

Geochemical evidence of continental fluid circulation in the Peru subduction zone

A.N. Dia
L. Aquilina
J. Boulegue

*Lab. de Géochimie et Métallogénie, UPMC, 4 Place Jussieu,
F - 75230 Paris Cedex 05, France.*

Introduction

The nature and origin of fluids in convergent margins have been investigated through geochemical and isotopic studies of venting fluids as well as pore fluids (BoulUgue *et al.*, 1987; Elderfield *et al.*, 1990; Kastner *et al.*, 1990; 1991). However, the extensive work done during the past ten years was mainly dedicated to active margins exhibiting well-developed accretionary prisms (Nankai, Barbados and Oregon-Cascadia). Little work was done on the fluid regime of Andean-type convergent margins (Suess *et al.*, 1988; Kastner *et al.*, 1990) where subduction-related erosion processes occur at depth.

One of the main purposes of the Nautiperc cruise (March-April 1991) was to acquire new insights into the hydrogeologic system along the nonaccreting convergent margin off Peru by analysing geochemical composition of fluids and surrounding sediments as well as closely related-baryte deposits.

Geologic setting

Fluids, sediments and associated baryte deposits from vents located along the Andean convergent margin off Peru between latitude 5° and 7° S have been sampled at depth ranging from 2500 to 5400 m below sea level, with the aim of elucidating the nature of the fluids and therefore their possible sources. Two different areas have been studied Paita and Chiclayo canyon areas, where the E-W striking major faults affecting the underlying basement strongly suggest a different tectonic context than the ODP Leg 112 area (Suess *et al.*, 1988; Kastner *et al.*, 1990). The Paita area includes a 1) 400–700-m-high scarp which marks the upper slope-middle slope boundary. This upper-slope scarp is a major détachement fault that penetrates the continental margin down to 3–5 km below sea floor. 2) A 1000–1200-m-high middle slope scarp located 10 km seaward from the upper slope scarp. 3) A 300–500-m-high subduction scarp which is at the base of the lower slope. This complex scarp system trends north and parallels the trench axis.

The Chiclayo canyon, 100 km south of the Paita area trends E-NE perpendicular to the trench axis and deeply penetrates the basement. We assume that the fluid flow across the continental margin off northern Peru is influenced by 1) the east-trending normal fault network explored in the Chiclayo canyon and 2) A north-trending fault network which includes a major détachement fault in the Paita area.

The fluid venting in both sites, located at the intersection of a complex fault network oriented E-W and N-S, is associated to dense biological communities (colonies of clams, tube worms and small patches of bacterial mats) and thick baryte deposits. No baryte deposits were found outside of the fluid-venting sites.

Methods

Fluids were collected by titanium syringes above the seawater-sediment interface for shore-based analysis of major, trace-element and Sr isotope contents. However, it is worth keeping in mind that the way of collecting the fluid samples implies a large dilution by ambient seawater, and that as a consequence, the seeping fluid cannot represent more than 1 to 5% of the fluid sampled. The method we used consists in comparison of samples to the local deep seawater references and IAPSO seawater standard in order to search the signature of a non local component. Solid samples (sediments and baryte concretions) were analyzed after dissolution in ultrapure distilled acids.

Results and discussion

The fluid samples are characterized by common chemical features wherever they are coming from: elevation of the chloride and the Ba contents as well as the $^{87}\text{Sr}/^{86}\text{Sr}$ ratios as compared to seawater local references and IAPSO seawater standard (Dia *et al.*, 1993). We suggest that the deep fluids recovered off northern Peru originated from a mixing between a basinal brine and meteoric waters which circulated in the metamorphic basement. We think that the brine may

originate from the onland Sechura basin which exhibits thick evaporitic deposits. The extensional regime indicated by seaward dipping normal faults probably favours greatly the contamination of the margin by continental fluids coming from the basins located in the upper part of the margin (Talara, Sechura). Furthermore, the influence of the E-W striking faults related to the Amazonian belt, which separates the Brazilian craton from the Guyana shield, is emphasized here because they are the most likely paths for continental fluids.

The chemical analyses of the sediments and baryte concretions recovered off Peru also bring indirect indications on the nature of the fluid circulating in the margin. 1) Their reduced redox character is in relation with the H₂S content of the soft sediments. 2) Oxide phase associated to the barytes indicates that they are enriched in metals. 3) The ⁸⁷Sr/⁸⁶Sr ratios of the barytes indicate that these fluids have interacted with a continental material. Thus it seems very likely that the fluids sampled during the Nautiperc cruise are similar to those from which the barytes precipitated.

Although difficult to interpret S and O isotopic ratios of the barytes implicate a temperature of precipitation of about 70°C (Aquilina *et al.*, 1994). Therefore, they testify of a hot paroxysmal fluid circulation event even if the lack of present day significant temperature anomaly indicates that the present regime strongly differs from the regime which led to baryte precipitation. The correlation which can be done between present fluid circulation (fluid samples) and past circulation (barytes) brings insights on the evolution during time of the margin fluid circulation.

The presence of the baryte deposits along the middle slope scarp in Paita assures us that the fluid event is posterior to the 14 kyr catastrophic debris flow (Bourgeois *et al.*, 1993) which modified the margin fluid pressure and may have caused the high fluid velocity regime. However, the baryte

concretion deposit should have occurred much more recently since it shows no sedimentary cover and covers fresh angular talus debris. Therefore, we favour the hypothesis which relates the higher temperature phase of baryte-related fluid escape with a recent short live tectonic event. The earthquake which affected this part of the Peru margin off Chiclayo in 1960 would be a good candidate for the initiation of this phase of high temperature fluid escape.

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