Crustal and mantle degassing in continental China

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The release of volatile elements (e.g., carbon, nitrogen and noble gases) in response to volcanic and tectonic processes occurs at plate boundaries, volcanic and tectonically active settings. Volatile degassing is prevalent in present-day continental China, which is comprised of continental tectonic blocks (e.g., orogenic belts, continental rifts and cratonic regions). Here, we briefly review the crustal and mantle degassing features of different tectonic units in the region, and specifically focus on the implications of volatile outgassing for regional tectonic affinities associated with growth of the Tibetan Plateau.

Helium isotope ($^3He/^4He$) data (reported in R_A, where R_A is air $^3He/^4He$) indicate that crustal and/or mantle degassing rates are variable for individual tectonic units of present-day continental China. Compared to tectonic degassing controlled by active faulting processes, magma degassing related to Quaternary volcanism is more efficient in transporting mantle volatiles to the surface (i.e., higher $^3He/^4He$). This feature has been identified in several Quaternary volcanic fields, especially the Changbaishan and Tengchong volcanoes that are characterized by Holocene eruptions of silicic magmas. Fluids with a resolvable mantle helium component ($^3He/^4He > 0.1\ R_A$) are also observed in hydrothermal fluids from active faults of ancient cratonic regions, such as Tarim craton and North China craton. In contrast, the Sichuan basin within the Yangtze craton is dominated by crustal degassing ($^3He/^4He < 0.1\ R_A$).

Thermal springs are extensively distributed in the Tibetan Plateau, making it an ideal laboratory for window of volatile outgassing and its tectonic implications for evolution of orogenic belts. In southern Tibet and the Himalayan region, there is a general northward increasing trend in $^3He/^4He$ values of hydrothermal fluids, suggesting transition from accretionary wedge dominated by crustal degassing to magmatic front that shows mantle helium contributions. The southeastern part of the Tibetan Plateau (SETP) represents an on-going spreading marginal area of the orogenic plateau due to India-Asia collision. Helium isotope mapping defines a zone of significant mantle degassing in the SETP. The release of mantle fluids strongly correlates with active faulting systems. In particular, non-radiogenic $^3He/^4He$ values ($^3He/^4He = 0.57–3.79\ R_A$) are observed in the bending section of the Xianshuihe-Anninghe fault, which is a block boundary fault with localized high shear strain. In contrast, lower degrees of mantle ^3He emissions ($^3He/^4He < 1\ R_A$) dominate the active faults with lower shear strain rates in the SETP interior. Such helium degassing patterns can reflect spatial variations in strain rates of different strike-slip fault systems under the control of the India-Asia collision and resistance by the Yangtze craton. Combined with regional tectono-magmatic history and plate reconstruction results, we propose that the present-day mantle degassing in the SETP has close affinities with tectonic and magmatic responses to westward rollback of the Indian slab, which initiated 13 to 10 million years ago. Strain reorganization triggered by the Indian slab rollback led to lateral expansion and localized surface uplift of the SETP, suggesting that mantle dynamics may have played an important role in southeastward growth of the Tibetan Plateau during late Cenozoic.

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