelische Wilhelms Universitaet Muenster, Institut fuer Mineralogie, Corrensstrasse 24, 48149 Muenster, Germany
[3] INGEMMET, Av. Canadá 1470, Lima, Perú

*corresponding author: reimannc@uni-muenster.de

ABSTRACT

We present a combined sedimentological and geochemical data-set including U-Pb LA-ICP-MS age data of detrital zircons. The aim of our study is to further constrain the plate tectonic setting of the Western Gondwana margin during Devonian time and particularily the development of the sedimentary basin, where the Cabanillas Group was deposited. From the framework mineral analysis and the geochemical composition of tourmalines and rutile we conclude that the major part of the detritus is well recycled and underwent at least one resedimentation event before final deposition. A minor part of the detritus from the Coastal deposits is immature and could reflect synsedimentary magmatism. U-Pb ages reveal that detrital zircons related to the Famatinian and to the Brazilian events are ominipresent in the Western Cordillera and Coastal successions. The zircons related to the Famatinan event derived from a western source on the Arequipa Massif. As intrusive rocks related to the Brazilian event are not known from the Arequipa Massif, the respective zircons must have been derived from eastern sources on the Amazonia craton. Both successions were derived in large parts from a common source area on the Amazonia craton, with the Coastal succession containing additional input from the Arequipa Massif which the Western Cordillera deposits lack.

INTRODUCTION

The sedimentary rocks of the Cabanillas Group in southern Peru were deposited in Early to Late Devonian time (Suarez Sorucco, 1992). In the Peruvian Western Cordillera close to the village Cabanillas (SW of Juliaca), the Cabanillas Group forms continuous and extensive outcrops (further on mentioned as WCo). In the Coastal Cordillera, the Cabanillas Group deposits are preserved in isolated, discontinuous outcrops (further on mentioned as CCo) near Aplao (Torán Formation), Cocachacra and Estique Pampa (50 km north of Tacna) where the deposits overlie the Neoproterozoic metamorphic basement of the Arequipa Massif with an angular unconformity. Even though the WCo and CCo successions correlate stratigraphically by their fossil content (Paredes, 1964; Laubacher, 1978; Boucot et al. 1980; Palacios et al. 1993), their lithology and geological setting are different as described further on. The tectonic setting of the basin is ambiguous but probably changed from an active margin setting in the Ordovician and Silurian to a passive margin setting in the Early Devonian (Loewy et al., 2004; Chew et. al 2007).

LITHOSTRATIGRAPHY AND SEDIMENTOLOGY

The Cabanillas Group close to the village Cabanillas is c. 1200 m thick (Palacios et al., 1993) and rich in brachiopods, trilobites, crinoids, and conularias preserved in concretions. In the lower part, thick beds of greenish sandstones occur, some of them with hummocky cross stratification indicating a storm depositional environment. This influence diminishes up-section and finer-grained, sometimes current cross-bedded, sandstones dominate. Paleocurrrent indicators point to transport towards the NE and SE. Fine sandstone and pelite layers alternate and the pelites bear most of the fossiliferous levels towards the top of the succession.

The thickness of the sedimentary successions found near Cocachacra does not exceed 100 m (Bellido & Guevara, 1963, Boucot et al. 1980, own observation). At the base of the succession conglomerates (cobble to granule-size) consist mainly of clasts of the underlying gneisses. The conglomerates grade into fine-grained sandstones and finally into pelites. Within the first 50 m of the succession, chert lenses and laminae occur, potentially representing reworked, silicified volcanic material. The brachiopod occurrences found in the pelite section were assigned by Boucot et al. (1980) to the Emsian stage.

Basal conglomerates with basement gneiss clasts can also be found at the base of the Estique Pampa section. They sometimes represent channel fill deposits above the angular unconformity to the basement gneisses. Fine to middle-grained sandstone beds interchange with pelite up-section. The sandstones include few cross-bedded sections and indicate paleocurrents towards the west. The thickness of the deposit at Estique Pampa is estimated not to exceed 400 m.

At Aplao, the Tóran Formation is estimated to be of 550 m thickness, of which only the basal 150 m are accessible (Guizado Jol, 1968). As the slope angle and the dip direction of the sedimentary beds are almost equal, we could only observe c. 40 m of the basal succession. The basal conglomerates described by different authors (Paredes, 1964; Guizado Jol, 1968; Boucot et al. 1980) were not observed. The succession is supposed to be of Early Devonian age as indicated by scarce fossils (Paredes, 1964; Boucot et al., 1980). It consists of alternating pelite and sandstone beds with trough cross-bedding indicating paleocurrents towards the NW.

PETROGRAPHIC COMPOSITION

FRAMEWORK MINERALS

The studied sandstones of the WCo locality are moderately to well-sorted. Mineral grains are subhedral to subrounded. The framework composition is dominated by quartz (average Qt/F/L percentage: 85/10/5) which is typical for well recycled sediments probably deposited in a stable plate tectonic setting like a passive margin. The sandstones of the CCo localities differ in their composition from the WCo strata. The Cocachacra and Estique Pampa sandstones differ from the WCo deposits by moderately sorted, subrounded grains. In contrast, the Aplao succession is characterized by relatively immature sandstones with a high content of feldspars (average Qt/F/L percentage: 40/55/5). Here, the grains are poorly to moderately sorted and subrounded. These features are typical for deposition in an active plate margin tectonic setting, including short transportation paths and low recycling rates of the detritus.

HEAVY MINERALS

The heavy mineral composition of the WCo sandstones is more mature than the one of the CCo localities, although both are dominated by the ultra-stable minerals zircon, tourmaline, rutile and apatite (ZTR(A): WCo > 90%, CCo > 75%). In the CCo sedimentary rocks, relatively unstable minerals such as titanite and monazite are more abundant than in the WCo ones. In the WCo sandstones, rutile is present only to a minor extent (<2%), but is prominent in the CCo sandstones (up to 35%). Titanite occurs in sandstones from the CCo Cocachacra and Estique Pampa sites (up to 18%) and few monazites are present (up to 5%) in the Estique Pampa and Aplao sandstones.

Detrital rutile is of metamorphic origin. The crystals break down at the beginning of greenschist facies metamorphism and are newly formed at upper amphibole conditions (Zack et al., 2004a). In contrast to the CCo successions the minor content of rutile in the WCo succession could be indicative of different source rocks or different metamorphic conditions the source rock or the sedimentary rocks had to endure. Titanite is indicative for orthogneisses and could be derived from the Arequipa Massif gneisses.

CHEMICAL COMPOSITION

We analysed six fine- to medium-grained sandstones of the Cabanillas Group from the WCo site and 11 samples from the CCo site (three siltstones, seven sandstones). The sedimentary rocks of the WCo and CCo sites have a SiO_2 content of 75-90% and 68-82%, respectively. The WCo sandstones have relatively high CIA values between 77 and 94. The CCo sedimentary rocks are much more homogeneous with moderate CIA values between 68 and 77. The rare earth patterns are parallel to PAAS with a pronounced negative Eu anomaly typical for the upper continental crust (McLennan, 2001). The Zr/Sc ratios are on average 54 and 19 for the WCo and the CCo sites, respectively. Considering also the discrimination diagrams of Bathia and Crook (1986), the WCo sandstones have ratios of incompatible to compatible elements typical of a passive margin settings. The chemical composition of the CCo sandstones from the Cocachacra and Aplao localities indicate an active continental margin setting for the source rocks. The ones from the Estique Pampa locality are chemically more enriched in Zr. However, a comparision with the geochemical composition of sandstones from modern marine environments demonstrates that the discrimination scheme of Bhatia and Crook (1986) can not be applied universally (Bahlburg, 1998). An alleged passive margin signature should at least initially be viewed as evidence of strong recycling. Our observations and data demonstrate that the sedimentary rocks of the WCo and CCo sites have quite different compositions. Because the grain size of the sandstones is similar, we consider the distinct geochemical features as primary provenance signals. The high Zr/Sc ratios of the sedimentary rocks from the WCo site indicate strong recycling, whereas the respective ratios in the CCo sedimentary rocks are more similar to that of the upper continental crust (UCC, McLennan, 2001), indicative of a minor degree of recycling.

U-PB LASER ABLATION ICP-MS AGES FROM DETRITAL ZIRCONS

In this ongoing study we have so far analysed the U-Pb isotope composition of zircons from four Devonian sandstones (two from the WCo and one each from the Cocachacra and Estique Pampa localities). From each sandstone the zircons were extracted and up to 150 single grains were analysed *in situ* for their U-Pb isotope composition by the LA-ICP-MS technique. Before dating, cathodoluminescence images were made of the zircon grains to reveal information about their morphology and to determine from their zoning if the grains were of magmatic (oscillatory and sector zoning) or metamorphic origin (irregularly zoned and homogeneous grains).

Detrital zircons derived from the WCo sandstones are mostly subhedral. Circa 65% of the grains have an oscillatory or sector zonation, which is indicative of magmatic source rocks. The remaining c. 35% could be assigned to metamorphic sources. In a frequency versus age histogram the largest age peak occurs in the interval between 0.4 and 0.5 Ga which can be related to the Famatinian Event. Smaller but still distinctive peaks occur at 0.56-0.70 Ga (Brasiliano event), 1.0-1.3 Ga (Grenvillian age Sunsas event) and 1.8-2.0 Ga (Ventuari Tapajos).

Detrital zircons from the CCo Cocachacra locality are subhedral to euhedral, c. 75% have a zoning typical for a magmatic source rocks and c. 25% of metamorphic source rocks. . The most prominent age peaks occur within the interval of 0.9-1.2 Ga, representing the Sunsas event, and between 0.4 and 0.5 Ga (Famatinian event). Smaller peaks can be related to the Brasiliano, Rondonia-San Ignacio and Río Negro-Juruena events. The CCo Estique Pampa detrital zircons are subhedral to euhedral. Circa 95 % are of magmatic and only c. 5 % of metamorphic origin. The U-Pb age distribution is similar to the Cocachacra site zircons with a most prominent peak at 0.4-0.5 Ga representing the Famatian event. Minor peaks relate to the Brasiliano, Sunsas, and Rio Negro-Juruena events.

CONCLUSIONS

Zircon-ages related to the Famatinian and to the Brasiliano events are ominipresent in the WCo and CCo successions. The zircons related to the Famatinan event were most probably derived from a western source on the Arequipa Massif, the only region where respective intrusive rocks occur or where volcanic centers were located (Loewy et al., 2004; Bahlburg et al., 2006). As intrusive rocks related to the Brasiliano event are not known from the Arequipa Massif, the respective zircons must have been derived from eastern sources on the Amazonia craton. Thus, at least partly the WCo and CCo successions must have had a common source area. Considering the paloecurrent data indicating transport towards the east for the WCo deposits and a western direction for the CCo deposits, a swell between the two deposits could have figured as such a common source area. However, the distinctive peak of "Grenvillian" age occurs in the CCo Cocachacra zircon age distribution and not in the respective one from the WCo and CCo Estique pampa site. Thus, it can be assumed the Arequipa Massif and not the Sunsas belt must have provided a major part sediment supply at least for the CCo Cocachacra and probably for the Aplao succession.

REFERENCES

Bahlburg, H., 1998. The geochemistry and provenance of Ordovician turbidites in the Argentinian Puna.- In: R.J. Pankhurst & C.W. Rapela, eds., The Proto-Andean Margin of Gondwana. Geological Society, London, Special Publication 142, p. 127-142.

Bahlburg, H., Carlotto, V., and Cárdenas, J., 2006. Ollantaytambo Formation and Umachiri beds: evidence of Late Cambrian to Ordovician arc volcanism in the Cordillera Oriental and Altiplano of southern Peru. Journal of South American Earth Sciences 22, p. 52-65.

Bellido, E. and Guevara, C., 1963. Geologiy de los cuadrangulos de Punta de Bombon y Clemensi. Boletin No. 5. Instituto Geológico Minero y Metalúrgico de la República del Peru, Lima. 92p.

Bhatia, M.R. and Crook, K.A.W., 1986. Trace element characteristics of graywackes and tectonic setting discrimination of sedimentary basins. Contrib. Mineral. Petrol. 92, p. 181–193

Boucot, A. J., Isaacson P. E, Laubacher, G., 1980. An early Devonian, Eastern Americas realm faunule from the coast of Southern Peru.- Journal of Paleontology 54, p. 359-365.

Chew, D. M., Schaltegger, U., Košler, J., Whitehouse, M.J., Gutjahr, M., Spikings, R. A., Miškovic, A., 2007. U-Pb geochronologic evidence for the evolution of the Gondwanan margin of the north-central Andes. GSA Bulletin; v. 119; no. 5/6; p. 697–711

Guizado Jol, J., 1968. Geologia del cuadrangulo de Aplao, Boletin No. 20. Instituto Geológico Minero y Metalúrgico de la República del Peru, Lima. 50p.

Laubacher, G., 1978, Géologie de la Cordillère Orientale et de l'Altiplano au nord et nord-ouest du lac Titicaca. Géologie des Andes péruviennes, Travaux et documents de L'O.R.S.T.O.M. 95, 217p.

McLennan, S. M., 2001. Relationships between the trace element composition of sedimentary rocks and upper continental crust.- Geochemistry, Geophysics, Geosystems (G^3) 2(4), DOI 10.1029/2000GC000109, http://g-cubed.org.

Loewy, S.L., Connelly, J.N., Dalziel, I.W.D, 2004. An orphaned basement block: The Arequipa-Antofalla Basement of the central Andean margin of South America, Geological Society of America Bulletin, v.116, no.1/2, p. 171-187.

Palacios, O., Klinck, B. A., De La Cruz, J., Allison, R. A., De La Cruz, N., Hawkins, M. P., 1993, Geología de la Cordillera Occidental y Altiplano al oeste del Lago Titicaca – Sur del Perú, Boletín No. 42, Instituto Geológico Minero y Metalúrgico de la República del Peru, Lima. 257p.

Paredes, J., 1964. Estratigrafia del Paleozoico en la costa del Departamento de Arequipa. Tesis de Bachiller, Universidad Nac, San Agustin, Arequipa, Peru, 110p.

Suarez Soruco, R., 1992, El Paleozoico Inferior de Bolivia y Perú. In: Paleozoico de Ibero-América (Edited by Gutiérrez- Marco, J.C., Saavedra, J. and Rábano), Universidad de Extremadura, p. 225-239.

Zack, T., von Eynatten, H. and Kronz, A., 2004a, Rutile geochemistry and its potential use in quantitative provenance studies.- Sedimentary Geology 171, p. 37-58.