Making Silica-rich Rocks without Plate Tectonics or Water by Partial Melting of a Primitive Meteorite

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Introduction

Relevant Background

Until the discovery of GRA 06128/9, found during the 2006-2007 Antarctic season (Fig 1), all known differentiated, silicate meteorites were mafic or ultramafic in composition. These two achondritic (igneous) meteorites (Fig 2) are andesitic in composition, suggesting that relatively silicic melts, analogous to Earth's crust, can form on planetesimals without complex geologic processes - like plate tectonics.

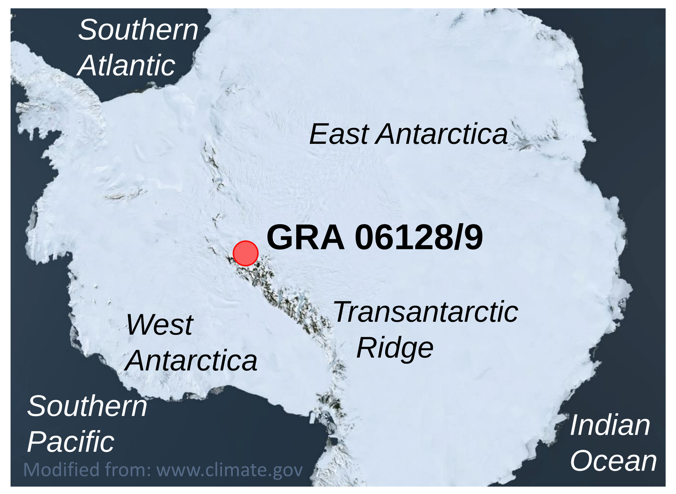


Fig 1: Map of Antarctica, the area where GRA 06128/9 were found is shown in red

Motivation

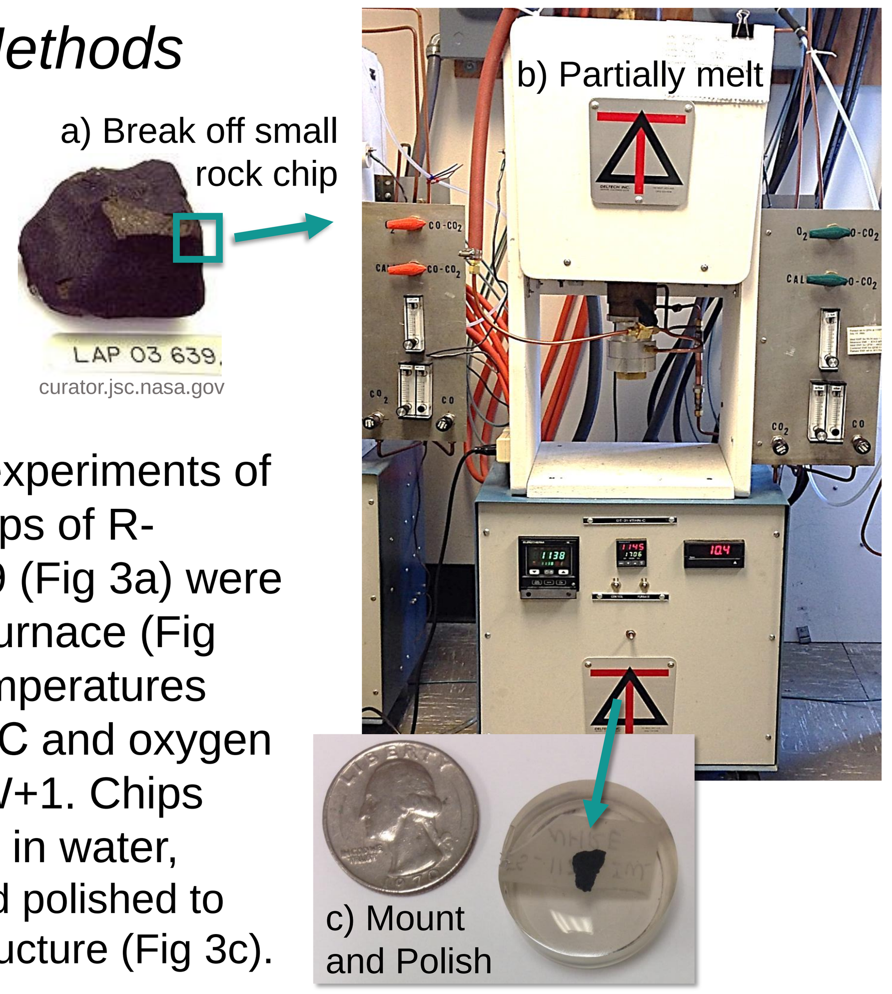
Gardner-Vandy et al. (2013) suggest that low degrees of partial melting of an R-chondrite can generate an andesitic melt, compositionally similar to GRA 06128/9. We aim to further explore this finding, and constrain the condition of formation of GRA 06128/9 with partial melting experiments of an R-chondrite.

Fig 2: GRA 06128, one of the only two andesitic achondrites known to science

Methods

Experimental Methods

Fig 3: Experimental method: (a) LAP 03639 before chips were broken off; (b) gas mixing furnace; (c) mounted and polished experiment, ready for analysis



Five partial melting experiments of 142.2 - 155.8 mg chips of R-chondrite LAP 03639 (Fig 3a) were run in a gas mixing furnace (Fig 3b) for 4 hours at temperatures between 1080-1140˚C and oxygen fugacities of IW to IW+1. Chips were drop-quenched in water, mounted in epoxy, and polished to expose the interior structure (Fig 3c).

Analysis

Potential melt pockets were located using a scanning electron microscope (SEM). Melt pockets > 2 µm were marked on back scatter electron (BSE) maps (Fig 5), which then guided field emission gun-electron microprobe (FEG-EPMA) analyses at the Carnegie Institution for Science Geophysical Laboratory.
119 melt pockets were analyzed.

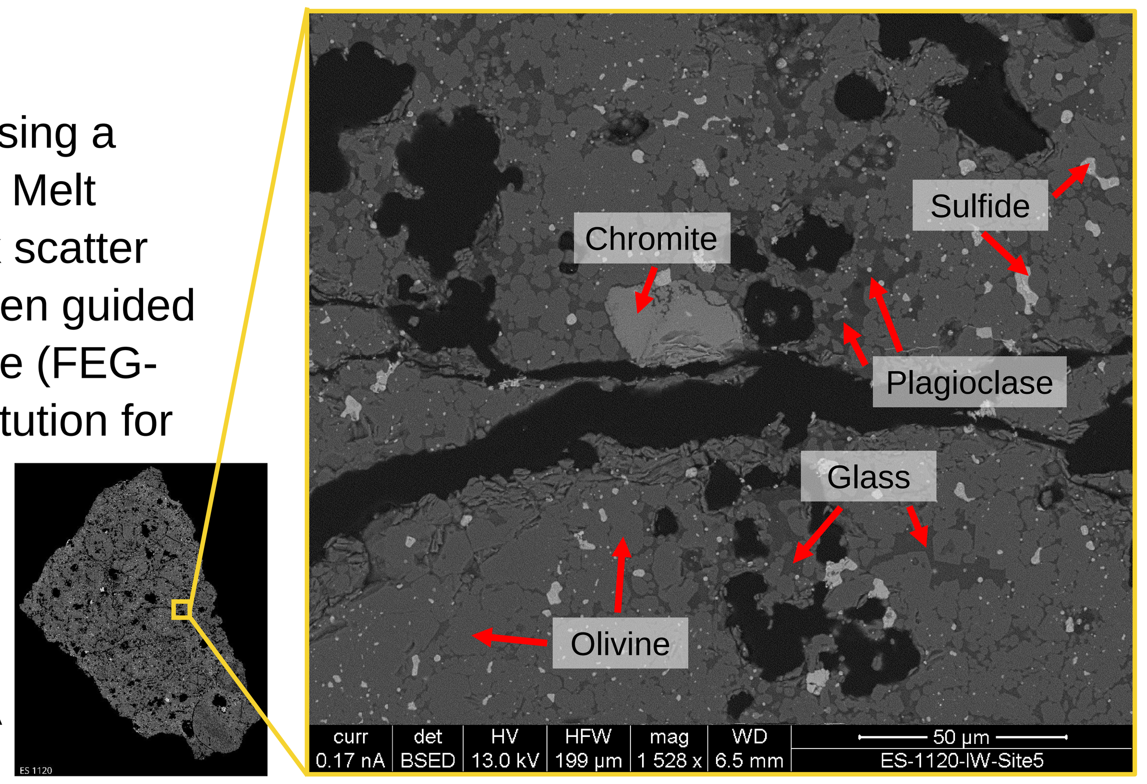
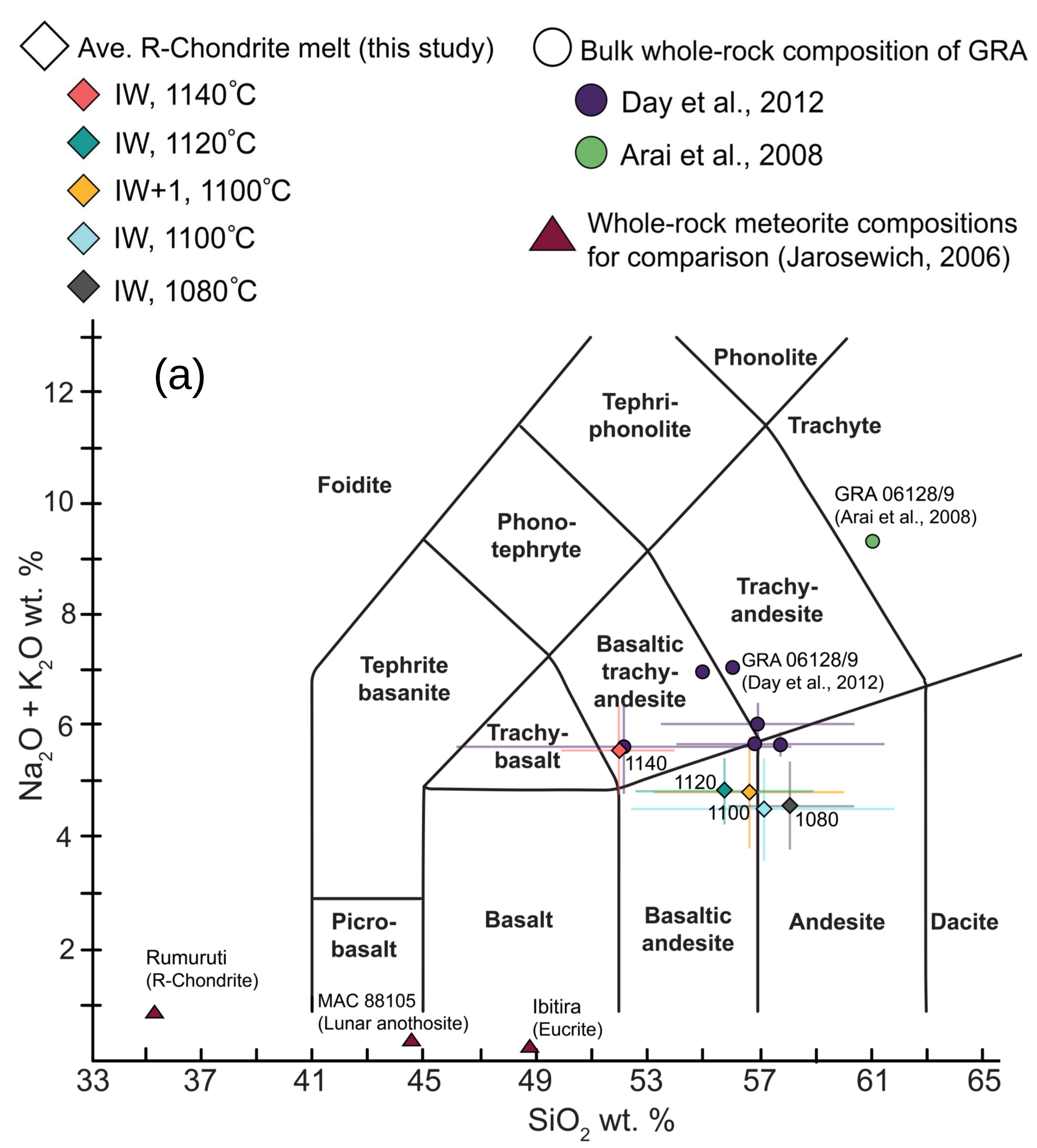


Fig 5: BSE mapping used to guide FEG-EPMA analysis

Results

Melt Composition

Melt compositions range from andesite to basaltic trachyandesite, similar to the bulk composition of GRA 06128/9 (Day et al., 2012). At higher temperatures, average wt.% SiO_2 and Al_2O_3 decreased (Figs 6a & 6b) and average wt.% CaO and FeO increased (Figs 6c & 6d). Melts generated at 1120 – 1140˚C provide the best match to the bulk composition of GRA 06128/9.



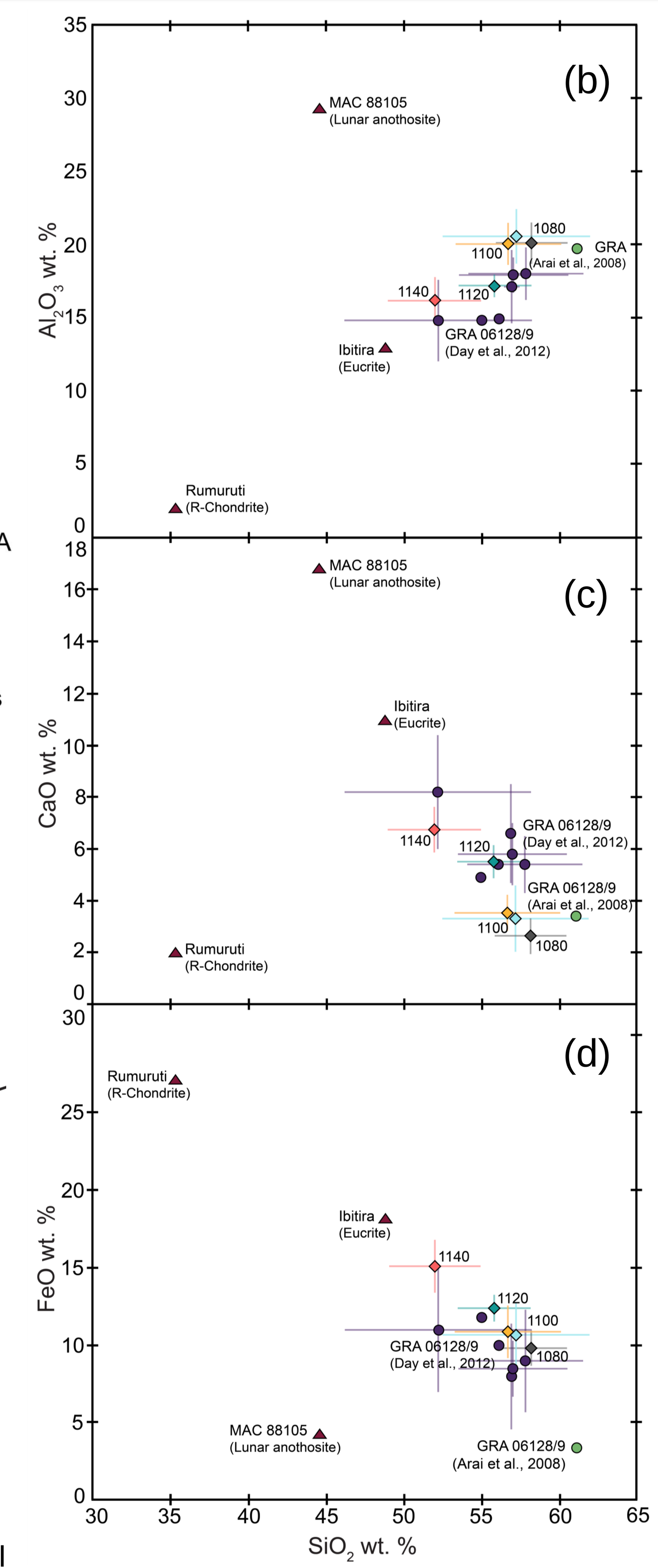


Fig 6: Compositional plots of melt data for the five experiments. Total alkalis vs. silica (a), Al_2O_3 vs. SiO_2 (b), CaO vs. SiO_2 (c) and FeO vs. SiO_2 (d)

Discussion

At lower temperatures, plagioclase is the dominant melting phase (Fig 7a), resulting in higher concentration of SiO_2 and Al_2O_3, with minor contributions from clinopyroxene and phosphates (like apatite). Our data suggest the contribution of relatively Si-poor and Fe/Ca-rich minerals (like clinopyroxene) increased in the higher-temperature experiments (Fig 7b).

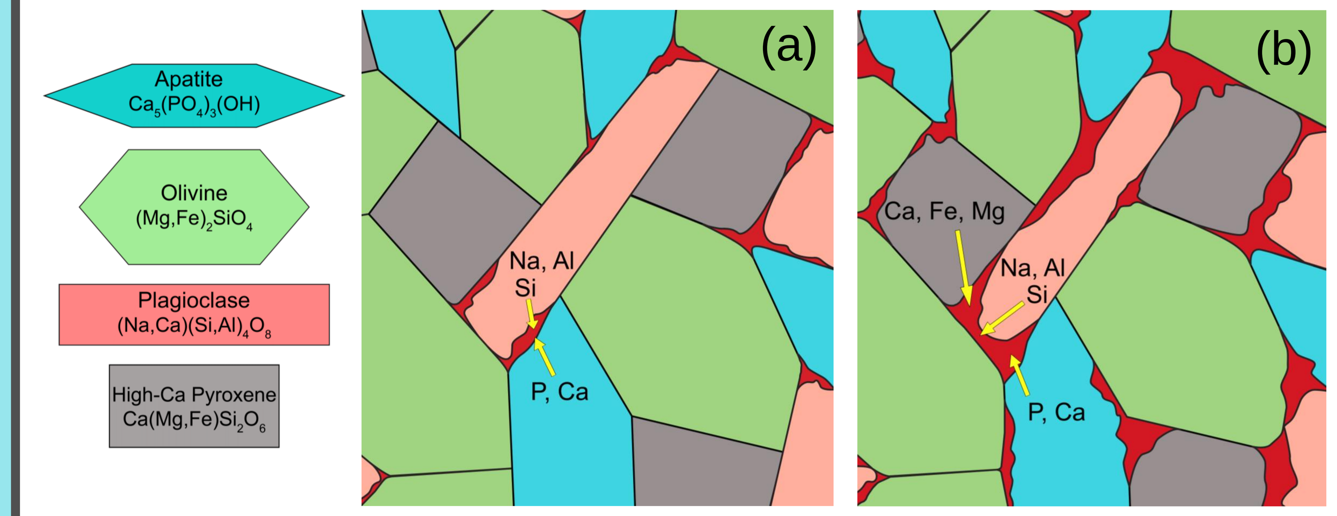


Fig 7: Influence of contributing phases to melt composition at 1080˚C (a) and 1140˚C (b). Melt concentrations of Ca, Fe, and Mg increase at 1140˚C as high Ca-pyroxene begins to melt

GRA 06128/9 likely formed on a small (<100 km) planetesimal, with weaker gravity, allowing melts to segregate from the residue more readily to form larger pools and, potentially, a silicic crust.

Conclusions

1. Our melts are most similar to the bulk GRA 06128/9 composition presented in Day et al. (2012), suggesting that the parent melt of GRA 06128/9 could have been produced by the low-degree partial melting of a primitive rock, compositionally analogous to an R-chondrite.

2. Compositional variations between IW+1 and IW experiments are statistically insignificant; our conclusions therefore hold true for the oxygen fugacity range of GRA (IW ≤ fO_2 ≤ IW+2).

3. Andesitic melts, analogous to those that formed the continental crust of earth, can be formed in dry environments (no water present) and without plate tectonics.

Acknowledgements and References

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