

**NATURE AND ORIGIN OF HYDROTHERMAL FLUIDS DURING THE LOW-
GRADE METAMORPHISM OF JURASSIC-TERTIARY VOLCANIC
SUCCESSIONS IN THE CHILEAN ANDES (35° S) -
PRELIMINARY RESULTS**

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GEOLOGICAL SETTING

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. It comprises the Río Damas Formation, characterized by a ca. 3700 m thick sequence of red continental detrital and volcanic rocks. The lower part contains abundant volcanic breccias of various sizes, whereas in the upper part andesitic basaltic lava flows are intercalated. A Kimmeridgian age is assumed based on the fossiliferous age of younger and older rock units. 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. Calcarenites and calcutites represent a platform facies whereas the shale horizons indicate a facies evolution to a deep shelf environment (Arcos, 1987). Based on several ammonite species, a Tithonian age was determined (Covacevich et al., 1976; Biro-Bagoczky, 1984). The Baños del Flaco Formation is conformably overlain by the ca. 200 - 250 m thick Brownish-red Clastic Unit. 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 (Zapatta, 1995). The ca. 1600 m thick sequence is of a volcanic character with alternating basaltic lavas and pyroclastic and detrital sediments. Various plutons, hypabyssal or subvolcanic bodies, dikes, and sills of mostly unknown age are exposed in the study area. The 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. Age determinations on biotite cluster at 8.4 ± 0.3 Ma. Intrusive bodies to the west give

age determinations of 14.1 ± 0.4 Ma (in Spichiger 1991) and correspond to the belt of lower Miocene Intrusions of Santa Rosa de Rengo and La Obra.

LOW-GRADE METAMORPHISM

The metamorphic pattern in the study area will be documented by the distribution 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. 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; Belmar et al., submitted).

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. No discontinuity in metamorphic grade is observed along the major unconformities, as between the Tertiary Coya-Machalí Formation and the Cretaceous Brownish-Red-Clastic Unit or the Cretaceous Brownish-Red-Clastic Unit and the Upper Cretaceous Baños del Flaco Formation. In the Coya-Machalí Formation, higher metamorphic prehnite-pumpellyite assemblages are observed within sills and dikes.

In addition, illite crystallinity, chlorite crystallinity and coal rank were determined and confirm the metamorphic facies pattern. The Coya-Machalí formation, belonging to the zeolite facies, yielded values of 221-276 °C with the “chlorite geothermometer. 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 Río Damas Formation, recording the transition from zeolite to prehnite-pumpellyite facies, yielded values of 223-272 °C with the “chlorite geothermometer.. In contrast to other low-grade metamorphic terranes where the smectite to chlorite transition is characteristic for the transition from the zeolite to the prehnite-pumpellyite facies, a K-mica/celadonite transition occurs which seems to be characteristic for the transition from the upper zeolite to the prehnite-pumpellyite facies in the K-rich rocks of the study area.

PRELIMINARY RESULTS

As described in the introduction, volcanic and volcanogenic rocks dominate in the study area. It is generally difficult to differentiate between effusive and hypabyssal intrusive rocks in the field, and the occurrence of amygdules or fluidal texture cannot be used as criteria for the determination of the effusive character of a rock. In addition, in the immediate proximity of intrusive rocks the regional metamorphic pattern is overprinted by contact metamorphism producing hornfels assemblages. The first results on the fluid inclusions indicate that in the Termas del Flaco area various types of hydrothermal/meteoric/basinal fluids can be observed. An amygdule with pumpellyite followed by quartz and calcite towards the center of the amygdule (TF10-12) is

considered to be the result of the regional metamorphic prehnite-pumpellyite facies. Four different fluid inclusion populations are observed in quartz. Fibrous quartz overgrowths pumpellyite and contains a metastable aqueous fluid. A second generation of quartz occurs at the top of the quartz fibers as a prismatic overgrowth. The homogenisation temperature of the fluid inclusions of this second quartz generation was determined at 92 °C and the salinity corresponds to 15 NaCl %equiv. The continuous overgrowth of quartz shows in the third fluid inclusion generation an increase of the salinity to ca. 30% NaCl %equiv and a T_{hom} of 85 °C. A fourth fluid inclusion population is similar to the second generation with $T_{\text{hom}}=93^{\circ}\text{C}$ and a salinity of 14 NaCl %equiv. A specimen close to an intrusion shows a population with a low salinity, a high CO₂ content and a $T_{\text{hom}}=290^{\circ}\text{C}$. Another specimen was taken from a vein within the marly shists of the Baños del Flaco Formation (TF1-10): It shows 2 fluid inclusion populations. The first generation contains higher hydrocarbons and a $T_{\text{hom}}=222^{\circ}\text{C}$, and the second generation contains a nearly pure propan-dominated population. The preliminary results indicate that various types of fluids circulated within the various rock types ranging from meteoric to high saline and organic rich compositions. A stable isotope analysis on quartz and calcite is currently being carried out to help to constrain the conditions and the nature of the altering fluids in the Termas del Flaco area .

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