Current Status of Phosphate (U-Th)/He Thermochronology of Meteorites

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Traditional whole-rock (U-Th)/He methods applied to meteorites commonly yield apparently younger ages than expected from other thermochronologic tools, suggesting that (U-Th)/He systems are disturbed by thermal event(s) after the primary cooling. However, recent investigations applied to phosphates at a grain scale have revealed that some of the phosphate (merrillite, apatite) grains retain their pristine (U-Th)/He ages, allowing for determination of the temporal and temperature conditions that their parent bodies experienced during the primary cooling or shock events. In this contribution, we aim to explain the current status of the (U-Th)/He methods applied to extraterrestrial phosphates.

For unshocked meteorites, the single-grain (U-Th)/He methods provide a unique way to determine absolute ages when the meteorites have passed through temperatures below ~200 °C. Recent stepped heating experiments indicate that the closure temperatures of merrillite and chlorapatite are generally in the range of 85-145 °C and 7-108 °C, respectively, for a wide range of cooling rates (0.1– 100 °C/Ma) and at a diffusion domain radius of 50 μm. Two examples of the single-grain (U-Th)/He thermochronometry used to constrain low T thermal histories are for the Acapulco and St. Séverin meteorites whose pristine ages are well consistent with the medium-to-high T cooling curves. For shocked meteorites, the phosphate (U-Th)/He ages can provide crucial information regarding shock temperature conditions. Due to the high He diffusivity in phosphates, the transient shock event causes significant fractional loss of He (f_{He}), which can be utilized for thermal modeling and peak T estimation. Because most of the phosphate crystals are severely fractured, most likely during the shock event, diffusion domains are smaller than crystals; therefore, requiring detailed petrographic examination and image analysis of phosphate grains for modeling. This approach has been applied to the Los Angeles, ALHA84001, Zagami and EETA79001 Martian meteorites. Some of the results from this approach indicate bias from the peak T estimated from traditional shock recovery experiments. (U-Th)/He study of Zagami indicates relatively high peak T (> 400 °C); whereas, shock recovery experiments yield minor shock conditions (post-shock T ~ 60 °C). It is unclear what causes such a large discrepancy. In order to improve phosphate (U-Th)/He methods, the following issues need to be thoroughly addressed. First, because the morphology-based α recoil correction is essentially impossible for meteoritic samples, an alternative way of avoiding this correction has been suggested. Although there is a tendency that large grains with other phases attached yield more pristine ages without α recoil correction, there are some exceptional cases that are not fully understood. Second, the He diffusion properties in meteoritic apatite seem to show relatively large sample-to-sample variations, rendering additional efforts to constrain the diffusion properties for various meteoritic phosphates.

The evolution of clay minerals and rift structure in Zhanhua Depression, China

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Introduction, Results and Conclusion

Zhanhua Depression is located in Bohai Bay Basin, China. The depression has an area of about 3800km^2. It is a major oil and gas exploring district in the basin.

The study on diagenesis of clay minerals in Zhanhua Depression shows that the disordered mixed-illite/smectite (R_0I/S) and kaolinite in the Neogene were formed at the burial depths <2000m during the post-rift in Zhanhua Depression, while the appearance of the ordered mixed-illite/smectite ($R_{\geq 1}$I/S) in the Paleogene at the burial depths >2000m and the disappearance of kaolinite at the same depths were symbolized as the syn-rift in the depression. This regularity is referred to the burial depths, which are controlled by the paleotemperatures in the evolution of the clay minerals.

By using the chlorite geothermometer [1, 2, 3], the forming temperature of chlorites during the rift period in the Paleogene is calculated as 135-180℃ in Zhanhua Depression. The relationship between the chlorite diagenetic temperature and its burial depth indicates that the paleogeothermal gradient is about 38℃/km in the Paleogene in Zhanhua Depression. It is higher than the present geotemperature (34.5-32℃/km [4]). This phenomenon was attributed to the evolution of the structural dynamics in the rifted basin [5, 6].

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