RARE EARTH AND TRACE ELEMENT GEOCHEMISTRY OF IMPACT MELTS FROM THE GARDNOS IMPACT STRUCTURE, NORWAY. S. J. Jaret, R. Chakrabarti, G. Yu, M. I. Petaev, and S. B. Jacobsen. Department of Earth and Planetary Sciences, Harvard University, Cambridge MA, 02138 (sjaret@fas.harvard.edu)

Introduction: Impact-induced melting is a major component of impact cratering. Particularly during the beginning of the Solar System, when impacts were larger and more frequent, impact melting had a significant role in the formation and evolution of early planetary crusts and the planets themselves. Therefore, it is important to understand impact melting as a geochemical process. While the exact nature of impact melting (e.g., major, trace element, or isotopic fractionations) remains unresolved, it has been suggested that impacts do cause elemental fractionation and depletion of volatile elements [1]. Additional questions include 1) to what extent these fractionations occur in impact melts, and 2) whether or not other geochemical trends are associated with impact melting. To address these issues, we use the Gardnos impact structure as a case study.

The Gardnos impact structure (60°40'N, 9°00'E) is a 6-km diameter crystalline-target impact structure, with a large suite of impactites. Impact melt at Gardnos consists of three types: 1) discrete melt clasts within suevite and suevitic breccias, 2) a small outcrop of melt-matrix breccia [2, 3], and 3) a few thin melt-breccia injection dikes. Previous work has suggested that melt clasts in the suevites represents localized melting, whereas the melt-matrix breccias may represent part of a melt-sheet which has been eroded post impact [3]. In order to test this further, melt-clasts have been selectively removed from the suevites in order to geochemically compare individual clasts with each other and with the other melt types.

Analytical Technique: Individual melt clasts within suevites and melt-breccia dike were powdered with a micro-drill (for suevite clasts, a tungsten drill bit was used and therefore W concentrations were excluded due to contamination). For each sample 30 to 100 mg of powder was dissolved in a nitric and hydrofluoric acid mixture. After dissolution, the samples were diluted to a 1:5000 solution of 10 ppb In (drift monitor) in 1% nitric acid. Solutions were analyzed on a GVI Platform XS quadrupole mass spectrometer. BCR-1, AGV-1, BHVO-1, and SR-1 were used as standards and internal drift monitors. Uncertainties are estimated to be less than 5%.

Melt Clasts in the Suevites: Melt clasts are enriched in incompatable elements (most notably Ba). Similarly intriguing Ba enrichments are seen at other crystalline target impact structures (Lonar [4], Tenoumer [5], and Lapparjarvi [6]), which may reflect an important process involved during impact melting. Are these Ba enrichments due to partial melting and/or vaporization of feldspar-rich targets?

Compared to bulk suevite analyses, individual clasts in this study have lower trace element concentrations normalized to Silicate Earth [7] (figures 1, 2). This suggests there should be a complementary enriched component of the suevites that has yet to be identified.

Rare Earth Element (REE) patterns of individual melt-clasts are similar to bulk suevites, but generally lower in concentration (figure 2), and show a slightly concave heavy REE pattern.

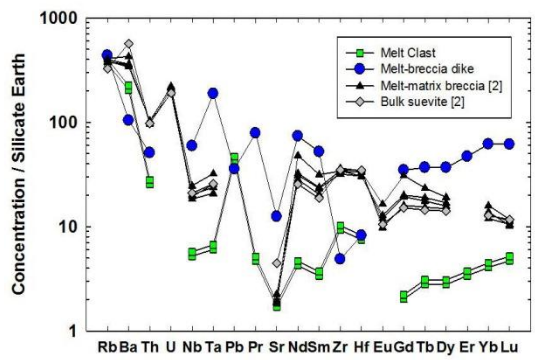

Figure 1: Trace elements of individual melt clasts, melt-breccia dike (this study), and bulk analysis of suevites and melt matrix breccia [2], normalized to the Silicate Earth [7]. Individual melt-clasts show a different trace element pattern than bulk suevites.

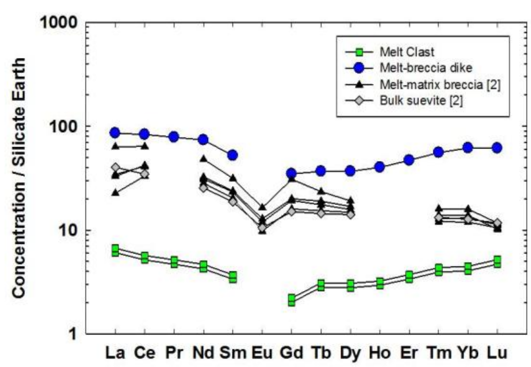

Figure 2: Rare Earth Element concentrations normalized to the Silicate Earth [7] of individual melt clasts, melt-breccia dike, and bulk analysis of suevites and melt matrix breccia [2]. The melt-dike is enriched in both heavy and light REE's.

Melt injection dike: Field work in 2010 identified a melt-breccia dike interpreted as an injection dike into the unshocked Gardnos Breccia. This dike shows higher trace element concentrations than melt-clasts in suevites (figures 1 and 2). This melt dike has a high sphene (figure 3) content which likely hosts many of the trace elements. Future work may target these for detailed trace element and isotopic analyses. If the enrichments in REE's occur during the impact event, then these sphene grains may be ideal for U-Pb or Sm-Nd age dating of the impact event.

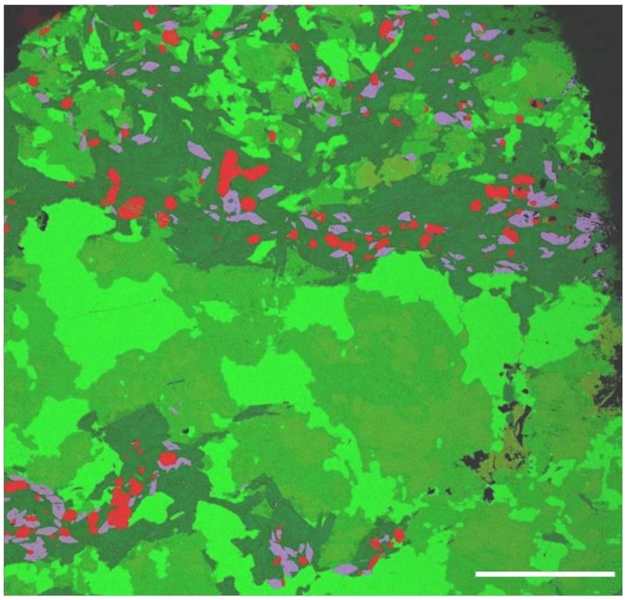

Figure 3: Electron Microprobe map of the sphene rich melt-breccia dike, showing Ca (red), Si (Green), and Ti (blue). Scale bar is 3 mm.

The geochemistry of this melt-breccia dike is consistent with the petrography and field observations suggesting it is a distinctly different unit from previously recognized litholoigies. As expected based on knowledge of crater formation, the Gardnos impact event consisted of brecciation of the basement, formation/deposition of suevites and injection of melt into the underlying basement.

Implications and Future Work: Trace elements of individual melt clasts within suevites are suggestive of partial melting events, and future work should include analyses of the matrix and other rock clasts to understand the relationship between individual melt clasts and the bulk suevite.

References: [1] Taylor, S. R. and Esat, T. M. (1996) in *Earth Processes Reading the Isotopic Code*, Geophysical Monograph 95. [2] French, B. M. et al. (1997) *GCA*, 61, 873-904 [3] Kalleson, E. et al. (2010), *Meteoritics and Planet. Sci.,* 45, No. 5, 798-827. [4] Chakrabarti, R. and Basu, A. (2006) *EPSL*, 247, 197-211. [5] Pratesi, G. et al. (2005) *Meteoritics and Planet. Sci.,* 40, No. 11, 1653-1672 [6] Reimold, W. U. (1982). *GCA*, 46, 1203-1225. [7] McDonough, W. F. and Sun, S. (1995) *Chemical Geology,* 120 p. 223-253.

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