



Zircon U–Pb geochronology and heavy mineral composition of the Camaná Formation, southern Peru: Constraints on sediment provenance and uplift of the Coastal and Western Cordilleras



Aldo Alván^{a,*}, Hilmar von Eynatten^a, István Dunkl^a, Axel Gerdes^b

^a University of Göttingen, Geoscience Center, Department of Sedimentology and Environmental Geology, Goldschmidtstrasse 3, D-37077, Germany

^b University of Frankfurt, Institute of Geosciences, Altenhofer Allee 1, D-60431, Germany

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ABSTRACT

In the forearc of the Central Andes of southern Peru, the Cenozoic Camaná Basin (16°25'S to 17°15'S) forms a ~NW–SE elongated depression filled with coarse-grained deltaic and fluvial deposits. These deposits are termed Camaná Formation. We have applied for the first time, advanced multi-method analytical techniques to sediments of the Camaná Formation in order to define precise sedimentation ages, unravel sediment provenance, and to explain its tectono-sedimentary evolution.

Zircon U–Pb geochronology and multiple geological evidences suggest that the Camaná Formation ranges in age from Late Oligocene to Late Miocene, and may even extend into the Pliocene. We propose a provenance model for the Camaná Formation based on U–Pb geochronology, heavy mineral analysis, and single-grain mineral chemistry by LA-ICP-MS. This model suggests that sediments of the lower part of the Camaná Formation derive from rocks forming the Coastal Cordillera (i.e. the Arequipa Massif and the San Nicolas Batholith) and the widespread ignimbrites of the ~24–10 Ma Huaylillas volcanic arc. In contrast, sediments of the upper part of the Camaná Formation derive predominantly from rocks forming the Western Cordillera (i.e. the Arequipa Massif, the Tacaza Group, and the Coastal Batholith) and products of the ~10–3 Ma Lower Barroso volcanic arc). Accordingly, we infer that uplift of the Coastal Cordillera has strongly influenced deposition of the Camaná Formation since Late Oligocene. A marked shift in provenance within the Camaná Formation at around Middle to Late Miocene time (14–12 Ma) suggests drastic uplift of the Western Cordillera at that time. This uplift has triggered increased relief and erosion in the Western Cordillera, and subsequent deposition of fluvial conglomerates in the Camaná Basin.

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1. Introduction

This manuscript focuses on the derivation of a chronostratigraphically well-defined provenance model for the Cenozoic Camaná Formation that explains consistently the interplay of tectonics and sedimentation in this segment of the southern Peruvian forearc (Fig. 1). Our study relies on shallow-marine coarse-grained deltaic and fluvial deposits. Such deposits mark the interface between terrestrial and marine environments and are generally

considered to intimately reflect uplift and erosion of the basin borders and/or the hinterland (e.g. Colella, 1988; Gawthorpe et al., 1990; Schlunegger et al., 1997; Gawthorpe and Colella, 1990). In the Camaná Basin, such deposits have already been analyzed in terms of sedimentary facies, stratigraphic architecture, and sequence stratigraphy (Alván and von Eynatten, 2014).

Sedimentary provenance analysis refers to the reconstruction of source area geology, the type of source rocks exposed, and the processes that modify the sediment on their way from source to sink (Weltje and von Eynatten, 2004). The compositional characteristics of a sedimentary basin fill are commonly controlled by the lithology of the respective source rock, weathering, erosion, sediment transport processes, and the nature of sedimentary processes within the basin. In many provenance studies emphasis is placed on high density accessory minerals (i.e. heavy minerals) because they

* Corresponding author. Present address: INGEMMET, Dirección de Geología Regional, Av. Canadá 1470, Lima, Peru.

E-mail addresses: aalvand@gwdg.de (A. Alván), hilmar.von.eynatten@geo.uni-goettingen.de (H. von Eynatten), istvan.dunkl@geo.uni-goettingen.de (I. Dunkl), gerdes@em.uni-frankfurt.de (A. Gerdes).

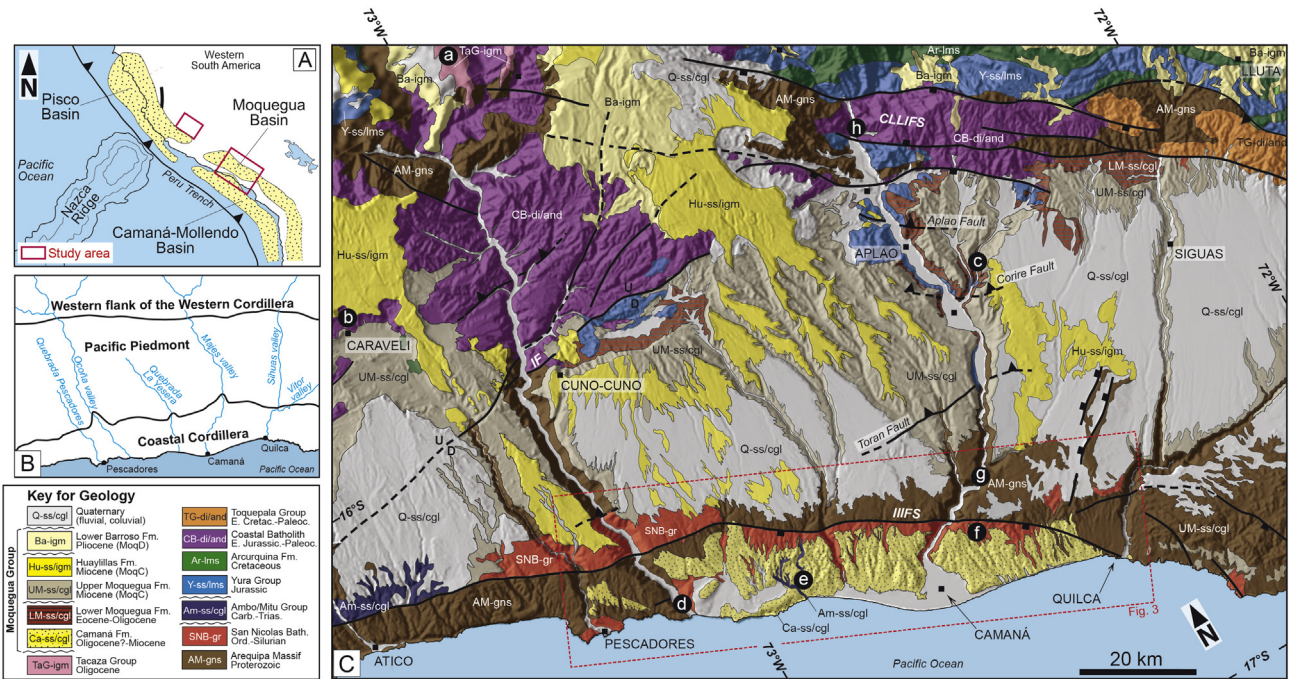


Fig. 1. Geology of the coastal region of Arequipa, southern Peru. A: Spatial relations among Pisco, Camaná, and Moquegua Basins. Red box shows the study area. B: Map showing the three main geomorphologic domains within the area and main valleys across. C: Simplified regional geology of the southwest area of Arequipa (after Vicente, 1989; Schildgen et al., 2009; Acosta et al., 2010a, 2010b, 2010c). Main faults are shown in continuous black lines and inferred in dashed black lines. The Cenozoic Moquegua and Camaná Basins are separated by the Coastal Cordillera. Abbreviations: IF = Iquipi fault, IIIFS = Ica-Ilo-Islay Faults System, CLLIFS = Cincha-LLuta-Incapuquio Faults System. White letters a–h on black circles indicate sampling sites of potential source rocks. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

are sensitive recorders of provenance change (e.g. Mange and Maurer, 1992; Morton and Hallsworth, 1999). In tectonically active settings, changes in heavy mineral composition are typically associated with tectonic processes, as demonstrated in various case studies (e.g. Pinto et al., 2007; von Eynatten et al., 2008; Decou et al., 2011; Moreno et al., 2011). The analysis of heavy minerals is considerably enhanced by individual single-grain analytical methods to extract precise petrogenetic and chronological information (von Eynatten and Dunkl, 2012). In this study we are heading to combine new information on sedimentary provenance and chronostratigraphy of the Camaná Formation with a previously published sedimentological-stratigraphical model (Alván and von Eynatten, 2014).

To constrain the timing of uplift of the hinterland of Camaná Basin (i.e. Coastal Cordillera and Western Cordillera), it is needed to precise the sedimentation ages of the Camaná Formation. U–Pb dating of detrital zircons by laser ablation ICP-MS has become an important tool in provenance analysis and stratigraphic dating (e.g. Jackson et al., 1992; Kosler et al., 2002; Kosler and Sylvester, 2007), and here it is applied for the both purposes. In case of coarse-grained deposits with poor fossil content, precise U–Pb ages of volcanic zircons from ashes or reworked ashes are the best candidates to identify depositional ages or maximum depositional ages of a given siliciclastic deposit when using the youngest age component of the age spectrum (e.g. Bowring and Schmitz, 2003; von Eynatten and Dunkl, 2012). U–Pb zircon ages usually express magmatic crystallization and are less sensitive to post emplacement lower temperature metamorphic processes (Cherniak and Watson, 2000). Accordingly, we expect to obtain the crystallization age of plutonic and metamorphic rocks in southern Peru. The older age components of the detrital zircon age spectra provide additional constraints on the provenance of the Camaná Formation.

For the first time, mineral chemistry of titanite is used for provenance discrimination because of its relative abundance and variable colors and composition observed in Camaná Formation. Titanite is a common accessory mineral in igneous (i.e. syenites, diorites, and granites) and metamorphic rocks that are rich in calcium and ferromagnesian minerals (Deer et al., 1982; Franz and Spear, 1985; Frost et al., 2000). Titanite is like zircon suitable for U–Pb geochronology because of its relative high Th and U contents, and its high closure temperature for Pb diffusion (650°C–700 °C, Cherniak, 1993; Scott and St. Onge, 1995; Frost et al., 2000; Sun et al., 2012). It tends to concentrate wide spectra of trace elements which are well-suited for discrimination of titanite from different source rocks (e.g. Frost et al., 2001; Aleinikoff et al., 2002; Sun et al., 2012). Titanite is expected to keep its original crystal chemical composition from the source rock due to its relative resistance to chemical weathering (Morton, 1991; Mange and Maurer, 1992).

2. Geologic setting of the southern Peruvian forearc

Since ca. Late Jurassic, convergence and variations in obliquity and subduction rate of the Nazca plate beneath the South American continent have triggered shortening of the Central Andes (Pitcher et al., 1985; Isacks, 1988; Sobolev and Babeyko, 2005; Oncken et al., 2006; Wipf, 2006). During Cenozoic two major phases of deformation during Cenozoic have been described (Isacks, 1988; Allmendinger et al., 1997; Kay et al., 1999; Oncken et al., 2006). At ~40 or ~35 Ma strong decrease of convergence rate, fragmentation of the slab, and initiation of flat subduction caused strong interplate coupling, crustal shortening, uplift, and decrease in volcanic activity (Somoza, 1998; Gilder et al., 2003; Oncken et al., 2006; Mamani et al., 2010; Martinod et al., 2010; Decou et al., 2013).

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