PETROGRAPHY AND ORIGIN OF THE UNIQUE ACHONDRITE GRA 06128 & 06129: PRELIMINARY RESULTS. A.H. Treiman[1], R.V. Morris[2], D.A. Kring[1], D.W. Mittlefehldt[2], J.H. Jones[2] and other GRAvediggers. [1]Lunar & Planetary Institute, 3600 Bay Area Blvd. Houston TX 77058 <treiman#lpi.usra.edu> [2]ARES division, Johnson Space Center, Houston TX 77058

GRA 06128 & 06129 are paired achondrites [1], with unique mineral proportions (75% oligoclase), mineral compositions, and oxygen isotope ratios. They appear to represent alkalic igneous rock from a hitherto unsampled differentiated parent body, modified significantly by thermal and shock metamorphism.

Samples and Methods. Bulk samples were examined at JSC during splitting for consortium analyses. Microscope and BSE images here are on thick section GRA06128,40. Chemical analyses of minerals were acquired at Johnson Space Center with the Cameca SX100, operated at 15 kV. Feldspar was analyzed with a defocused 5 µm beam @ 5 nA; other minerals were analyzed with a focused beam @ 20 nA. Mössbauer spectra were obtained at ARES, JSC [2]. Intrinsic radioactivity was measured in the low-level counting facility at ARES JSC [3]. An estimated abundance of ^{26}Al of ~70 dpm/kg is within the range determined for eucrites.

Bulk Sample: The meteorites are slab-shaped gray rocks with partial fusion crusts of shiny black glass. They consist of massive rock (grain sizes ~500µm) gradational and interlayered with strongly foliated easily split rock (grain sizes ~ 50 µm). The foliation is defined by parallel fractures; no lineations were seen.

The meteorites are extensively rusted, and emit a sulfurous odor on crushing.

Thin Section: GRA06128 consists mostly of oligoclase feldspar (75% area), with lesser proportions of mafic silicates (olivine and two pyroxenes, ~20% total), and percent levels of Ca-phosphates, sulfides and chromite (Fig. 1). Small grains of Ni-rich metal are reported [1]. Alteration is pervasive, and appears as rusty deposits on grain boundaries and cracks.

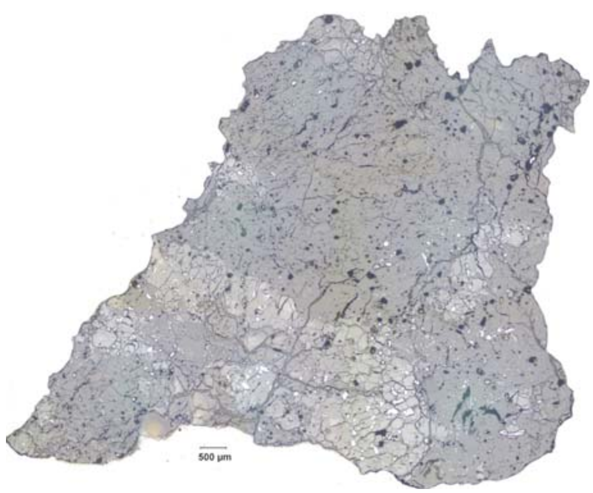

Fig. 1. Mosaic of reflected light images, GRA06128,40. Dark gray is oligoclase; intermediate are mafic silicates, bright are sulfides and chromite. Upper center is ½ cm-size mass of oligoclase in upper-center, composed of several ~mm grains.

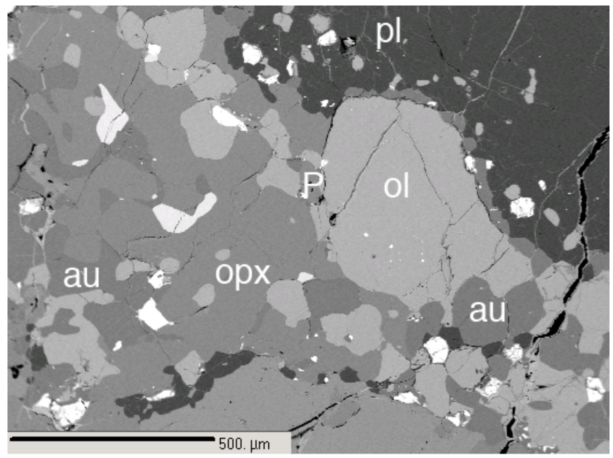

Fig. 2. BSE image at boundary of an oligoclase-rich mass (pl) and a mafic clot (bottom), near center of Fig. 1. Olivine, ol; orthopyroxene, opx; augite, au; phosphates, P.

Our section contains masses (to ½ cm) of nearly pure oligoclase (Fig. 1) that are separated by lenses and angular masses of ferromagnesian minerals and sulfides. The largest oligoclase-rich area (Fig. 1) is nearly square, and is composed of several tabular crystals with smaller irregular grains between them. The oligoclase-rich areas contain masses (to 500 µm) of mafic minerals, sulfides and oxides, similar to the mafic clots that bound the oligoclase areas. Oligoclase grains contain abundant small ellipsoidal inclusions of sulfide minerals, commonly marking planes or curving surfaces in the section. Oligoclase has a constant composition across the section: $Ab_{82.3}An_{16.0}Or_{01.7}$.

Clots of mafic material among the oligoclase-rich areas are lens-shaped or blocky, and up to a ½ cm long; individual grains are in the 100 µm size range. Some areas show a poikilitic texture of rounded silicate and oxide grains within pyroxene (left side of Fig. 2); other areas have a granulitic texture (lower right, Fig. 2). Silicates include olivine (Fa_{59}, NiO=0.06%), orthopyroxene (Wo_2En_{51}, Fe/Mn=46), augite with sparse exsolution lamellae ($Wo_{43}En_{37}$, Fe/Mn=37), and oligoclase. EMP data and visible-NIR spectra suggest low Fe^{3+} in the silicates. Troilite (Fig. 3), pentlandite, and chromite are present at percent levels.

Ca-phosphate is common as Cl-rich apatite, surrounded and replaced by Na-Fe-Mg-bearing merrillite. The largest such grain is ~1mm x 250 µm. In one area, Ca-phosphate appears to have replaced augite, or grew from an interstitial melt that was resorbing augite.

The meteorites are extensively oxidized, with ~20% of their iron as nano-phase ferric oxide (Fig. 3).

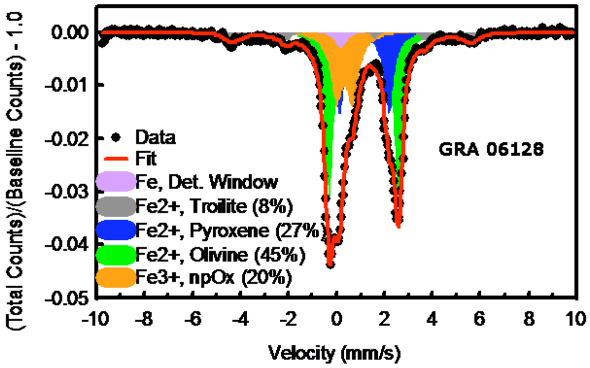

Fig. 3. Mössbauer spectrum of a bulk sample GRA06128, and peak fit. Percentages are of Fe in the sample. 'npOx' is nano-phase iron oxide.

Origin and History: With the data in hand, one can only speculate on the origin and history of the GRA 06128 & 01629 meteorites. It seems most likely that they represent a alkalic igneous rock (Na_2O+K_2O of 5-15%) from a hitherto unsampled differentiated parent body, and were modified significantly by thermal and shock metamorphism.

'New' Parent Body. The GRA meteorites' combination of isotopic and mineral compositions is unlike those of any other meteorite. $\delta^{18}O \approx +6‰$ and $\Delta^{17}O \approx -0.05‰$ [1] are distinct from other meteorites [4-6] except the primitive achondrite NWA 2788 [7]. Mineral compositions in GRA are distinct from those of other achondrite groups and NWA 2788 (although Fe/Mn in olivine is like Earth's) [7,8].

Alkalic Igneous Rock. In the IUGS classification of igneous rocks, GRA would be a leucodiorite [9]; its highly sodic feldspar warrants the adjective 'alkalic.' The tabular shapes of oligoclase grains, the poikilitic textures of mafic areas, and the replacements of augite by apatite, and apatite by merrillite, suggest an igneous origin. From our examination of bulk sample and microscopic views, there is no evidence that GRA is an impact melt breccia. It does not contain, for example, relict clasts of an impacted protolith. On the other hand, the report of Ni-rich metal [1] would be consistent with contamination from an impacting projectile. Thus, it is unclear if GRA was an endogenous igneous rock, or was formed in a differentiated impact melt.

Differentiated Parent Body. The low NiO and low Fe/Mn of the mafic minerals in GRA suggest that its source was depleted of Ni and Fe relative to a chondritic precursor. Such depletions in eucrites and Martian rocks are interpreted to reflect segregation of metal via core formation; a similar inference could be made for the GRA parent body.

It is not clear how extensively differentiated the GRA parent body must have been. On one hand, the GRA oligoclase has essentially the same Ab content as those in grade 5 & 6 chondrites [5], suggesting that GRA could be a simple flotation cumulate of a melted chondrite. However, this scenario requires a source chondrite different from known varieties: compared to O and R chondrites, GRA's oligoclase has far less K and its mafics have lower Mg*. On the other hand, if GRA did evolve from a partial melt of a known chondrite, its low Mg* and high phosphate abundances suggest extensive differentiation, i.e. as inferred for the QUE 94201 Martian basalt [10,11].

Metamorphism. GRA 06128 & 06129 experience a prolonged interval at high temperature, as shown by the homogeneity of mineral compositions, and the areas of granulitic texture. Augite-opx solvus thermometry gives ~700°C [12] for exsolved augite – peak T would have been higher. The ellipsoids of sulfide minerals in the silicates bespeak sulfide melting.

The slabby nature of the hand samples and the abundance of aligned fractures suggest shock deformation. Oriented thin sections (in preparation) will permit characterization of these deformation effects, and possible mineralogical indicators of shock.

Forthcoming. This abstract is the first report from a consortium study of the GRA achondrites. Data presented here will be enlarged and augmented with petrofabric study and mineral trace element analyses. Additional studies in progress include reflectance spectroscopy, bulk chemistry, Ar isotope analyses and Ar-Ar dating, and radiogenic isotope analyses in the systems Rb-Sr, Sm-Nd, Re-Os, and Lu-Hf.

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References: [1] Satterwhite C. & Righter K. (2007) *Antarctic Meteorite Newsletter* 30(2). [2] Morris R.V. et al. (2000) *JGR* 105, 1757. [3] Lindstrom D.J. (1990) *Nucl. Instr. Meth. Phys. Res., A299*, 584-588. [4] Mittlefehldt D.W et al. (1998) Ch 4. in *Planetary Materials* (MSA RIM 36). [5] Brearly A. & Jones R. (1998) Ch 4. in *Planetary Materials* (MSA RIM 36). [6] Rumble D. et al. (2007) *Lunar Planet. Sci.* XXXVIII, Abstr. 2230. [7] Bunch T. et al. (2006) *EOS* 87(52), Abstr. P51E-1246. [8] Papike J.J et al. (2003) *Am. Mineral.* 88, 469-472. [9] LeMaitre R. ed. (2002) *Igneous Rocks: A Classification*. Cambridge. [10] McSween H.Y.Jr. et al. (1996) *GCA* 60, 4563-4569. [11] Kring D.A. et al. (2003) *MaPS* 38, 1833-1848. [12] Lindsley D.H. and Anderson D.J. (1983) *JGR* 88, A887-A906.