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The Boltysh Impact Crater, Ukraine: Smectites from the Crater-fill Suevites.

F. A. Williams[1*], S. P. Kelley[1], I. Gilmour[1], D. W. Jolley[2] and M. Gilmour[1]. [1]Department of Physical Sciences, Open University, Milton Keynes, UK. [2]Department of Geology and Petroleum Geology, University of Aberdeen, Aberdeen, UK. *Corresponding author (email: Felicity.Williams@open.ac.uk).

Abstract

The Boltysh crater has an entire suite of crater-fill impactites preserved, including two impact melt-bearing breccias. Smectite occurrence in the breccias suggests two stages of alteration; an early hydrothermal mineralization, and a later, low temperature weathering. δD and $\delta^{18}O$ of smectite separates are currently being measured and will be presented.

1. Introduction

Large impact events are capable of generating a hydrothermal system in water- or ice-rich targets [1]. The potential significance of these hydrothermal systems as habitats is dependent on their longevity and the continued availability of liquid H_2O and nutrients, as well as whether they provide hospitable environments for life in the form of post-impact lakes and lacustrine sediments [2].

The 24-km-diameter Boltysh impact crater (48°45' N and 32°10' E) formed in the Proterozoic granites and gneisses of the Ukrainian shield 65.59 ± 0.64 Ma [3][4]. It is buried beneath 600 m of early Danian sediments and later Quaternary deposits. Below the sediments is an impact melt-bearing breccia (classified as suevite) above impact melts.

There is evidence that a hydrothermal system was established at Boltysh. The aim of this work is to analyse the resulting mineral assemblages in the impact melt-bearing breccias to infer the conditions of the alteration environment with depth. Considered here are the smectite clays; their compositional variability and ubiquity through different environments makes them useful tracers of hydrous alteration conditions.

Smectite isotopic composition has been used to calculate temperature of formation for Ries crater suevites, using a single mineral geothermometer equation [5]. $\delta^{18}O$ becomes lighter and δD heavier, from the surficial suevites to the crater-fill suevites, reflecting a change from low-temperature weathering by meteoric water to hydrothermally-derived smectites. [6]. A similar method is currently being applied to Boltysh crater-fill suevites.

2. Methods

Samples of "suevite" and impact melt rock (IMR) were collected from borehole core 42/11. Polished thin sections were prepared for use in an FEI Quanta 2003D SEM. Smectite composition was analysed with an Oxford Instrument EDS, and BSE imaging was used to observe textures. Smectites were separated by sieving and filtering using a Büchner funnel to obtain at <10 µm size fraction. This was centrifuged in the heavy liquid LST (density 2.3) for 2 hours and then frozen at -80°C for 1 hour. The float material was removed and confirmed as smectite by XRD.

3. Results and discussion

Argillic-type alteration and zeolitization have affected the Boltysh "suevite", characterised by smectites, zeolite, calcite, quartz and pyrite.

The groundmass of the upper "suevites" contains an Al-rich montmorillonite-type mesostasis with elevated Fe. It is chemically heterogeneous and occurs with carbonate, forming globular and vesicular textures. Plagioclase crystallites formed from the mesostasis in some samples, putting these "suevites" at odds with the suevite definition ("clastic groundmass"). Downwards, the mesostasis thins and becomes draped and wrapped around groundmass fragments. Al-smectite formed at high W/R ratios in an open system (these were once subaerial rocks). Alkalis and Mg are removed from feldspars and glasses, while Al is immobile. Conditions were more acidic due to the influence of the atmosphere, inhibiting Fe-Mg smectite. Boltysh developed a crater lake and this water extensively altered the "suevites". The open system ended 2 m below the original surface, as platy hydrothermal calcite occurs here; atmospheric CO_2 increases carbonate solubility and prevented precipitation above 2 m. Zeolite in the groundmass shows that weakly alkaline hydrothermal water once affected the upper and lower impactites.

Downwards through the core the mesostasis disappears and the suevites are smectite poor. Clinoptilolite and calcite occur as amygdales. Fe-Mg smectite appears towards the bottom of these suevites and continues into the IMR, within vesicles and fractures in the glasses. Fe-Mg smectites show less heterogeneity with respect to alkalis, but figure 1 reveals a spread across nontronite to saponite compositions. The Fe-Mg smectites formed in a closed, low W/R system; the water reached chemical equilibrium with the glasses, and temperature and pressure would become the main controls on precipitation. Fe and Mg became enriched, while Si and cations moved upwards to form the clinoptilolite and quartz.

The upper "suevites" at Boltysh resemble the Ries surficial suevites described in [7] and are distinctly different from the lower suevites. Textural similarities and alteration products of the groundmass suggests that Boltysh upper and Ries surficial suevites formed by the same processes. The origin of the globular textures between the Al-smectite mesostasis and carbonate is still unclear, but has been suggested to be a result of carbonate-silicate immiscibility in impact-generated melts [7]. Low temperature alteration at Boltysh was a result of the crater lake above, implying that Ries surficial suevite alteration resulted from long standing meteoric water.

4. Conclusions

Hydrothermal mineralisation occurred through the whole impact melt-bearing breccia section, but the upper breccias experienced later, low temperature weathering from meteoric water. The two distinct smectite types reflect changing depth and W/R ratios. Textures through the core suggest two phases of suevite formation- crater fill and surface deposition- as well as different alteration regimes.

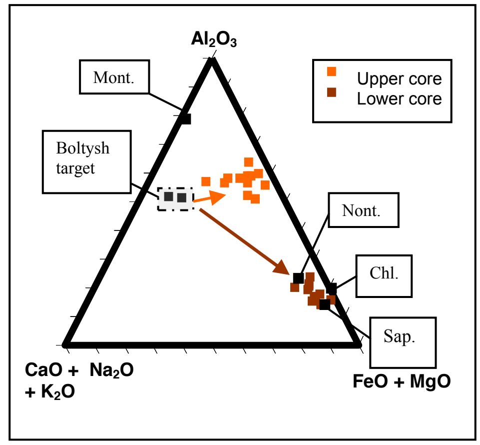

Figure 1: Smectite compositions.

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References

[1] Osinski, G. R. et al.: Impact-generated hydrothermal systems on Earth and Mars. Icarus, in press, 2012.

[2] Cockell, C.S. and Lee, P.; The biology of impact craters-a review. Biol. Rev, vol. 77, pp. 279-310.

[3] Kelly, S. P. and Gurov, E.: Boltysh, another end-Cretaceous impact. MAPS, vol. 37, pp. 1031-1043, 2002.

[4] Renne, P. R. et al.: Response to the comment by W.H. Schwarz et al. on "Joint determination of ^{40}K decay constants and ^{40}Ar*/^{40}K for the Fish Canyon sanidine standard, and improved accuracy for ^{40}Ar/^{39}Ar geochronology" by P.R. Renne et al. (2010). GCA, vol. 75, pp.5097-5100. 2011.

[5]Delgado, A. and Reyes, E. Oxygen and hydrogen isotopic compositions in clay minerals: A potential single mineral geothermometer. GCA, vol. 60, pp. 4285-4289, 1996.

[6] Muttik, N. et al.: Stable isotope composition of smectite in suevites at the Ries crater, Germany: Implications for hydrous alteration of impactites. EPSL, vol. 299, pp. 190-195, 2010.

[7] Osinski, G. R. et al.: The nature of the groundmass of the surficial suevite from the Ries impact structure, Germany, and constraints on its origin. MAPS, vol. 39, pp. 1655-1683.