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Geochronology and implication of oxygen isotopic data for ongonites from Ongon Khairkhan, Mongolia

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ABSTRACT

The inferred primary $\delta^{18}O$ (~+6 to +7‰) and Pb isotopic values for ongonite from Ongon Khairkhan, Central Mongolia, are consistent with a granitic parent magma and interaction with orthomagmatic fluids. The ongonites and constituent minerals record (1) an extensive and protracted crystal fractionation history, in part due to the presence of volatiles (particularly F) which depressed the solidus temperature of the felsic rocks and extended its duration of crystallization and (2) subsolidus exchange with fluids which includes late flux of heated meteoric water as indicated by modified whole rock $\delta^{18}O$ values (+0.5 to +2.7‰). The interaction of the ongonites with internally derived orthomagmatic fluids is considered to result in enrichment and/or redistribution of several incompatible elements, but not to have greatly modified their original major element chemistry which indicates that this suite represents the last stages of fractionation of a highly differentiated, F-rich granitic magma. Late stage magmatic, water-rich fluids enriched in incompatible elements including Nb, Ta, Sn and W were responsible for the late- to post-magmatic alteration and associated W mineralization. The results of $^{40}Ar/^{39}Ar$ dating on two dyke rocks provide an age of 123 ± 1 Ma.

Key words: ongonite, oxygen isotope, geochronology, Mongolia

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Geological setting

The Cretaceous ongonites are hosted by Devono-Carboniferous clastic sedimentary rocks of the Kharkhorin rift (Fig. 1). Although the rift contains numerous granitic plutons, there is no clear relationship between the dykes and an obvious progenitor granitic pluton. The nearest granitic body of similar age, the Ongonhairkhan pluton, is about 10 km from the ongonite locality. Geophysical data suggest, however, the presence of a granitic body beneath the ongonite dykes at a depth of about 600 m (Kovalenko et al., 1971), but a hole drilled to 516 m did not encounter such a body (Stemprok, 1991). The ongonites form a dyke swarm of about 1 km in length that consists of micro-leucogranitic bodies ranging from several cm to about 2 m in thickness and the length of the larger dykes spans from tens of meters to 500 m. In the type locality (Kovalenko et al., 1971; Kovalenko & Kovalenko, 1976), two main dykes were sampled (Fig. 2). The first dyke, which is moderately to steeply dipping (45°-90°) and about 2 m thick, can be followed intermittently for 0.5 km. The second dyke is located about 100 m S of the first dyke, is sub-parallel in strike, and ≤ 1 m thick (Fig. 2). The dykes have chilled margins ≤ 10-20 cm wide with sharp contacts. The ongonite dykes are massive with conchoidal fractures and their texture varies from aphanitic at the chilled margin to porphyritic in their central parts. The margins may show a flow lineation, which suggests that the magma was intruded upwards rather than horizontally and may imply that the magma source lies beneath the dyke swarm rather than some lateral distance away. That the ongonite dykes are texturally homogeneous without pegmatitic textures indicates the melts were relatively "dry" during their emplacement. The dykes are spatially associated with a tungsten mineralization (Kovalenko et al., 1971; Stemprok, 1991). This mineralization, up to 200 m in extent, is composed of a stockwork of quartz veinlets containing wolframite, minor sulphides, scheelite and accessory topaz and several wolframite-bearing quartz veins (Fig. 2). The quartz veins are up to 2 m thick, whereas the stockwork veinlets are typically 3-5 cm thick. Kovalenko et al. (1971) inferred that the ongonites and the tungsten mineralization are related to the same evolved granitic magma at depth.

Geochronology

The results of $^{40}Ar/^{39}Ar$ dating on two dyke rocks provide an age of 123 ± 1 Ma (Dostal et al, 2015). These ages are similar to both the Rb-Sr whole-rock age of 118 ± 7 Ma and the Rb-Sr mica-whole-rock age (117.0 ± 1.6 Ma) reported by Jahn et al. (2004) for these dyke rocks. In addition, these ages are comparable to those of the Ongonhairkhan pluton (119 ± 2 Ma Rb-Sr biotite-whole rock), which was suggested to be related to the ongonite dykes (Jahn et al., 2004). The time of emplacement of both the granitic pluton and ongonite dykes corresponds to the widespread Late Jurassic-Early Cretaceous (~150-120 Ma) stage of magmatism of the MTIP (Jahn et al., 2009)

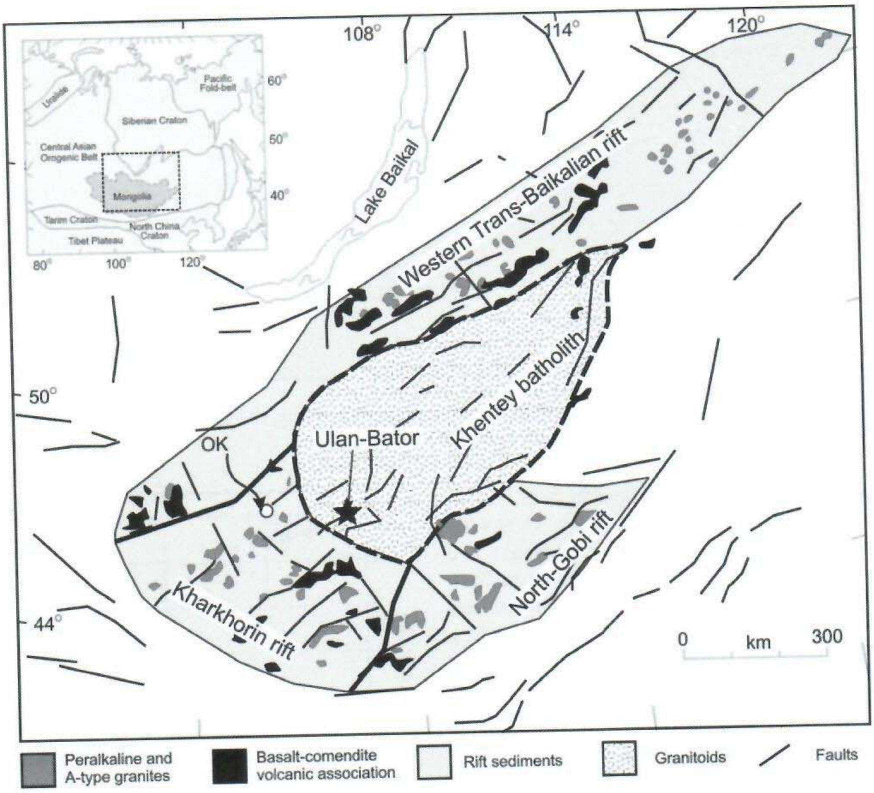

Fig. 1. Simplified geological map of central part of the Early Mesozoic Mongolian-Transbaikalian igneous province of the CAOB showing the Mesozoic North Gobi, Kharkhorin and WesternTransbaikalian rifts and associated igneous rocks including Khentey batholith, peralkaline and alkaline granite complexes and bimodal volcanic suites (modified after Yarmolyuk et al., 2002, and Yarmolyuk & Kuzmin, 2011, 2012). OK- Ongon Khairkhan, the type locality of ongonites.

Implications of the $\delta^{18}O$ data for sources regions and fluid - rock interaction

The whole-rock $\delta^{18}O$ data for the ongonites fall into two distinct groups: high- and low-^{18}O suites although the rocks of both groups have overlapping major and trace element compositions and similar petrography. This suggests that the differences are the result of fluid - rock interaction. The susceptibility of feldspar to exchange with fluids and to re-equilibrate to lower temperatures may lead to a disturbed whole-rock $\delta^{18}O$ value, particularly in rocks where feldspar dominates the modal composition as in ongonites. To evaluate this process, we compare the measured and inferred feldspar $\delta^{18}O$ values based on the SIMS quartz data for the two representative samples analyzed. Using the quartz $\delta^{18}O$ data, the $\delta^{18}O$ feldspar value can be calculated assuming isotopic equilibria, for example Δquartz-feldspar is 1.5‰ for high T fractionation (Bottinga & Javoy, 1973). Likewise, the proportion of $\delta^{18}O$ contributed to the rock by feldspar can be determined using mass balance and the mineral proportions obtained from normative composition. With these conditions, the high-^{18}O sample has a calculated $\delta^{18}O$ feldspar value of +7.3‰ versus an inferred value of +6.1‰ using the average SIMS quartz value of +7.6‰ and assuming equilibrium fractionation. In contrast, for the low-^{18}O sample the calculated $\delta^{18}O$ feldspar value is -3.3‰ versus the inferred value of +6.6‰ using the average SIMS quartz value of +8.1‰ and assuming equilibrium fractionation. Thus, for sample with low-^{18}O the feldspar component of the ongonite must have exchanged with a low ^{18}O reservoir, most likely a meteoric fluid (e.g., Criss & Taylor, 1986). The low-^{18}O ongonite samples are interpreted to reflect interaction with a low-^{18}O fluid of meteoric origin given that quartz from one of the low-^{18}O ongonite samples has a normal $\delta^{18}O$ value compared to the very low feldspar values that occur in these samples.

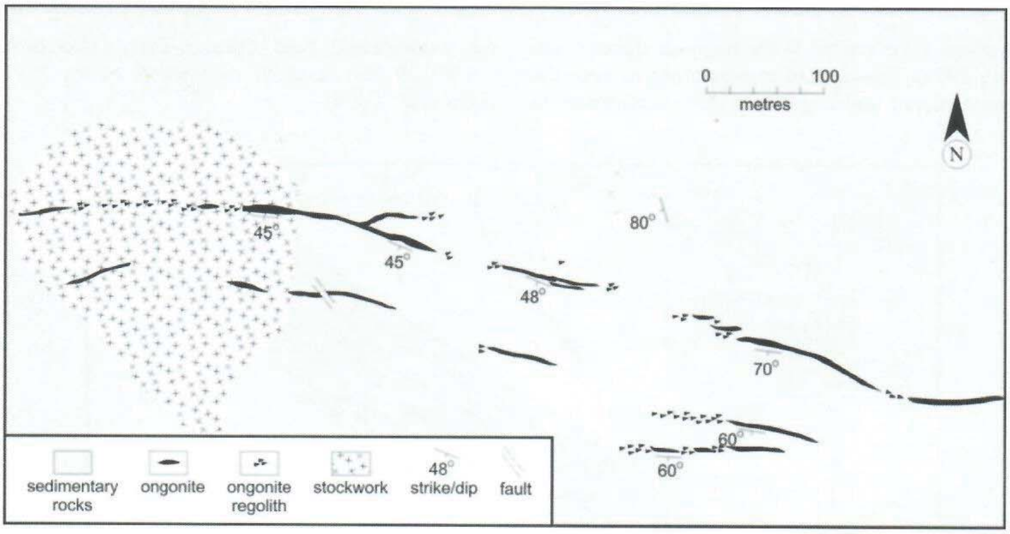

Fig. 2. Geological sketch map of the Ongon Khairkhan area showing the type locality of the ongonites and the tungsten mineralization (after Kovalenko et al., 1971).

The quartz $\delta^{18}O$ SIMS data can also been used to estimate the original $\delta^{18}O$ whole rock values by assuming isotopic equilibrium between quartz and feldspar and the mineral proportions obtained from the norms; values of +6.2 to +7.1‰ were obtained for the two ongonites (high- and low-^{18}O samples). These $\delta^{18}O$ values fall at the low end of compilations for granites and equate better to I- and A-type granites rather than S-type peraluminous granites (Sheppard, 1986). The origin of I- and A-type type granites is generally attributed to differentiation of mantle-derived melts or partial melting of igneous source material rather than metasedimentary rocks. In order to investigate this fluid - rock exchange, we use the inferred $\delta^{18}O$ value for the fresh feldspar component of the low-^{18}O sample versus its present day $\delta^{18}O$ value, these being 6.6‰ and -3.3‰, respectively, to model the fluid - rock ratio at different T values for a given fluid value and Δfeldspar-H_2O (Taylor, 1977). The results of these calculations are summarized in Fig. 3, which shows that the necessary δ^{18}Orock/feldspar value is obtained when a fluid with $\delta^{18}OH2O \approx -5‰$ reacts with the fresh rock and at a high T (350° to 450°C). These calculations indicate, therefore, that the incursion of the low-^{18}O fluid must a have occurred shortly after ongonite emplacement when the dyke rocks were cooling. We further suggest that fluid ingress was facilitated by the same general brittle structure which also controlled the injection of the ongonitic melt. The nature of the fluid inclusions in quartz are consistent with trapping of a high-T fluid (Dostal et al. 2015).

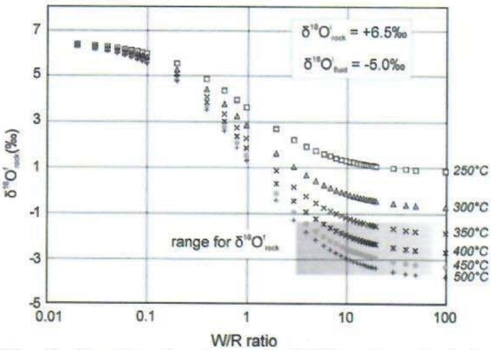

Fig. 3. Results of water–rock (W:R) ratio calculations (Taylor, 1977) for ongonite sample having a calculated whole rock (using feldspar as a proxy for this) initial $\delta^{18}O$ value of+6.5‰that reacts with a fluid having a $\delta^{18}O$ value of–5‰, as discussed in the text, for temperatures that range from 250° to 500 °C. The shaded box indicates the range of conditions for the temperature and water:rock ratios that satisfy the measured whole-rock (i.e. feldspar values) δ18O values.

Conclusion

The ongonites represent the end product of extreme and protracted crystal fractionation, which is due in part to the presence of elevated fluorine which causes lowering of the solidus temperature and allows the melts to crystallize over a large temperature range from liquidus temperature that likely exceeded 800oC to anomalously low solidus temperature, possibly less than 600°C. Crystallization was accompanied in its latest stages by at least two episodes of fluid mediated events which transported/remobilized some incompatible elements. One episode involved fluids enriched Ta, Hf and Ga, among others, and led to anomalous

Nb/Ta and Zr/Hf ratios that depart markedly from chondritic values (Dostal et al., 2015). The secondary processes which also influenced the ongonite chemistry involved late-stage fluid-melt interaction rather than subsolidus hydrothermal alteration, as suggested by the correlation of enriched Rb, Cs and Tl with F. Finally, it is inferred that during the final stages of crystallization of the ongonitic magma, a late-stage, magmatic fluid enriched in incompatible elements (e.g., Nb, Sn, W) was responsible for the late- to post-magmatic alteration. The fluids were internally derived from the granitic magma that is orthomagmatic in nature.

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