PETROGRAPHY AND GEOCHEMISTRY OF LUNAR METEORITE DHOFAR 1673. P. J. A. Hill[1]; G. R. Osinski[1,2]; N. R. Banerjee[1]; A. Ali[1]; R. L. Korotev[3]; S. Nasir[4] [1]Department of Earth Science and Centre for Planetary Science and Exploration (CPSX), University of Western Ontario, London, ON, Canada. [2]Department of Physics and Astronomy, University of Western Ontario, London, ON, Canada, [3]Department of Earth and Planetary Sciences, Washington University, Saint Louis, MO, USA. [4]Earth Sciences Research Center, Sultan Qaboos University, Muscat, Oman.

Introduction: Dhofar 1673 is a lunar meteorite from Dhofar, Oman. The sample is rich in anorthosite and due to presence of spherules, is classified as a feldspathic regolith breccia [1] (Fig. 1).

Fig. 1: Scanned thin section of Dhofar 1673.

Petrography: Dhofar 1673 is a feldspathic regolith breccia dominated by anorthosite clasts contained in two distinct domains. Most of the anorthosite clasts are contained within a fine-grained, brown mesostasis, likely glass with clasts aligned in a common orientation. In certain areas the clasts are embedded within a darker, fine-grained domain with clast-rich impact melt rock clasts. Spherules are also present and are predominately found within the finer-grained domain. There are 4 main types of clasts within Dhofar 1673: anorthosite, clast-rich impact melt rock (impact melt breccia), gabbro, and mineral fragments. A majority of the clasts are anorthosite clasts dominated by subhedral plagioclase (>90% of clasts). A poikilitic texture is commonly associated with these clasts with inclusions of clinopyroxene (augite and pigeonite) often present. The anorthosite clasts vary from 50 µm to 1000 µm in size. Approximately 10% of the anorthosites are noritic anorthosites due to the abundance of clinopyroxene.

The clast-rich impact melt rock is present as brown and black rounded isotropic clasts. Most of the clasts are between 100 µm to 500 µm but a few are up to 1 mm across. Many clasts are comprised predominately of impact melt rock with fine crystalline grains of plagioclase and pyroxene. In addition, a more anorthositic clast-rich impact melt rock clast is present with microporphyritic, tabular grains of plagioclase surrounded by impact melt rock. The aggregates are generally small and range in size from 100 to 400 µm. Gabbroic clasts of subhedral clinopyroxene grains with subophitic texture are less abundant throughout Dhofar 1673. Olivine is also present as anhedral inclusion but the modal abundance does not exceed 10%. The composition of these clasts ranges from gabbro to anorthositic gabbro. Veins of calcite and sulphates indicative of terrestrial weathering cut across Dhofar 1673.

Mineral Chemistry: The lithic clasts are comprised predominately of anorthosite ranging in composition from An 92–98 (n=46). Figure 2 shows the range in composition of pyroxene and olivine grains throughout Dhofar 1673. Figure 3 plots the Mg# of mafic minerals versus the anorthite number of coexisting plagioclase; fields taken from [2]. This anorthosite is predominately ferroan anorthosite (FAN) with some clasts plotting intermediately between the FAN and Mg-rich suite. The Fe-Mn ratios of pyroxene and olivine in Dhofar 1673 plot along the lunar trend and are consistent with a lunar origin [3].

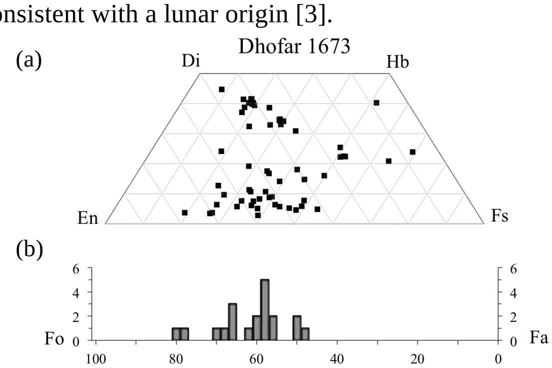

Fig. 2: (a) The composition of pyroxene observed in Dhofar 1673 (n=60). (b) The composition of olivine observed in Dhofar 1673 (n=20).

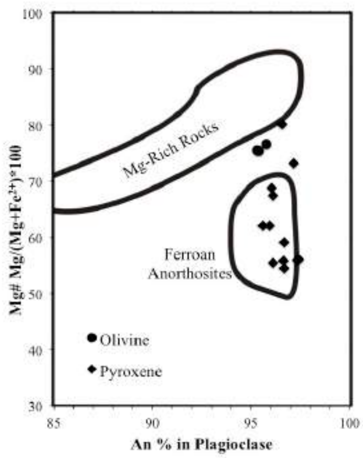

Fig. 3: Mg# of olivine and pyroxenes versus the An content in coexisting plagioclase grains of Dhofar 1673. A comparison is made to FAN and Mg-rich suite taken from [2].

Isotope Geochemistry: The oxygen isotope composition of Dhofar 1673 is best represented by $\delta^{17}O$ = +3.30‰ and $\delta^{18}O$ = +6.30‰. The 6 runs used to determine the oxygen isotope composition of Dhofar 1673 are shown in figure 4. The calibration method used for triple oxygen isotope data gives an accuracy and precision better than ± 0.1‰ for both $\delta^{18}O$ and $\delta^{17}O$ [4]. This sample plots on the Terrestrial Fractionation Line (TFL) and is consistent with other lunar meteorites but plots relatively high compared to other meteorites (Fig. 4) [5-7].

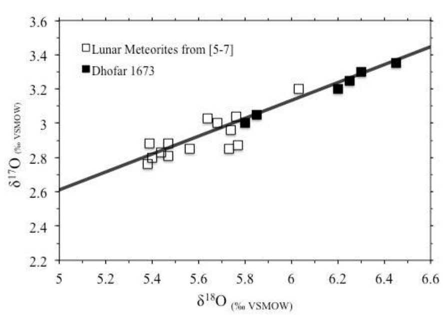

Fig. 4: The oxygen isotopic composition of Dhofar 1673 plots on the terrestrial fractionation line. The oxygen isotope composition of other lunar meteorites comes from [5-7].

Bulk Chemistry: The Th and Sm concentration of Dhofar 1673 falls on the trend for lunar meteorites, and the Sc-Fe ratio (3415) falls within the range of highland lunar meteorites. Overall the bulk chemistry of this meteorite is indicative of a feldspathic lunar meteorite with the abundance of anorthosite resulting in a high Al_2O_3 content (~26 wt %) and low FeO content (~5.5 wt %). There is a significant enrichment in Ba and Sr due to terrestrial weathering.

The REE-pattern is distinctive of feldspathic meteorites with slightly enriched LREE and a positive Eu-anomaly. Dhofar 1673 REE plot is much lower in comparision to more mafic lunar meteorites such as: Yamato 793274, and Calcalong Creek [8,9]. However, Dhofar 1673 is more similar to Dhofar 026, Dhofar 1436, and Sayh al Uhaymir 300 [6,10,11] and the chondrite normalized REE plot for Dhofar 1673 is also very similar to Dhofar 1983 [12] as seen in Figure 5. Incompatible elements, such as Th (0.42 ppm), are also low in Dhofar 1673.

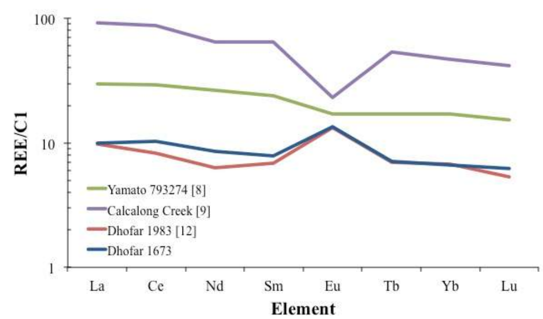

Fig. 5: C1 normalized REE plot for Dhofar 1673. A comparison is made to Yamato 793274 [8], Calcalong Creek [9], and Dhofar 1983 [12].

Discussion: The lunar origin of Dhofar 1673 is seen in the bulk Fe-Mn ratio (~69) and O-isotopes being consistent with other lunar meteorites. As indicated by its mineral and bulk chemistry, this meteorite is dominated by the lunar anorthosite, fairly typical for feldspathic lunar meteorites. In the absence of a KREEP geochemical signature, a low concentration of incompatible elements and the abundance of FAN, the source region could have been within the feldspathic highland terrain distal from the Imbrium Basin.

References: [1] Strickland P. and Herd C. (2012) The Meteoritical Bulletin, no. 101, *Meteoritics & Plant. Sci.*, 47. [2] Goldrich C. A. et al. (1984) *J. Geophys. Res.*, 88:C87-C94. [3] Papike J. J. et al. (1998) *Amer. Mineral.*, 88:469-472. [4] Ali A. et al. (2013) *LPSC XLIV*, Abstract #2873. [5] Clayton R. N. and Mayeda T. K. (1996) *Geochim. Cosmochim. Ac.*, 60:1999-2017. [6] Taylor L. A. et al. (2001) *LPSC XXXII*, Abstract #1985. [7] Haloda J. et al. (2009) *Geochim. Cosmochim. Acta.*, 73:3450-3470. [8] Koeberl C. et al. (1991) *Proc. NIPR Symp. Antarct. Meteorit.*, 4:33-55. [9] Hill D. H. and Boynton W. V. (2003) *Meteoritics & Planet. Sci*, 38:595-626. [10] Korotev R. L. (2012) *Meteoritics & Planet. Sci*, 47:1365-1402. [11] Hsu W. et al. (2008) *Meteoritics & Planet. Sci*, 43:1363-1381. [12] Hill P. J. A. et al. (2015) LPSC XLVI, *this conference*.