IMPLICATIONS OF R CHONDRITE MELTING EXPERIMENTS ON THE FORMATION OF GRA 06128/9. K. G. Gardner-Vandy[1], T. J. McCoy[1], C. M. Corrigan[1], D. S. Lauretta[2], and G. K. Benedix[3]. [1]Division of Meteorites, Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560-0119, [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, [3]Department of Applied Geology, Curtin University of Technology, Bentley, Western Australia. Email: Gardner-VandyK@si.edu.

Introduction: Graves Nunataks (GRA) 06128 and 06129 are paired oligoclase-rich (~71-90 vol. %) (Fig. 1) achondrite meteorites that contain geochemical and petrologic evidence that links them to the brachinites [1-3]. The brachinites are olivine-dominated primitive achondrites with FeO-rich silicates (Fa_{32-36}) that exhibit recrystallized texture [3-4]. GRA may have formed as a primary partial melt of an oxidized, volatile-rich chondritic precursor complementary to a brachinite-like olivine-rich residue [1,3]. If correct, GRA would represent the first meteoritic felsic melts complementary to a sampled olivine-rich residue.

Two models have emerged for the formation of GRA 06128/9. Given its unusual bulk composition and texture, some authors have argued that GRA samples a single, crystallized partial melt [1,3]. In contrast, others have suggested that GRA is an annealed breccia consisting of a nearly-pure feldspar lithology and a mafic assemblage, the former of which might require physical separation of feldspar, akin to magma ocean processes [2].

We previously presented partial melting experiments of R4 chondrite LaPaz Ice Field (LAP) 03639 in order to simulate brachinite formation [5]. Partial melting of an R chondrite at 1250 °C and an fO_2 of IW-1 produces ~28% melting, resulting in mineralogies and compositions similar to the brachinites (Fa_{32-36}) [5]. In addition to running experiments comparable to brachinite formation (i.e. fO_2 of IW-1 to IW [5]), we also ran an experiment at an fO_2 of IW+1 to extend the experimental space to include the formation conditions of GRA [2]. These experiments generated lower degrees of partial melting (13-19%). We examine the experimental melt compositions to constrain whether GRA is a complementary partial melt to a brachinite residue.

Results: Relative to the bulk composition of GRA 06128/9 [6], our experimental melt compositions are depleted in SiO_2 (48 vs. 61 wt.%) and Al_2O_3 (8 vs. 20 wt.%) and enriched in FeO (25-30 vs. 3 wt.%), MgO (8-10 vs. 2 wt.%) and CaO (6 vs. 3 wt.%).

To represent our melt compositions, we have plotted these bulk compositions, along with bulk R chondrites, in the Ab-SiO_2-Fo ternary [7] following the methodology of [8] (Fig. 2). Rather than the more widely cited An-SiO_2-Fo phase diagram, we chose this system because of the sodic nature of the feldspar in GRA and the exceptionally plagioclase-rich composition of the eutectic. We recognize the limitations of this phase space, particularly owing to the lack of free SiO_2 in R chondrites, brachinites or GRA.

Not surprisingly, GRA plots at the extreme edge of this ternary at ~98% plagioclase and ~2% forsterite. In contrast, R chondrites plot in the forsterite field, consistent with their modal mineralogy. Interestingly, the composition of our 1250°C melts plot on or near the forsterite-enstatite reaction boundary. With calculated abundances of albite of up to 70%, these compositions are significantly more plagioclase rich than the eutectic melt in the Ab-SiO_2-Fo system, although still less plagioclase-rich than the GRA modal mineralogy.

Discussion: A first-order conclusion of our work is that melting of an R chondrite at 1250°C (~13-28% partial melting) does not produce a partial melt comparable in composition to GRA. Interestingly, this percentage of melting is nearly identical to that suggested by [1] for the formation of brachinites and GRA from a chondritic precursor. One possible explanation is that they were not derived from an R chondrite precursor.

Alternatively, GRA could have formed as a mixture of a near-eutectic, plagioclase-rich melt and a mafic residue, akin to the model suggested by [2]. This model is untenable, as the mafics in GRA ($Fa_{\sim 60}$) are much more FeO-rich than the mafics in R chondrites ($Fa_{\sim 40}$), counter to the expectation for a residue.

Finally, GRA might represent a partial melt composition. In this case, the composition (~10% mafics) lies close to, but not at, the eutectic in the Ab-SiO_2-Fo ternary. The melting temperature would have to be less than 1250°C and the degree of partial melting likely less than 10%. This model can be explored experimentally, but leaves unresolved the question of how a partial melt of such low degree would migrate and concentrate or how its subsequent crystallization would produce the textures, particularly the mafic enclaves, observed in GRA.

References: [1] Day J. M. D. et al. (2009) *Nature 457*, 179-182. [2] Shearer C. K. et al. (2010) *GCA 74*, 1172-1199. [3] Day J. M. D. et al. (2012) *GCA 81*, 94-128. [4] Mittlefehldt D. W. et al. (1998) *Planetary Materials* (ed. J. Papike). *Rev. Mineral., 36*. [5] Gardner-Vandy K. G. et al. (2012) *LPS XLIII*, Abstract #1610. [6] Arai T. et al. (2008) *LPS XXXIX*, Abstract #2465. [7] Schairer J. F. and Yoder H. S., Jr. (1961) *Carnegie Inst. Wash. 60*, 69-70. [8] McCoy T. J. et al. (1999) *M&PS 34*, 735-746.

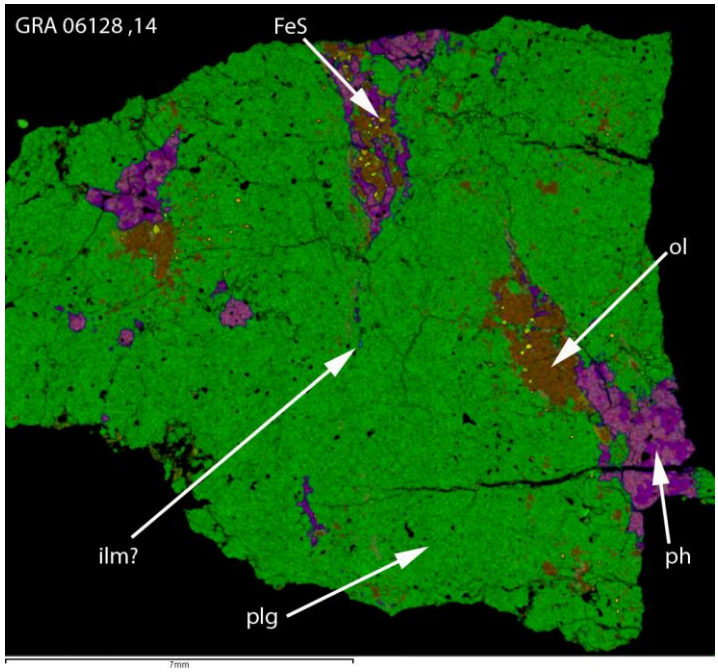

Figure 1: Combined elemental maps displaying the mineralogy and texture of GRA 06128. Plagioclase (plg) is the green phase, phosphate (ph) is the purple phase, olivine (ol) is the brown phase, troilite (FeS) is the bright yellow phase, and a Ti-rich oxide (possibly ilmenite) is shown. Scale bar is 7 mm.

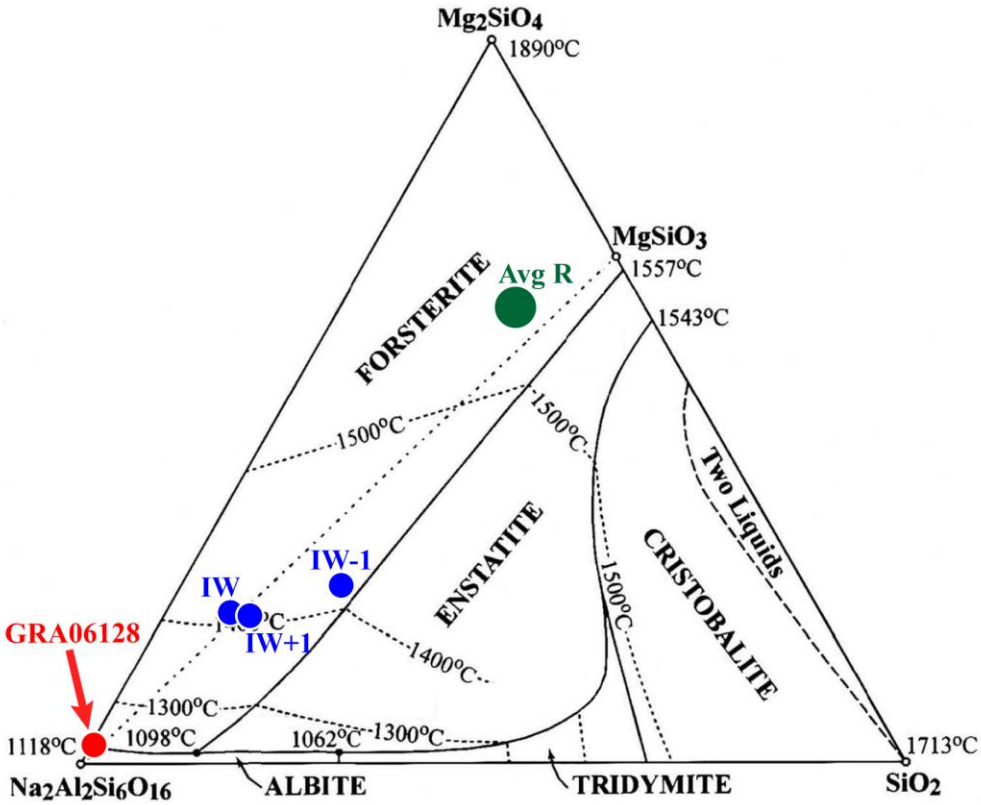

Figure 2: Albite-Forsterite-Quartz phase diagram [7] showing the bulk composition of GRA 06128/9 (red dot) [6], melt composition from three R chondrite partial melting experiments done at fO_2 of IW-1, IW, and IW+1 (blue dots) [5], and the bulk composition of average R chondrite (green dot) [Bischoff et al., 2011].