

Ancient magmatic CO₂ degassing from non-volcanic area in West Taiwan: Helium and carbon isotopic evidences

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Representative gas samples of fumaroles, springs, mud volcanoes, natural gases were collected from Taiwan for helium isotopes measurement. Samples from northern and eastern Taiwan exhibit higher ³He/⁴He ratios, which indicates significant mantle-derived signature. The result is not unexpected, since hydrothermal activity is still active at those areas. Nevertheless, some abnormally high ³He/⁴He ratios (up to 6.4 Ra) are obtained from non-volcanic area in western Taiwan. Carbon isotopes of CO₂ and CO₂/³He ratios in those samples are similar with those from mid-ocean ridge basalts, which believed to be derived from upper mantle. Hence, we are able to conclude that they are mantle-derived in origin.

Intrusive magmatism and/or deep normal faults occurred in western Taiwan could be the straight forward way to explain the high helium isotopic ratios observed in non-volcanic area. Considering the possible inversion of tectonic stress from compression to tension, post-collisional magmatism around northern Taiwan may have occurred since late-Pliocene. The model might explain the possible mantle source for northwest Taiwan area, however, it is still unable to demonstrate why there is no any magmatic activity reported since late-Miocene and, presently, the areas are still under severe tectonic compression environment where we found the high helium ratio samples, especially in southwestern Taiwan.

I propose that the high ³He/⁴He ratio gases are not in-situ mantle-derived volatiles. They may be associated with Miocene magmatism and have been trapped by impermeable formation during the stage of basin subsidence before orogenic event occurred. Consequently, the deep normal faults may be reactivated as reverse faults by continuous compressive stress and cut through the capped rock of the gas reservoir. The "old" mantle gases, hence, could be released to surface through the leakage.

Studying crystal growth with NanoSIMS: An example of zircon

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Zircon has become one of the most widely used minerals for studying the prehistory and genesis of the host rock, because it is an excellent geochronometer, geochemical tracer and geothermometer. In many applications, the partition of trace elements between zircon and silicate melts is assumed to exhibit Henry's Law behavior and the crystal growth to be an equilibrium process. However, these assumptions may not be fulfilled in natural systems. For example, oscillatory zoning, a predominant texture of igneous zircon, appears to indicate non-equilibrium crystal growth [1].

To better understand origins of oscillatory zoning in zircons, distributions of REE (represented by Ce, Sm, Dy, Lu), Y, Ti, Li and P in zircons have been investigated with Cameca NanoSIMS 50L. The QH igneous zircons with oscillatory zonings display large trace element variations by a factor up to 13.5, with Y ranging from 574 to 7754 µg/g. By contrast, the DMP06-14 metamorphic zircons without oscillatory zonings show much smaller trace element variations by a factor of 1.4, with Y ranging from 477 to 636 µg/g. In the QH zircons, the cathodoluminescence (CL) images and ion images of Y show strong correlations with the CL-dark bands having high Y abundances than those of adjacent CL-bright bands by a factor of 2 to 10. The Y abundances are strongly correlated with the concentrations of P and REE (R² > 0.97). The corrections between P and (Y+REE) can be divided into three groups, with (Y+REE)/P atomic ratios of 3.3, 1.0 and 0.5, respectively, indicating three types of solid solution substitution of phosphates in zircon.

The oscillatory zoning can be well explained by a crystal growth kinetics model associated with substitutions of phosphates. The oscillatory distribution of P in zircon could be controlled by the fluctuation of P/Zr ratio in the melt adjacent to the mineral-melt boundary, because P diffuses slower than Zr in silicate melts. Such a zoned distribution of P in turn controlled the substitution types of phosphates in zircon, and consequently formed the oscillatory distributions of Y and REE in zircon.

[1] Hoskin, P.W.O., Schaltegger, U., 2003. Reviews in mineralogy and geochemistry 53, 27-62.