# Application of stable isotopes (O, H and S) to the understanding of fluids in porphyry Cu-Au systems with particular emphasis on advanced argillic alteration: Oyu Tolgoi mineral district, Mongolia

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Oxygen, H and S isotopes can help to identify the nature of fluids in the porphyry and epithermal environment involved in mineral formation, and help to understand the evolution of magmatic fluids. The Oyu Tolgoi porphyry Cu-Au deposit in Mongolia was chosen as the research project. It consists of 8 deposits which occur in a linear belt 12 kms long. They occur in a mid-late Paleozoic arc terrane and are related to late Devonian quartz monzodiorite intrusion.

This isotope study mainly investigated the origin of the advanced argillic zone and muscovite alteration and possible connections between these two late alteration types. The isotopic composition of the fluid was calculated from fractionation equations, and compared to standard published references. Alunite ($\delta^{18}O_{(SO4)}$= -4.5 to 12.2 ‰, δD = -67 to -37 ‰, $\delta^{34}S$= 8 to 17.9 ‰) was formed from a magmatic condensate, with a minor component of meteoric water (<20%), at a temperature of 240-300° C. Muscovite ($\delta^{18}O$= 2 to 6.9 ‰, δD= -96 to -72 ‰) may be derived from a magmatic-hydrothermal fluid, with less than 10 % meteoric component, if it was formed at 300° C. However, if muscovite is regarded as transitional from early high temperature potassic alteration, and stable at 450° C, then the calculated fluid would have no significant meteoric component. Hornblende ($\delta^{18}O$= 5.9 ‰, δD= -77 ‰), actinolite ($\delta^{18}O$= 4.5 ‰, δ D= -93 ‰) and magnetite ($\delta^{18}O$= 6.6 ‰) from relatively unaltered quartz monzodiorite, are used to estimate fluid composition of the earliest magmatic-hydrothermal fluids. Late minerals in veins, such as dickite (150° C) and illite (estimated at 220° C), trend towards the meteoric water line, and give an estimate for δD of Late Devonian meteoric water at about -150 per mil. The light δD isotopic composition of the meteoric water suggests that Oyu Tolgoi was at high elevation, or possible at high latitude (or both). Pyrophyllite ($\delta^{18}O$= 1 to 7.3 ‰, δD= -95 to -67 ‰) is derived from a magmatic-hydrothermal fluid similar to muscovite; if calculated at 300° C, and it occurs in two groups, with pyrophyllite from the Central deposit showing a meteoric water mixing trend. At Hugo Dummett, pyrophyllite occurs in two geological settings, one associated with quartz monzodiorite and the other to basaltic wall rock, but both have the same O and H isotopic signature. For this reason, and since ascending fluids in basaltic wall rocks are strongly buffered by Fe-minerals, it seems more likely that pyrophyllite is related to a condensate fluid, rather than cooling of a muscovite-stable fluid.

Three possible different geological environments for anhydrite-gypsum in the porphyry environment are identified; 1) anhydrite in veins on the margins of the advanced argillic zone, related to magmatic condensate fluids, 2) anhydrite surrounding deep parts of the porphyry system, related to magmatic-hydrothermal fluids mixing with shallow sulfate water formed in a steam-heated environment, 3) anhydrite deep in the porphyry system, related to high temperature magmatic-hydrothermal fluids, with minor external fluid. Sulfur isotope systematics, for sulfide-sulfate minerals suggest that the magmatic-hydrothermal fluids involved in sulfide mineralization and formation of post-potassic alteration mineral assemblages, were relatively oxidizing ($H_2S$: $SO_2$ ratio of one or less).

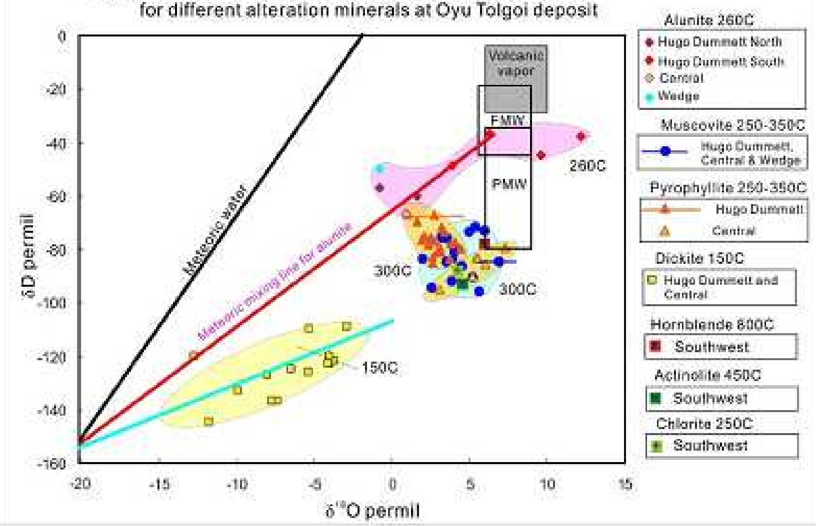

Fig 1. Calculated $\delta^{18}O$ and δD values of fluids responsible for different alteration minerals at Oyu Tolgoi deposit

**次回のお知らせ**
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