La minéralogie de l'uranium dans le massif des Aiguilles Rouges (Alpes occidentales)

MEISSER Nicolas ; , 2003

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The Aiguilles Rouges Massif is located in the Helvetic realm, on the NW flank of the Alps. The pre-Mesozoic basement of this massif includes Late Carboniferous detritic series and hosts a number of U-mineralizations. Seven types of occurrence are reported. The most important type consists of U, Fe, Cu, Zn, Bi, S, Se and V-bearing quartz-cemented hydrothermal breccias. These mineralizations are related to a Permo-Triassic (~240 Ma) hydrothermal event and, locally, to a Middle Triassic (~230 Ma) S- rich event related to massive marine transgression, brine circulation and bacterial reduction of sulfate into sulfides in reopened old U- breccias. Near Lavey-les-Bains (Canton Vaud), shallow Lower Triassic U and V- bearing calcite veins contain bacterial fossils that have been unequivocally identified by high diaminopimelic acic content and low d13C values.

The La Creusaz prospect (1973-1981) near Les Marécottes (Canton Valais) provides the best opportunity to study the uranium mineralogy in the area.

During the Alpine orogeny, low greenschist facies metamorphism and subsequent late Alpine hydrothermal alteration (350°C/2.5kb) partially overprint older mineralogical associations. The large difference (?34S = ~ 20) between the isotopic compositions of sulfur in primary sulfides and sulfur from potential source rocks (paragneiss and Vallorcine granite), yields an excellent record of sulfur inheritance and recycling phenomena. The association of uraninite with the rare Bi-Pb selenides laitakarite, weibullite and wittite, described for the first time in the world, results from the Alpine remobilization of the Paleozoic mineralization.The most abundant supergene U6+ -bearing mineral is uranophane-a. This mineral was dated with the 238U-234U-230Th disequilibrium method at 141,000 ± 3,000 years. This age corresponds to the beginning of the interglacial Riss-Wurm period. At this time, the melting of the inlandsis produced a rapid decompression that resulted in the fracturing of the bedrock and was followed by intense melt-water circulation. This oxygen-bearing water oxidized uraninite and produced uranophane-a and numerous and rare other U6+, Pb, As, P, V, Si and Se -bearing supergene mineral species. The clay minerals illite and vermiculite were also formed during this stage as gouge filling in decompression fractures and faults oriented perpendicularly to the glacial valley axis.

The oxidation of sulfides by oxygen-bearing waters produces sulfate-rich acid waters that can leach and transport large quantities of heavy metals and actinides. Acid sulfate waters may also be present in and around radioactive waste deposits, in particular those located in sulfide-bearing host-rocks such as shales (e.g. proposed Swiss repository in Mesozoic shales). At the La Creusaz deposit, outcropping veins and stockpiled high-grade U, Se, As and heavy metals-ore have been exposed to acid mine drainage water and atmospheric oxygen in the abandoned galleries. The oxidation of the sulfides under the presence of strong bacterial activity resulted in the

production of acid (pH = 3.1), sulfate-rich waters. These waters reacted with uraninite and after in situ natural evaporation formed a rich assemblage of secondary uranyl minerals, including the new triclinic species marecottite, [Mg3(H2O)18](UO2)8(SO4)4O6(OH)2 . 10H2O. The solution of the crystal structure of marecottite allowed to resolve the contentious nature of the zippeite-group of minerals, which are important phases controlling U-mobility under acide drainage conditions.

Plants growing on outcropping U veins were systematically studied for their potential use in bioremediation. Higher U, Cr, Cu and Tl concentrations were observed in rapidly growing species such as the grasses Luzula nivea and Agrostis schraderiana. Due to the huge biomass production that these species achieve under alpine conditions during the short Summer season and to their capacity to act as U- and heavy metals-bioaccumulations, these plant appear to be well suited for use in the remediation of contaminated soils.