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Provenance from zircon U–Pb age distributions in crustally contaminated granitoids

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ABSTRACT

The basement of sedimentary basins is often entirely covered by a potentially multi-stage basin fill and therefore removed from direct observation and sampling. Melts intruding through the basin stratigraphy at a subsequent stage in the geological evolution of a region may assimilate significant volumes of country rocks. This component may be preserved in the intrusive body either as xenoliths or it may be reflected only by the age spectrum of incorporated zircons. Here we present the case of an Ordovician calc-alkaline intrusive belt in NW Argentina named the "Faja Eruptiva de la Puna Oriental" (Faja Eruptiva), which in the course of intrusion sampled the unexposed and unknown basement of the Ordovician basin in this region, and parts of the basin stratigraphy. We present new LA–ICP-MS U–Pb ages on zircons from 9 granodiorites and granites of the Faja Eruptiva.

The main part of the Faja Eruptiva intruded c. 445 Ma in the Late Ordovician. The zircon ages obtained from the intrusive rocks have a large spread between 2683.5 ± 21.6 and 440.0 ± 4.9 Ma and reflect the underlying crust and may be interpreted in several ways. The inherited zircons may have been derived from the oldest known unit in the region, the thick siliciclastic turbidite successions of the upper Neoproterozoic–lower Cambrian Puncoviscana Formation, which is inferred to represent the basement of the NW Argentina. The basement to the Puncoviscana Formation is not known. Alternatively, the inherited zircons may reflect the geochronological structure of the entire unexposed Early Paleozoic crust underlying this region of which the Puncoviscana Formation was only one component. This crust likely contained rocks pertaining to and detritus derived from earlier orogenic cycles of the southwestern Amazonia craton, including sources of Early Meso- and Paleoproterozoic age. Detritus derived, in turn, from the Faja Eruptiva intrusive belt reflects the origin of the granitoids as well as the inherited geochronological and isotope geochemical structure of either the basement and/or distant sources having supplied material to the basement rocks. If unrecognized, sediment formed from such granitoid sources may erroneously be used to infer the exposure of, and direct detrital contributions from, a variety of older source rocks in fact not directly involved in the studied source–sink system.

1. Introduction

Detrital zircon geochronology has developed into an indispensible and major tool in provenance research (Fedo et al., 2003; Scherer et al., 2007; Gehrels, 2011). Zircon is an abundant mineral in most siliciclastic sediments because of its resilience under most physical and chemical conditions (Morton and Hallsworth, 1999). Detrital zircon geochronology is a crucial tool for defining the geochronological signal preserved in sedimentary units and for investigating the source–sink relationships of sedimentary routing systems. It is also conducive to defining maximum depositional ages particularly in units with poor biostratigraphic control (Fedo et al., 2003; Gehrels, 2011). Geochronological tools are probably the only means allowing distinguishing temporally changing contributions from several plate tectonically distinct sources.

Zircon is originally supplied mainly from intrusive rocks of granodioritic to granitic composition and from metamorphic rocks. Zircon grains may subsequently be reworked from these sources and from intermittent storages in sedimentary rocks. Consequently the detrital zircon record is biased towards upper crustal lithologies (Fedo et al., 2003; Hoskin and Schaltegger, 2003; Hawkesworth et al., 2009, 2013). To obtain a more comprehensive compositional and geochronologic reflection of available source lithologies, studies of zircon can be combined with other heavy mineral chronometers like rutile and hornblende (Zack et al., 2004; Hawthorne and Oberti, 2007; Meinhold, 2010; Bracciali et al., 2013).

Zircon has become the mineral of choice in provenance research on siliciclastic sedimentary rocks due to the mineral's favorable properties and the increasing availability and precision of LA–ICP-MS (e.g. Košler and Sylvester, 2003; Chang et al., 2006; Gehrels, 2011). Increasingly

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abundant and voluminous data sets have been used successfully to address highly variable provenance problems including the growth of the continental crust (e.g. Iizuka et al., 2005; Rino et al., 2008; Bahlburg et al., 2009; Condie et al., 2009, 2011; Hawkesworth et al., 2009, 2013; Cawood et al., 2012), paleogeographic linkages (e.g. Ireland, 1992; Avigad et al., 2003; Chew et al., 2007; Cardona et al., 2009; Bahlburg et al., 2011; Linnemann et al., 2012; Augustsson et al., 2015; Zimmermann et al., 2015), the derivation and placement of allochthonous and exotic tectonostratigraphic terranes (e.g. Samson et al., 2005; Gleason et al., 2007; Linnemann et al., 2007; Adams, 2010; Chen et al., 2015), and stratigraphic and spatial relationships (e.g. Avigad et al., 2007; Kryza and Zalasiewicz, 2008; Pearson et al., 2012; Boekhout et al., 2013; Decou et al., 2013). Constraints on the applicability of a data set to a specific problem are posed by statistical parameters demonstrating that at least 117 data points are required to maintain a 95% chance of designating every component representing 5% of the data set, i.e. the grain population (Vermeesch, 2004). A large spread of discrete geochronologic events represented in the data is considered indicative of a respective number of sources and variable source compositions (e.g. Flowerdew et al., 2007; Chew et al., 2008; Elliot and Fanning, 2008; Rino et al., 2008; Bahlburg et al., 2009).

The informative value of detrital zircon geochronology is limited, however, by several factors. Its capability to differentiate between monocyclic or polycyclic sedimentary reworking is restricted. Also, U–Pb and Hf isotope studies on zircons have demonstrated that older arc systems of the central Andes and elsewhere record significant crustal recycling (Chew et al., 2007; Willner et al., 2008; Bahlburg et al., 2009; Morag et al., 2011). If the respective magmatic rocks were to be exhumed and eroded they would supply the inherited zircons to the sedimentary system. Another limitation arises from the fact that metamorphic zircon growth occurs mainly under high amphibolite and granulite facies conditions (Hoskin and Schaltegger, 2003). No new zircon growth would occur, no respective detrital signal would be produced, if an orogeny were low in magmatism and characterized by low to medium-grade metamorphism. Individually or in combination these factors may result in non-unique provenance interpretations. Furthermore, changes in drainage patterns may block the transport of orogenic detritus to sedimentary basins causing otherwise prominent tectonic and zircon forming events to remain undetected (Krippner and Bahlburg, 2013).

It is the goal of this contribution to demonstrate that a single, voluminous and wide spread granitic source, the magma of which underwent significant crustal contamination, can feign input from a large number of sources of different ages and spatial distributions. This potentially leads to strongly erroneous interpretations of provenance if undetected.

2. Geological framework

In the Puna highland of northwestern Argentina, which is a southern extension of the Bolivian Altiplano, a prominent belt of Ordovician granitoid bodies extends from c. 22°S to c. 26°S (Fig. 1a). This belt was named 'Faja Eruptiva de la Puna Oriental' (referred to subsequently in this contribution only as Faja Eruptiva) by Méndez et al. (1973). The Faja Eruptiva belt is very well exposed in the northern Puna between 22°S and 24°30′S (Fig. 1b). It consists predominantly of an association of porphyric to equigranular and partly hypabyssal intrusive rocks of felsic composition (Fig. 2; Méndez et al., 1973; Bahlburg, 1990). The intrusives are associated with intermediate to felsic volcanic rocks and subordinate occurrences of basalts (e.g. Coira et al., 1999, 2009). The entire magmatic belt is characterized by north trending, subvertical and sinistral shear zones having affected the granitoids during a late stage of intrusion at temperatures between 500 °C and 300 °C (Bahlburg, 1990).

The granitoids of the Faja Eruptiva are calc-alkaline, peraluminous and corundum normative. Their geochemical features class them as granites and granodiorites in a TAS diagram (Bahlburg, 1990). The mineral assemblage consists mostly of quartz, plagioclase, K-feldspar and biotite. Large K-feldspar crystals with diameters of several centimeters formed around and partly replaced primary minerals and are the result of late stage metasomatic processes. Some intrusives are rich in sedimentary xenoliths (Méndez et al., 1973; Bahlburg, 1990). Significant crustal contamination is indicated geochemically by εNd(t) values

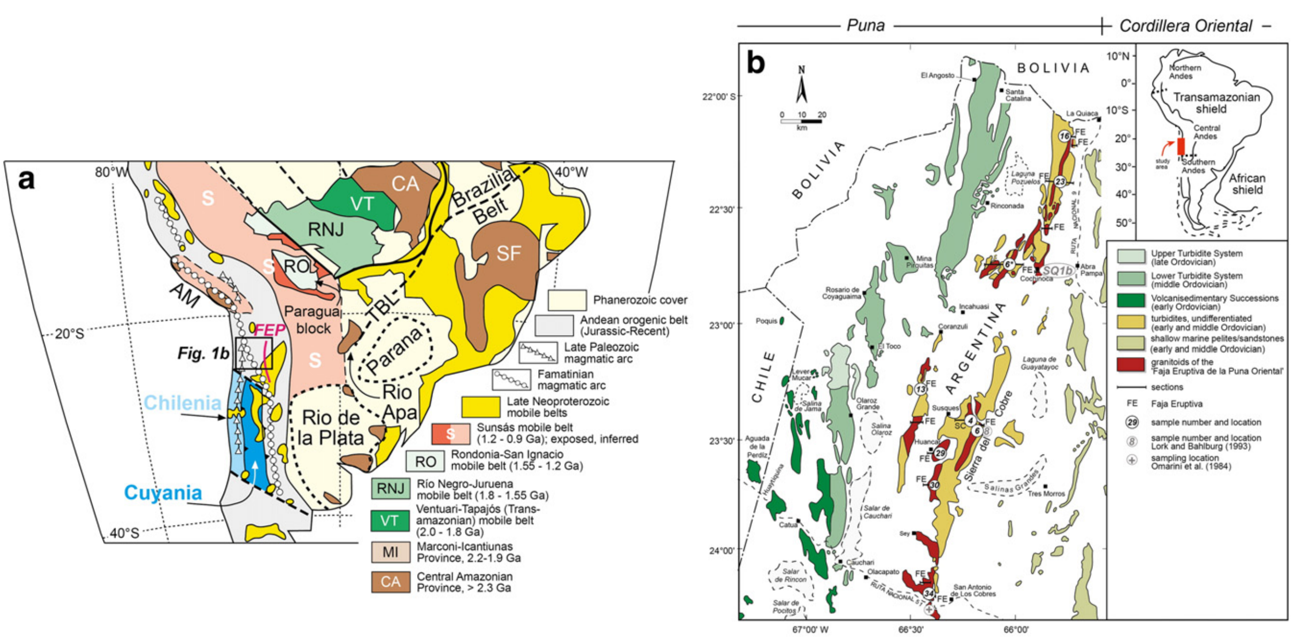

Fig. 1. a) Main cratons, Precambrian orogens and Paleozoic magmatic arcs of central South America (compiled from Cordani et al., 2000, Ramos, 2008; Bahlburg et al., 2009). FEP: Faja Eruptiva de la Puna Oriental. Black box marks position of panel b. Orogenic cycles: Br, Brasiliano; CA, Central Amazonian; F, Famatinian; Gr, Grenville; MI, Marconi-Icantiunas; P, Pampean; RNJ, Rio Negro-Juruena; RO, Rondonia–San Ignacio; S, Sunsás; Tr, Transamazonian. TBL: Transbrasiliano Lineament. b) Outcrop map of Ordovician Faja Eruptiva de la Puna Oriental magmatic and hosting siliciclastic rocks in the Puna of northwestern Argentina (modified from Bahlburg, 1990). Section indices correspond to sample numbers in electronic supplement Table 1.