

Low-grade zeolite facies metamorphism in gneisses of the Simano nappe (Arvigo, Val Calanca, Grisons, Switzerland)

T. WEISENBERGER AND K. BUCHER

University of Freiburg, Germany,

(tobias.weisenberger@minpet.uni-freiburg.de)

Banded biotite gneisses intercalated with coarse light coloured two mica gneisses and less frequently with calcsilicate lenses are mined as building stones at Arvigo. The rock series belongs to the upper Simano nappe of the crystalline Penninic basement. The Arvigo quarry became famous for a large number of Alpine fissure minerals, which occur in extensional fractures and cavities of the granitic gneisses. Fissures and gashes formed by semi-brittle deformation of granitic gneisses, which were generated during exhumation and uplift of the Alpine orogen. These fractures and cavities were filled with fluids and new minerals crystallized in the open space.

The Arvigo fissures contain the assemblage epidote, prehnite and various species of zeolites. In general epidote is overgrown by prehnite and zeolites. The specific zeolite mineral formed in the fissures depends of the temperature (Fig. 1). In the Arvigo fissures the following zeolites precipitated from the fluid with decreasing temperature, in agreement with the predicted sequence on figure 1 (300°-100°C): scolecite, laumontite, heulandite, chabazite and stilbite.

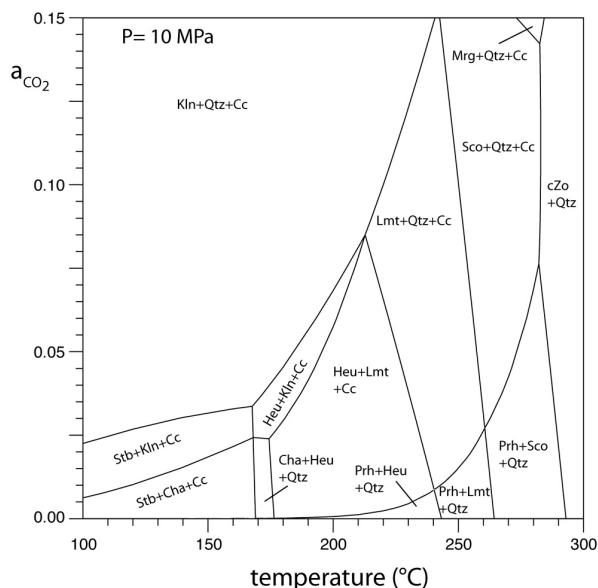


Figure 1: Assemblages stability diagram; CO₂ activity versus temperature for a bulk composition of epidote and quartz, H₂O and CO₂.

Se isotopic variations in black shales of the Yutangba Se deposit, China

H.J. WEN^{1,2} AND J. CARIGNAN²

¹SKLODG, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, 550002, China

(wenhanjie@vip.gyig.ac.cn)

²CRPG-CNRS, 15, Rue Notre-Dame des Pauvres, B.P. 20, 54501, Vandoeuvre-lès-Nancy Cedex, France

(carignan@crpg.cnrs-nancy.fr)

The Yutangba Se deposit is the only sedimentary-type Se deposit known in the world to date. Se is present in relatively high abundance in both host rocks and ores, with concentrations of up to 1.3% on average in the enriched zones. Our preliminary study showed that about 66% Se occurs as nanograins of elemental Se (Se⁰) embedded in kerogen. Three hypotheses are proposed to explain the presence of Se⁰: 1) sea water Se was reduced by a high productivity of marine plankton, which died rapidly, and were scavenged to the sea floor to form Se-rich carbonaceous rocks; 2) larger Se crystals are related to combustion of stone coal (Se oxidation); 3) redox processes related to water table fluctuations, resulting in Se oxidation-reduction reactions (Wen and Carignan, 2006).

Se isotopic measurements on Se-rich rocks provided large variations of $\delta^{82/76}\text{Se}_{\text{NIST}}$, which varied from -12.77‰ to 4.93‰ for a total range of 17.7‰. This is the largest Se isotopic variation found so far in natural terrestrial samples. One of the high-Se carbonaceous shale samples yielded the most depleted composition, with a $\delta^{82/76}\text{Se}_{\text{NIST}}$ of -12.77‰. On the other hand, Hagiwara (2000) reported that bioaccumulation of Se by plankton do not lead to large isotopic fractionation, generally about 1-2‰ between available dissolved oxidised species and biologically reduced Se. In addition, no significant isotopic fractionation is observed during oxidation reactions of Se, as reported by Johnson (2004). Obviously, the “redox model” is favoured to explain the Se isotopic variations in the Yutangba black shales. Above or in the close vicinity of the water table (oxidizing conditions area), Se⁻² in rocks and ores is readily oxidized to 0, +4, or +6 valences, without isotopic fractionation. Then, Se⁺⁴ and Se⁺⁶ mobilised in oxidising solutions may be readily reduced again to zero (or partly -2) valence, as the water migrates and eventually encounters lower redox potential. At the scale of the deposit, repeated reduction reactions should induce significant Se isotopic variations (Johnson 2004).

The extreme isotopic variation measured in the black shales of the Yutangba Se deposit strongly supports the high potential of Se isotopes as a powerful redox tracer.

References

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