The Chlorine Isotope Composition of the Moon. Z.D. Sharp[1], C.K. Shearer[2] and J.D. Barnes[3]. [1]Dept. of Earth and Planetary Sciences, Univ. of NM, Albuquerque, NM 87131 (zsharp@unm.edu), [2] Institute of Meteoritics and Dept. of Earth and Planetary Sciences, Univ. of NM, Albuquerque, NM 87131, [3] Dept. Geological Sciences, Univ. of Texas, Austin, 78712.

Introduction: The higher halogens chlorine, bromine and iodine have unique chemical behavior. These monovalent anions are highly incompatible and strongly partition into aqueous fluids. The major reservoirs of Earth and meteorites have only a narrow range of chlorine isotope values, and fractionation between different reservoirs are generally low, especially at high temperatures. Sharp *et al.* [1] found that the mantle has a δ^{37}Cl value of -0.5 to 0.0 with two outliers on the East Pacific Ridge. Bonifacie et al [2] obtained slightly lower mantle values. Additional samples from hotspots and a Cl-bearing diamond support the near-zero value for the mantle (Fig. 1). The ocean and evaporites have a similar range [3] and limited meteorite data also span -0.5 to 0.0 (with several outliers from sodalite inclusion from Allende)[1]. Given this restrictive isotopic range and lack of high temperature equilibrium fractionation mechanisms applicable to Earth, the Cl isotope composition of lunar materials could provide information about the heterogeneities of the Earth-Moon system.

Results and Discussion: We have measured five lunar samples, with five recently acquired samples yet to be analyzed. In stark contrast to terrestrial samples, the lunar samples cover an enormous range of δ^{37}Cl values, from -0.74 to +16.00‰ (vs SMOC) (Table 1, Fig. 1). This is larger than the entire range of all terrestrial samples that have been measured to date. There are no known processes which occur on Earth that could explain the large variation. Instead, the spread of data must be controlled by processes that are unique to the lunar surface. Unlike all other elements, Cl (and Br and I) require interaction with only a single proton to create the gaseous species HCl. (In contrast, sulfur requires near simultaneous interaction with two protons to make H_2S). Fractionation could occur either during interaction with protons (and formation of HCl) or by preferential loss of $H^{35}Cl$ (*g*) to space due to the higher translational velocities of the light isotopologue. The higher translational velocities of $H^{35}Cl$ relative to $H^{37}Cl$ (1.027 times greater for a fixed kinetic energy) would lead to a preferential loss of the lighter isotopologue to space. We are testing the first possibility by exposing a thin film of NaCl to high energy proton flux. Formation of HCl (*g*) could occur from interaction with high energy protons or micrometeorite bombardment.

Loss of Cl related to surface exposure should increase the δ^{37}Cl value and decrease the Cl content. There is no correlation between these two variables, but this is not surprising given the wide range of Cl contents in the samples analyzed to date. There is a

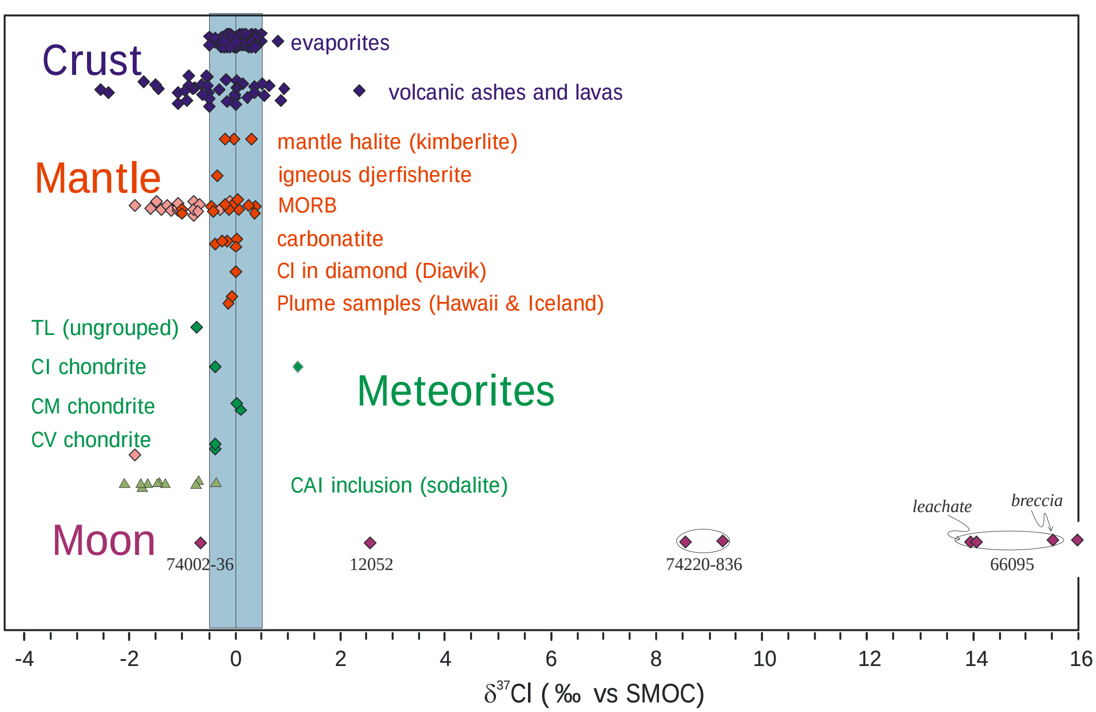

Fig. 1. From Sharp *et al.* (2007) with unpublished mantle plume and Cl inclusions in diamond data. Pink diamond symbols are data from Bonifacie *et al.* (2008).

positive relationship between δ^{37}Cl and δ^{34}S values, which may be interpreted in terms of greater exposure to solar wind (Table 1 and Fig. 2). The sample with the lightest δ^{37}Cl value should be the one least affected by interaction with solar wind/micrometeorite bombardment. The lightest δ^{37}Cl value of -0.74‰ was measured in sample 74002, which is thought have had minimal exposure [e.g., 4]. This value overlaps with terrestrial mantle values, suggesting that the isotopic composition of the Moon may be indistinguishable from the bulk Earth. However 74002 has had vapor loss and redeposition during eruption. Numerous studies of pyroclastic glasses have identified small deposits on their surfaces that have been attributed to vapor condensation during fire-fountaining. These surface deposits are enriched in a variety of volatile elements relative to the interior of the glass beads. NaCl has been one of the phases identified as a product of sublimation [5]. Vaporization and redeposition of NaCl can fractionate Cl isotope ratios, so the -0.74‰ value may be partially affected by this process.

Conclusions: Excepting the unusual 74002 sample, the lowest δ^{37}Cl value of 2.5‰ is found in the pigeonite basalt 12052. Surface exposure was minimal for this sample, so that 2.5‰ provides an upper limit for the δ^{37}Cl value of the Moon. Additional pristine samples are being analyzed to refine the bulk Moon value. Our preliminary estimate for the lunar δ^{37}Cl value is between -0.74 and +2.5‰.

References: [1] Sharp et al. Nature 446 (2007),[2] Bonifacie et al. Science 319, 1518-1520 (2008), [3] Eastoe et al. Appl. Geochem. 22, 575-588 (2006), [4] Morris et al. Proc. LPSC 9th, 2033-2048 (1978), [5] Clanton et al . Proc. LPSC 9th, 1945-1957 (1978), [6] Jovanovic & Reed. Proc. LPSC 5th, 1685-1701 (1974), [7] Ding et al. GCA 47, 491-496 (1983), [8] Epstein and Taylor. LPSC 2nd, 1421-1441 (1971), [9] Epstein and Taylor. LPSC 4th, 1559-1575 (1973), [10] Friedman et al. Science 185, 346-349 (1974).

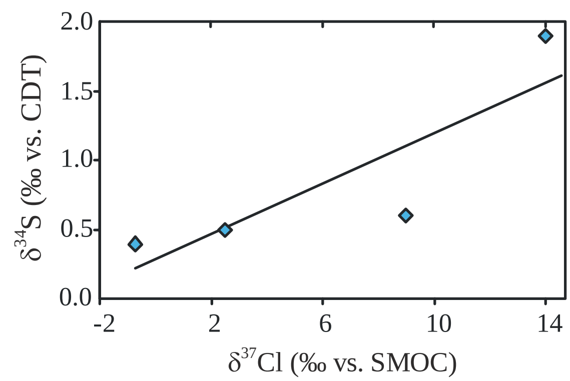

Fig. 2. Correlation between δ^{37}Cl and δ^{34}S values.

Table 1. Cl content and isotopic composition for selected lunar materials.

Sample	Notes:	Cl content – publ./this study	δ^{37}Cl value	δ^{34}S value	δ^{13}C value	δ^{30}Si value
74220-862	pyroclastic glass	70-103[6]/50[*]	8.59, 9.32	0.6±0.5[7]	-7.2[8]	-3.44, -3.70[9]
66095	'rusty rock' fumarole?	203, 400/117[*]	13.95[*], 14.08[*], 15.59[†]	1.9	-20 to -30[10]	
12034, 116	Regolith breccia	46	16.00 (bulk)			-0.25[8]
12052	Pigeonite basalt	1.7, 1.8	2.52 (bulk)	0.47 to 0.68		-0.18
74002,36	Hand-picked glass beads	40/80[*]	-0.74[*]	~0.4		

[*]leachate, [†]leached rock