EFFECT OF IMPACT-RELATED PROCESSES ON THE LEAD ISOTOPE SYSTEMATICS OF ANORTHOSITES: A LUNAR ANALOGUE STUDY AT MISTASTIN LAKE CRATER, LABRADOR. A. K. Souders[1], P. J. Sylvester[1] and G. R. Osinski[2], [1]Department of Earth Sciences, Memorial University of Newfoundland, St. John's, NL, Canada A1B 3X5 (kate.souders@mun.ca; psylvester@mun.ca), [2]Centre for Planetary Science and Exploration, Depts. Earth Sciences/Physics and Astronomy, University of Western Ontario, London, ON

Introduction and Rational: The origin of the Moon is one of the fundamental questions in planetary science. It is generally thought that the Moon was derived from a giant Mars-size body impacting the Earth (e.g. [1]). Indistinguishable $\Delta^{17}O$ [2,3] and $\delta^{30}Si$ [4] signatures between the Moon and silicate Earth provide geochemical evidence in support of this theory, yet it remains unclear whether the Earth and Moon also share similar primitive compositions for other isotopic systems, such as Pb, due to the uncertain composition of primitive lunar Pb.

It is important to establish the primitive lunar Pb composition in order to further evaluate the giant impact origin for the Moon. Many attempts have been made to characterize primitive lunar Pb yet have been hindered by the low Pb abundance in most lunar samples, the radiogenic nature of lunar Pb and the susceptibility of the U-Pb system to disturbance due to secondary processes such as impacts and metasomatism, or laboratory contamination. The primitive Pb isotope composition of the Earth is represented by the composition of triolite from the Canyon Diablo iron meteorite (CDT) [5]. It can be assumed the Moon shares a similar initial Pb composition if both the Earth and Moon formed from material condensed within the same nebular source region [6], yet the radiogenic nature of primary Pb in lunar rocks (μ ~35 to > 1000) is in sharp contrast to Pb in the terrestrial mantle (μ ~8 to 10).

The Pb in lunar samples is a complex, multi-component mixture of initial Pb, initial radiogenic Pb and primary radiogenic Pb [6]. An excess of radiogenic Pb, unsupported by radioactive decay of U and Th, is common in most lunar samples, including some of the oldest Ferroan Anorthosites (FAN; > 4.36 Ga). Models to explain the excess radiogenic Pb in FAN have included early (> 4.36 Ga) development of a high-μ, KREEP-rich reservoir within the lunar upper mantle/lower crust, and volatile mobilization of radiogenic Pb from KREEP sources during 3.9 Ga basin-forming impacts [6]. However, evidence of a secondary heating process necessary for Pb mobilization has not been identified in many lunar samples with unsupported radiogenic Pb [7].

In order to assess the effect of impact processes on Pb isotope systematics, in preparation for examining lunar samples directly, we have investigated the elemental and Pb isotope systematics of well-preserved magmatic plagioclase, shocked plagioclase and maskelynite from terrestrial anorthosites of the Mistastin Lake impact structure, Labrador, Canada. We used an in-situ analytical approach in order to target the best-preserved areas of minerals, eliminate the difficulty of mechanically separating components for analysis and reduce the potential for laboratory Pb contamination.

Geological Setting: Mistastin Lake impact structure represents an intermediate-size complex crater. It is an unique lunar analogue site, being the only known terrestrial crater to produce impact melt largely from an anorthositic source [8]. In contrast to the Moon, impactites at Mistastin are the product of a single impact event, preserving simple field relationships of shocked and unshocked anorthosite. Mangerite and granodiorite are also target rocks at Mistastin. Both can be consdered proxies for radiogenic, incompatible element enriched KREEP-like compositions identified in lunar rocks. Mangerite occurs with anorthosite on Horseshoe Island, the central uplift of Mistastin Lake.

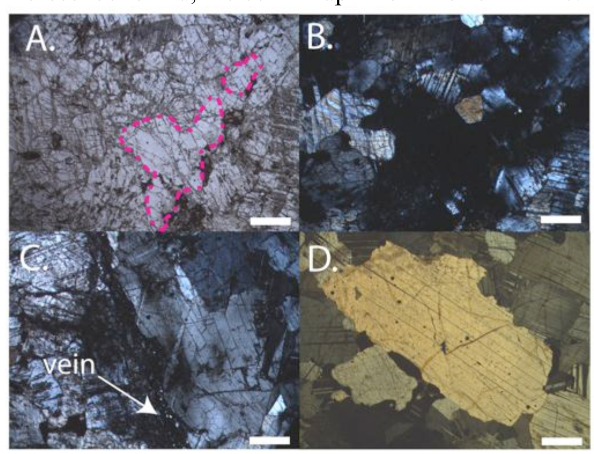

Fig 1: Optical images of plagioclase crystals analyzed. All images taken in cross-polarized light (XPL) with the exception of (A). (A) Shock-fractured plagioclase and maskelynite (traced) in plane-polarized light. (B) XPL view of A, showing isotropic maskelynite. (C) Clast-bearing glassy vein. (D) Unshocked anorthosite crystal. Scale bar is 1000 μm.

Components Analyzed: Five different materials were analyzed: (1) Plagioclase from shocked anorthosite (Figs. 1A,B,C) in 3 samples collected on Horseshoe Island. (2) Maskelynite found in association with anorthosite plagioclase crystals in the 3 Horseshoe Island samples (Figs. 1A,B). (3) A clast-bearing glassy vein, adjacent to plagioclase in one sample (Fig.1C). (4) Unshocked plagioclase laths from anorthosite located east of South Creek, on the east side of the lake (Fig 1D). (5) Well-preserved areas of plagioclase megacrysts from mangerite at Steep Creek, on the north side of the lake.

Methods: Elemental data were acquired using a Thermo-Scientific ELEMENT XR magnetic sector, single-collector inductively coupled plasma mass spectrometer (ICP-MS) coupled to a 193 nm GeoLas laser ablation (LA) system at Memorial University. A 49 μm laser spot was used for all LA-ICPMS element analyses. Raw data were reduced with LAMTRACE [9]. Pb isotope measurements were acquired with the same LA-ICPMS system described above using a method similar to that described in [10]. Pb isotope ratios were calculated using 'SC-Pb-Tool', an in-house spreadsheet modified from 'LAM-Tool' [11].

Results: *Major and Trace Elements*: Na/Ca vs. [Pb] are shown in Fig. 2A and Na/Ca vs. chondrite-normalized $[La/Sm]_n$ in Fig. 2B for all components analyzed. Shocked and unshocked anorthosite plagioclase and maskelynite have similar Pb concentrations (avg. ~3.5 ppm), Na/Ca (avg. ~0.6) and $[La/Sm]_n$ (avg. ~10). The glassy vein has similar Pb and $[La/Sm]_n$ as the shocked and unshocked anorthosite plagioclase and maskelynite but distinctly lower Na/Ca (avg. ~0.35). Mangerite plagioclase has the highest Na/Ca (avg. ~1.4), Pb concentration (~25 ppm) and $[La/Sm]_n$ (avg. ~60), forming a distinct group on both plots.

Pb isotopes. Due to the low total Pb concentrations (< 10 ppm Pb) of most materials analyzed, only $^{207,208}Pb/^{206}Pb$ data are presented at this time. Two distinct groups are observed in the Pb isotope data (Fig. 3). The Pb isotope compositions of the shocked and unshocked anorthosite plagioclase, maskelynite, and mangerite plagioclase all overlap. The clast-bearing glassy vein has distinctly higher $^{208}Pb/^{206}Pb$ with generally over-lapping $^{207}Pb/^{206}Pb$.

Conclusions: Impact at Mistastin did not result in modification of $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$ in the studied anorthosite plagioclase, based on the observed similarities in Pb-isotopic compositions of the unshocked and shocked plagioclase and maskelynite. The glassy vein may represent impact melt that invaded the anorthosite from an external, ^{208}Pb-enriched source, perhaps a phase other than plagioclase in the mangerite. Similarities in Pb concentration and $[La/Sm]_n$ between the unshocked and shocked plagioclase and maskelynite indicate, however, that the anorthosite plagioclase was not affected by mobilization of melt veins into the anorthosite. If the unsupported radiogenic Pb found in lunar FAN is the result of volatilization and mobilization of Pb related to ~3.9 Ga impact events, the Mistastin results suggest that infiltration of Pb from external sources was much more pervasive in lunar anorthosites than in the anorthosites of Horseshoe Island. This may reflect more intense impacting on the Moon and/or a more intimate spatial relationship between lunar FAN and KREEP than Mistastin anorthosite and mangerite-granodiorite.

Acknowldgement: Funding provided by the Canadian Space Agency (GRO, PJS), an NSERC Discovery Grant (PJS) and a NSERC CREATE Fellowship (AKS)

References: [1] Hartmann W.K. and Davis D.R. (1975) *Icarus, 24*, 504-515. [2] Wiechert U. et al. (2001) *Science, 294*, 345-348. [3] Spicuzza M.J. et al. (2007) *EPSL, 253*, 254-265. [4] Armytage R.M.G. et al. (2012) *GCA, 77*, 504-514. [5] Patterson C.C. (1956) *GCA, 10*, 230-237. [6] Premo W.R. et al. (1999) *Int. Geol. Rev., 41*, 95-128. [7] Nemchin A.A. et al. (2011) *GCA, 75*, 2940-2964. [8] Marion C.L. and Sylvester P.J. (2010) *Planet. Space Sci., 38*, 552-573. [9] Jackson S. (2008) *MAC, 40*, 305-307. [10] Jochum K.P. et al. (2006) *JAAS, 21*, 666-675. [11] Kosler J. et al. (2008) *MAC, 40*, 315-317.

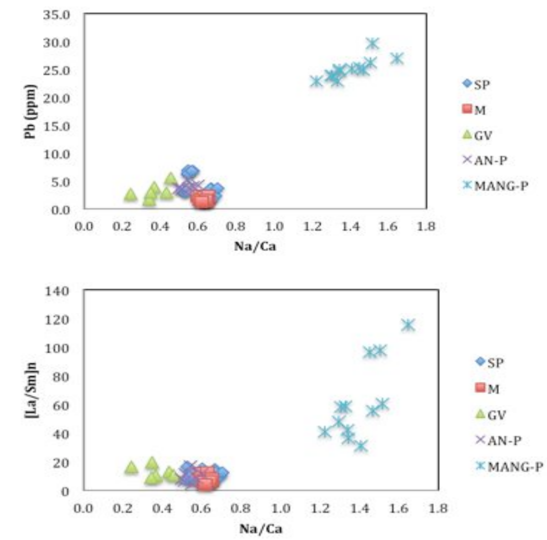

Fig 2: (A, top) Pb (ppm) vs. Na/Ca and (B, bottom) [La/Sm]n vs. Na/Ca for all 5 components analyzed. Legend (SP) = shocked plagioclase; (M) = maskelynite associated with shocked plagiocalse; (GV) = clast-bearing glassy vein; (AN-P) and (MANG-P) = well-preserved, unshocked plagioclase in anorthosite and mangerite respectively.

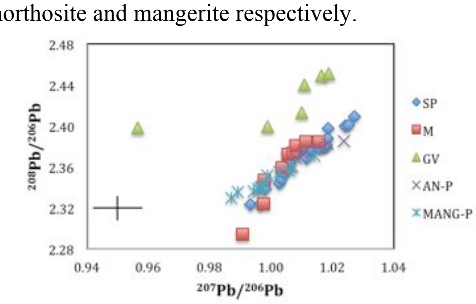

Fig 3: $^{208}Pb/^{206}Pb$ vs. $^{207}Pb/^{206}Pb$ for all 5 components analyzed. Legend key is the same as for Fig 2. Typical error bars located in the lower-left corner of the plot.