MITT.ÖSTERR.MINER.GES. 143 (1998)

CRUSTAL FLUIDS LECTURES

by

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Lectures to the Austrian Mineralogical Society
given during March/April in Vienna, Graz, Leoben, Salzburg and Innsbruck

In March 1998, I had the opportunity to visit and speak at the five Earth Science departments in major universities in Austria. The overall theme of the presentations was on the nature of crustal scale fluid systems and their interactions with differing rock types. In Graz, Salzburg and Wien, talks entitled „Geology and Geochemistry of Regional Scale Crustal Fluid Systems in Western Canada“ were presented. In Leoben, a talk on „Role of Regional Fluid Systems in the Genesis of Hydrothermal Ores in Western Canada“ was given, and in Innsbruck the presentation was on „New Geochemical Approaches to the Understanding of Carbonate Diagenesis“.

The major theme linking these talks was the characterization of the geology and geochemistry of ancient, crustal scale fluid systems in western Canada. Regional scale studies across the Canadian Cordillera incorporate extensive sampling of veins and altered rocks in the context of their relation to deformational and metamorphic features in outcrop. The sampled areas range in metamorphic grade from unmetamorphosed to amphibolite grade and encompass both sedimentary units of western North America and exotic terranes that have been acoreted to the western coast of North America.

Analytical work on the samples encompasses a number of techniques. As a first step, the mineralogy of the samples is determined. This is followed by detailed fluid inclusion and stable isotope ($\delta^{18}O$, $\delta^{13}C$, δD) studies at the University of Alberta, Edmonton, Alberta. In addition studies of solute chemistry of inclusion fluids are carried out in collaboration with Dr. W. Prochaska, Montanuniversität. Leoben. Studies of radiogenic isotopes (Sr, Pb, Nd) on selected samples are conducted at the University of Alberta.

The results of the research program show that large scale, paleo-fluid systems can be recognized and characterized. The geological and geochemical characteristics of such crustal scale systems are strongly controlled by variations in structural style. In extensional regimes, meteoric water forms large, deep convection cells, penetrating to depths >10 km and attaining temperatures of 350 to 400°C at hydrostatic pressures of approximately 10^8 Pa. Through water-rock interaction and fluid mixing along the flow path, the fluids evolve to higher $\delta^{18}O$ values and acquire increased solute, CO_2 and other gas contents. The δD values of the fluids remain relatively unchanged allowing the recognition of their primary origin as meteoric fluids. On the upflow path, quartz veins are formed at temperatures of 250 to 350°C, quartz-calcite veins form at lower temperatures, and calcite veins at the lowest temperatures. Gas phase immiscibility removes much of the CO_2 and other gases in the quartz-calcite zone.
In compressional settings, crustal scale fluid systems are substantially more heterogeneous. At relatively deep levels, fluids from devolatilization reactions dominate the fluid regime and fluid pressures are inferred to approach lithostatic. At shallower levels, especially during post-compressional rebound, the opening of fractures to the surface permits the infiltration and circulation of surface fluids and associated vein formation. Typically fluid temperatures and pressures attained in this setting are less than those attained by fluids in extensional settings.
Three examples of the role of crustal fluids in ore formation were presented. Mesothermal Au-quartz veins in the Canadian Cordillera form as part of the overall process of the convection of surface fluids. Mineralization is concentrated in quartzcarbonate veins associated with CO_2 immiscibility. Consequently, it is possible to utilize the zonation patterns obtained in the regional studies to identify areas which have high probability to host such mineralization. Work on porphyry Cu-Mo mineralization indicates that crustal fluids are incorporated into magmatic systems at relatively high temperatures and constitute a significant proportion of the high salinity and high temperature fluids exsolved from the melt. Studies of epigenetic Pb-Zn mineralization in dolomites indicate that the ores formed from migrating evaporitic brines in the late Devonian. This result indicates that in western Canada epigenetic Pb-Zn mineralization did not form from gravity driven meteoric water, as had been proviously believed.
Recent work in Leoben and Edmonton on the solute and isotope chemistries of inclusion fluids from limestones and dolomites of the Western Canada Sedimentary Basin have documented the involvement of a variety of fluid typos in diagenesis. Solute and isotope characteristics of fluids extracted from limestones contrast sharply with values from sea water and indicate that limestones entrap and preserve diagenetic fluids which have a large component of biogenically generated fluids. Grey replacement dolomites from the Western Canada Sedimentary Basin have very low Na/Br and Cl/Br values indicative of thevir formation from evaporitic brines, most likely generated during formation of the Elk Point Evaporites in the Middle Devonian. In contrast late vug-filling, saddle dolomite originated from the infiltration of sea water, which had dissolved halite prior to formation of the dolomite.

In conclusion, I would like to thank the Österreichische Mineralogische Gesellschaft, who sponsored the lecture tour and the individual universities who hosted me. It was an educational and enjoyable experience.