FLUID SOURCE ON LOW-GRADE METAMORPHISM IN THE CHILEAN ANDES (35º S): PRELIMINARY RESULTS

Mauricio Belmar (1), Javier Carrillo (2), Diego Morata (1), Kurt Kyser (3) Susanne Th. Schmid (4), and Salvador Morales (2)

(1) Departamento de Geología, Universidad de Chile, Casilla 13518, correo 21, Santiago. mbelmar@ing.uchile.cl.


(3) Department of Geological Sciences and Geological Engineering Queen’s University Kingston, ON, K7L-3N6. Canada.

(4) Département de Minéralogie, Rue des Maraîchers 13, CH1211 Genève, Switzerland

INTRODUCTION

Most of the metamorphic reactions in the very low to low-grade metamorphism of basic to intermediate rocks imply hydration of previous anhydrous minerals by metamorphic fluids. Understanding the nature and origin of these low-temperature fluids is critical for the correct integration of this type of metamorphism in its geotectonic context. Most of the papers in which low-grade metamorphism in the Andean range has been studied use metamorphic mineral chemistry with the aim to determine P-T-X conditions of metamorphism. In this work we present preliminary stable isotope and fluid inclusion data from low-grade metamorphic rocks in the Chilean Andes. These data allow us to determine the nature of metamorphic fluids and the P-T conditions during metamorphism.

GEOLOGICAL CONTEXT

A ca. 6000 m thick section of mainly volcanic and volcanoclastic as well as some marine and alluvial sedimentary rocks is exposed in the upper Río Tinguiririca and Río Damas valleys (≈ 35ºS). It comprises the Río Damas Formation, characterized by a c.a. 3700 m thick sequence of red continental detrital and volcanic rocks. The lower part contains abundant volcanic breccias of various block sizes, whereas in the upper part andesitic basaltic lava flows are intercalated. The Baños del
Flaco Formation lying on top of the Río Damas Formation has an approximate thickness of 390 m and is a marine fossiliferous unit. Calcarinites and calcilutites represent a platform facies whereas the shale horizons indicate a facies evolution to a deep shelf environment. Based on several ammonite species, a Tithonian age was determined.

The Baños del Flaco Formation is conformably overlain by the c.a. 200 – 250 m thick Brownish Red Clastic Unit. This unit was originally attributed and correlated to the Colimapu Formation. It represents a continental unit with mainly volcanic breccias in the lower part and conglomerates and conglomeratic sandstones in the stratigraphically thicker upper member. The Brownish-red Clastic unit is unconformably overlain by the Coya-Machalí Formation. The ca. 1600 m thick sequence is of a volcanic character with alternating basaltic lavas and pyroclastic and detrital sediments. An unconformity separates the Coya-Machalí Formation from the basaltic lavas of the Altos del Padre Unit (1.1 Ma) of the Tinguiririca Volcanic Group. Various plutons, hypabyssal or subvolcanic bodies, dikes, and sills of mostly unknown age are exposed in the study area. The two biggest pluton of the study area occurs at the Río Damas Pass. It is not explicitly dated but geochemical similarities suggest that it probably belongs to a group of intrusive bodies known as the Nacimiento Río Cortadera pluton, described only a few kilometers to the North. Biotite ages K-Ar method clustering at 8.4±0.3 Ma. Another non described intrusive bodies are dated K-Ar method in the confluence of Río del Azufre and Río Tinguiririca giving ages of 15±0.5 Ma.

LOW-GRADE METAMORPHIC PATTERN

The metamorphic pattern in the study area will be documented by use of several index minerals from a large data base of ca. 4000 microprobe analysis of volcanic rocks as well as by X-ray diffraction of individual minerals such as zeolites and phyllosilicates. Fluid inclusion thermometry was carried out on amygdules and fissure filled by calcite and quartz. The illite and chlorite crystallinity method was applied to marine and fine-grained sediments, effusive volcanic and hypabyssal rocks. The vitrinite reflectance was also measured in all shales of the sequences (Belmar, 2000).

Two metamorphic zones are observed. A zeolite zone with laumontite as the main index mineral in the Tertiary Coya-Machalí Formation, as well as in the upper Cretaceous Brownish-Red-Clastic Unit and the Upper Jurassic Baños del Flaco Formation. The lower Upper Jurassic
Río Damas Formation lying below the Baños del Flaco Formation has experienced prehnite-pumpellyite facies in the lower part of the unit, whereas the upper part displays a non-diagnostic celadonite-K-mica-chlorite assemblage. Peak metamorphism was dated at different time for these two metamorphic zones suggesting the existence of two low-grade metamorphic events of Cretaceous and Miocene age. K-Ar celadonite ages ranging from 101 ± 3 to 108 ± 4 Ma have been obtained for Jurassic lavas with prehnite-pumpellyite facies whereas celadonite in Eocene-Oligocene lavas and tuff with zeolite facies from Coya-Machalí Formation gave a K-Ar age between 16.3 ± 0.8 to 22.8 ± 1.8 Ma (Belmar et al., 2001).

Summarizing the geothermometric data, and bearing in mind the limitations of the different geothermometers, temperatures derived by different methods are generally consistent with each other. Volcanic rocks of the Coya-Machalí Formation, belonging to the zeolite facies, yielded values of 221-276 °C with the “chlorite geothermometer” and minimum temperatures of >141-189 °C from fluid inclusion data. The temperatures derived from chlorite composition appear to be rather high. Sedimentary rocks of the Baños del Flaco Formation, belonging to the late diagenetic zone according to illite and chlorite crystallinity data, yielded peak temperatures derived from vitrinite reflectance data of 150-168 °C for a burial heating model and 175-204 °C for a hydrothermal metamorphism model. The latter data are slightly lower than a value of 220 °C derived from fluid inclusion data. Volcanic rocks of the Río Damas Formation, recording the transition from zeolite to prehnite-pumpellyite facies, yielded values of 223-272 °C with the “chlorite geothermometer” and minimum temperatures of >290-307 °C from fluid inclusion data.

STABLE ISOTOPES ANALYSES

Stable isotopes analyses (δ¹³C, δ¹⁸O, δD) were carried out on minerals (silicates and carbonates) occurring in amygdules and veins from 29 samples in order to get a better understanding about the nature of the alteration fluids. Calcite shows a very wide range of δ¹³C (-27.2 to -0.6‰) and δ¹⁸O (5.5 to 20.6‰). Nevertheless the majority of δ¹⁸O fit in a range between 12 and 15‰. The lower carbon values correspond to samples from amygdules from Río Damas Formation, whereas calcites from other units have δ¹³C higher than -10‰. Quartz also shows a quite broad
δ¹⁸O range, from 4.6 to 20.6‰, whereas fluid inclusion hosted in these quartz show δD from -110 to -56‰.

**DISCUSSION**

The isotopic data from quartz and calcite infilling amygdules and veins are consistent parent fluids (i.e. basinal and low grade metamorphic fluids) having components of different sources. There is very light C coming from an organic source (i.e. devolatilization of organic matter due to temperature effect) especially in the case of Rio Damas unit. There is also probably heavy C coming from the dissolution of limenstones, and from a magmatic carbon source (derived from the intrusive rocks or leached from the volcanics rocks). Oxygen estimated for the fluids range from negative to considerable positive number (-5 to 10‰ for quartz and -3 to 9‰ for calcite), suggesting participation of meteoric waters and more equilibrated fluids, maybe, in part, produced by dehydration due to incipient metamorphic processes. With the available data it is not possible to rule out the participation of direct exsolved magmatic fluid. neither marine water, further results coud be aid to discriminate between them.

**ACKNOWLEDGEMENTS**

This research is financially supported by “Fundación Andes Grant” and from the Universidad de Chile and Ministerio de Educación through the “MECESUP Grant”. The participation to this congress it was supported by the FONDECYT project n° 1061266.

**REFERENCES**
