Fluid flow in the southern termination of the Bolfin fault of the Atacama Fault System, northern Chile

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The NNW-striking subvertical Bofin fault is part of the Atacama Fault System (AFS), which is a large-scale trench-parallel structure developed within mesozoic rocks of the present-day Coastal Cordillera in northern Chile (Cembrano et al., 2005). A well-documented left-lateral activity of the AFS has been interpreted as the result of the SE-ward oblique subduction of the Aluk (Phoenix) oceanic plate between 190 and 110 Ma (e.g., Schuber and González, 1999).

The studied area is in the southern termination of the Bolfin fault, where the fault terminates in a distributed network of low-displacement strike-slip fault zones in a horsetail-type structure (Faulkner et al., 2011). A number of NNW-striking subvertical fractures filled mainly by calcite and quartz are observed in the area. They are 1-20 mm in width and hosted by coarse-grained metadiorite. Some of them cut a thin (~ 10 cm) NW-striking subvertical leucocratic dike with 20-35 mm left-lateral displacements, while the others disappear at the southwestern wall of the dike. A fracture density (number of fractures (> 3 mm in width) per 1.8 m) is 11 in the southwestern host rock of the dike, while only 4 in the northeastern host, indicating NNW-ward propagation of the fracture tips. Faulkner et al. (2011) also concluded that the asymmetry of the damage (alteration) development around the fractures implies northwest propagation if a process zone model is assumed. Green-colored hydrothermal alterations are well developed around the fractures in the southwestern host of the dike, while they are poor in the northeastern host. It is also remarkable that the host metadiorite at the southwestern wall of the dike is strongly altered, while no alteration can be seen at the northeastern wall. Those evidences may suggest that the dike acted as a fluid-barrier during fluid flow through the fractures migrating from the south. Hence, we may conclude that the fluid flow, as well as the fracture propagation, was toward the north, that is, toward the main body of the Bolfine fault.

Although the host metadiorite is highly weathered and altered by hydrothermal fluids percolating through the fractures, it might have consisted mainly of plagioclase and hornblende. On the other hand, chlorite, epidote, calcite and quartz are major in the altered rocks around the fractures. The bulk chemical data obtained by XRF analyses of the rocks indicate that CaO and SiO_2 were added as 2.77 and 4.21 moles, respectively, per a littler of rocks during alteration, while Na_2O, K_2O, Mg_2O and Al_2O_3 were partly removed. Chemical compositions of chlorite in equilibrium with quartz analyzed by EPMA indicate their formation temperatures as around 330°C. On the other hand, microthermometric analyses of fluid inclusions in calcite of the fractures show their homogenization temperatures as about 280°C with a modal salinity of 11.3 wt.% ($CaCl_2$ eq.). Hence, the pressure obtained on an isochore for the brine is 69 MPa. The pressure is consistent with the study of González et al. (2003) in which they noted that the fault has been passively exhumed from depths greater than 3 km.

We simulated the fracture-filling by precipitation of calcite and quartz from the fluids infiltrating through the fractures at the above P-T conditions by MIX99 (Hoshino et al., 2000). The fluids were assumed as equilibrated with calcite, quartz, epidote and chlorite. The compositions of epidote and chlorite were taken as ideal solid solutions of epidote (0.60) - clinozoisite (0.40) and daphnite (0.55) - clinochlore (0.45), respectively, from EPMA data. The result indicates that

86 kg of fluids are needed to fill a litter of space (fracture aperture) with a temperature decrease from 340°C to 330°C. Therefore, a huge amount of fluid might have percolated through the fractures toward the main body of the Bolfin fault.

Keywords: fault, fluid, fracture