Deformation stages in granitoids of uranium deposit: reconstruction on the basis of special technique of microstructural analysis

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Cracks in rocks can be considered as Open Cracks (OC: not filled with secondary mineral phases) or Filled Cracks (FC: filled with secondary mineral phases or fluid inclusions). FC are often partially filled or reopened after a first event of filling. The best records of fluid percolation are paleofluids trapped as Fluid Inclusions (FI) in healed microcracks of the rock-forming minerals (Lespinasse *et al.*, 2005). Usually such FIs with liquid, vapour and solid phases form differently oriented systems, known as Fluid Inclusion Planes (FIPs). FIPs are result from the healing of former open cracks and appear to be fossilized fluid pathways (Roedder, 1984). FIPs are totally sealed and do not present secondary opening.

Microcracks should provide valuable information about the local stress and deformation in rocks and can be assumed to be ($\sigma_1\sigma_2$) planes (Tuttle, 1949). The FIPs are mode I cracks that occur in sets with a predominant orientation perpendicular to the least principal compressive stress axis σ_3. These mode I cracks propagate in the direction which favors the maximum decrease in the total energy of the system. They do not disrupt the mechanical continuity of mineral grains and do not exhibit evidence of shear displacement like mode II and III cracks. The FIPs are usually observed and characterized in minerals which crack according to the regional stress field, independently of their crystallographic properties, and may easily trap fluids as fluid inclusions when healing. The rate of healing is most rapid in quartz (compared to geological times), so it is more informative for studying FIPs systems (Lespinasse, 1999).

FIPs form well defined networks. This fact allows revealing a chronology of different deformation stages of rocks. When a first generation of FIPs formed, a second crack family can be formed, cross-cutting the first one. Thus, FIPs provide good records of successive episodes of crack initiation and fluid migration.

As orientation of FIPs is defined by reorganization of the local stress field so besides reconstruction of deformation stages it is possible to use them as geostructural markers for reconstruction of porosity and paleopermeability of rocks, geometry of fluids migration pathways, reconstruction of fluid migration stages and for studying dynamics of change of PT, physical and chemical conditions at various events of deformation of geological objects.

FIP generations were studied at the giant Antei uranium deposit. Besides there were studied different types of microcracks – filled with mineral phases, partially filled, filled with ore components, opened and reopened cracks (Ustinov & Petrov, 2012). Antei uranium deposit is located in Eastern Transbaikalia within the Streltsovskaya caldera, generated in process of late-Mesozoic activation of tectono-thermal processes in the region. Samples were taken from main fault zones – from the central part (core), the zone of its dynamic effect (failure), and undestroyed wall rock (protolith) at the 9th and 11th horizons. Microcracks of different types were studied by means of special technique of microstructural analysis. For realization of this technique it is important to take samples oriented in space. The considered method allows to carry out statistical analysis of 2D digital images of thin sections by means of the special software and thereby to reconstruct chronology of deformations. Besides, this analysis allows quantifying paleofluid flow porosity and permeability by the reconstruction of the crack network consisting of cracks described as discs using the geometry of the crack network. Using microstructural analysis one can determine dip direction, length, thickness, porosity and paleopermeability for each microcrack system. The data on composition and properties of fluid inclusions trapped by cracks (temperature, pressure, salinity and phase composition) to separate different sets of FIPs can be found out using microthermometry and Raman spectroscopy.

As the main ore component of the Antei deposit is uranium, also it was used sufficiently effective method for reconstruction fluid filtration processes and stages of intraore tectonics during the past geological events – fission-track radiography (FTR) of thin sections.

The comparative characteristic of orientation of different types of microcracks and objects was carried out by construction of roses-diagrams for each type of objects. It allowed defining spatial parameters of chosen linear objects and allocating stages of deformation and fluid migration, to confirm conception about polystage development of the intraore tectonic processes.

After getting spatial parameters of each microcrack generation, FIP system, making their interpretation and finding out distribution of uranium ore the following conclusions can be drawn:

1) Hydrothermal process at the Antei uranium deposit took place through four main stages of deformation with differently oriented microcracks which trapped fluid inclusions with different properties. Each stage of deformation directly connected with certain events of transformation of ore containing rocks.

2) According to the FTR and microstructural data the intraore tectonic processes occurred during two main stages of uranium-bearing fluids inflow.

3) This approach can help us to model porosity and paleopermeability of crystalline massifs (tectonics, fluid flow pathways, fluid chemical composition, etc.) as a function of stressed-strained and temperature state in space-time context.

Lespinasse, M. (1999): J Struct Geol, 21: 1237-1243.
Lespinasse, M., Désindes, L., Fratczak, P., Petrov, V. (2005): Chem Geol Spec Iss, 223: 170-178.
Roedder, E. (1984): Rev Mineral, 12.
Tuttle, O. F. (1949): J Geol, 57: 331-356.
Ustinov, S. A., Petrov, V. A. (2012): Abs Baikal Intern Conf «Geol Mineral Dep» Ulan-Ude, Enkhaluk on the Baikal: 57-58.

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