WHAT IS THE SOURCE OF APOLLO 17 SAMPLE 77017? W. Iqbal[1], T. Liu[2], T. Haber[3], C. H. van der Bogert[1], E. E. Scherer[3], H. Hiesinger[1],. [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany, [2] Museum für Naturkunde Leibniz-Institut für Evolutions- und Biodiversitätsforschung, 10115 Berlin, Germany. [3]Institut für Mineralogie, Westfälische Wilhelms-Universität Münster, (iqbalw@uni-muenster.de).

Introduction: Apollo missions played a crucial role in shaping our knowledge of the Moon and its geological features. The collected samples and data improve our understanding of both ancient and ongoing processes occurring on the Moon and throughout the Solar System. However, the source units and craters of many collected samples are still in question. In this study, we examine possible source craters for Apollo 17 sample 77017, with the aim of using this information to better constrain the lunar stratigraphy.

Previous studies of 77017 [e.g., 1-3] interpreted three main events recorded in the sample: (1) the formation of an impact basin in anorthositic crust; (2) the metamorphism; and (3) formation of a younger crater from which the sample was excavated and launched to Taurus-Littrow valley. Haber and Scherer (2018) [4] suggested that the age of the metamorphic event is ~4.2 Ga, and that excavation occurred at ~2 Ga. Here, we used several tools to investigate the history of the sample, which will eventually enable us to link the isotopic dates of the sample to its formation and excavation.

Methods: First, we considered the geology [5] of the region surrounding the Apollo 17 landing site to search for Erathosthenian aged craters that could potentially sample the plagioclase-rich highlands and mare material, which are both present in the sample. Since the sample contains anorthositic highland material in the impact breccia [6], we searched for the craters that had possibly excavated material from the regions of continuous basin ejecta where the probability of finding such target material is the highest. On the basis of the ejecta mixing model of [7], we considered the contribution of ejecta mainly from Serenitatis, Crisium, and Imbrium basins [Fig. 1]. Later, we used spectral Kaguya Mineral Imager data and Clementine data to estimate the composition of the material excavated from the candidate Erathostehenian age craters.

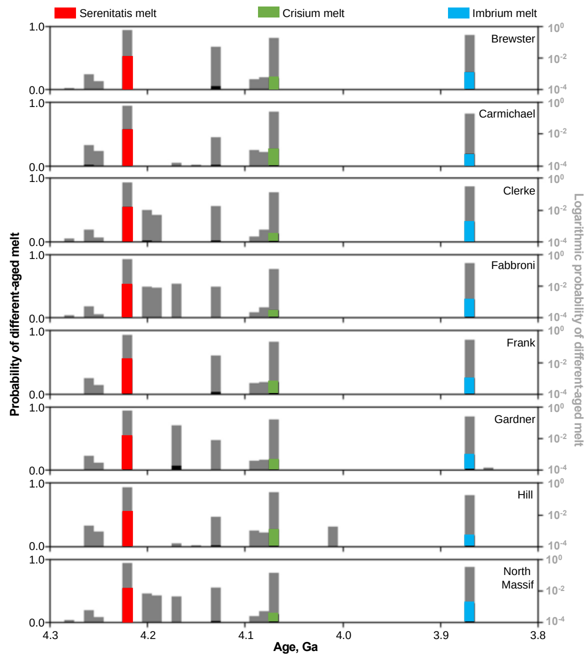

Fig.1. Model histograms are shown in black (linear scale, left) and in grey (logarithmic scale, right). In the black histograms, the peaks caused by Imbrium, Crisium, and Serenitatis melt are highlighted in blue, green, and red, respectively.The modeling [7] shows that the ejecta of all the potential source craters likely contains some Serenitatis, Imbrium and Crisium basin melt. The abundance of the Serenitatis basin melt is higher than that of Crisium and Imbrium basin melt (Table. 1).

Results: We observed a few craters whose target material includes both mare and highland material, which could have been excavated and then transported to the Apollo 17 landing site. These include Clerke, Fabbroni, Brewester, Gardner, Frank, Hill, and Carmichael craters. The ejecta mixing models suggest that >50% of the material excavated from these craters is from Serenitatis [Fig 1]. Ejecta material from the Imbrium and Crisium basins is most abundant after Serenitatis ejecta material (Table. 1).

		Fractions of different melt sources			
Crater	Diameter km	Serenitatis	Imbrium	Crisium	Smythii, Nectaris
Brewester	10.2	0.51	0.27	0.17	0.0008
Charmichael	20	0.56	0.17	0.26	0.002
Clerke	6.1	0.54	0.30	0.12	0.0004
Fabbroni	10.6	0.52	0.28	0.12	0.001
Frank	12.2	0.54	0.25	0.18	0.009
Gardner	18.0	0.53	0.23	0.16	0.05
Hill	16.0	0.55	0.18	0.28	0.002
North Massif	-	0.53	0.30	0.14	0.001

Table 1. Calculated fraction of ejecta material contributed by various craters. The calculations are made using the model from [7].

Craters	Diameter (km)	Distance from Apollo 17 landing site (km)	Approx Ejecta thickness[a] at landing site (m)	Extent	Plagioclase *wt%*	Clinopyroxene *wt%*	Orthopyroxene *wt%*	Olivine *wt%*	FeO *wt%*	TiO_2 *wt%*
Clerke	6.1	51	0.009	Rim	62	10	25	2	10	0.7
				Ejecta	62	12	23	4	11	2
Fabbroni	10.6	66	0.037	Rim	43	22	31	5	14	0.3
				Ejecta	40	26	25	9	15	0.8
Brewster	10.2	141	0.003	Rim	60	14	25	2	9	0.02
				Ejecta	57	12	25	6	11	0
Frank	12.2	150	0.057	Rim	63	16	18	4	11	0.2
				Ejecta	56	18	20	5	12	0.3
Gardner	18	116	0.002	Rim	78	8	12	2	5	0.02
				Ejecta	82	7	10	2	5	0.04
Hill	16	283	0.2	Rim	61	12	22	6	9	0.05
				Ejecta	68	13	16	3	9	0.1
Carmichael	20	273	0.49	Rim	68	11	20	2	8	0
				Ejecta	62	13	21	3	9	0.07

Table 2. Approximate concentrations of plagioclase, clinopyroxene, orthopyroxene, olivine, FeO, and TiO_2 (wt%), determined on the rim and ejecta materials of Clerke, Fabbroni, Brewster, Frank, Gardner, Hill, and Carmichael craters. These values were determined from Kaguya Mineral Imager data [8], except TiO_2 concentration, which was from Clementine data [9].(a) Approximate ejecta deposition at the landing site location using model of Pike et al. (1974) [10].

Next, we used well-calibrated spectral data to investigate the composition of the ejecta of the possible sample source craters. According to these data, Clerke, Fabbroni, and Gardner craters are the best candidates for ejection of highland and mare material in proportions similar to those found in the sample.

Discussion: Sample 77017 records several events in the lunar bombardment history, with the two most significant being excavation by a basin impact, and reexcavation from an Eratosthenian age crater, and later disturbance by regional processes [e.g. 11]. The determination of isotopic dates [4] ideally provides absolute ages for these events. Identification of the Erathosthenian-aged excavation crater of the sample can provide constraints on possible basin units from which the sample was derived. This hybrid study includes geological, spectral, modelling, and sample investigations, and suggests that the source crater is no further than ~116 km from the landing site, considering calculation of the ejecta thickness from particular craters at the landing site (Table 2). The three Erathosthenian craters, Clerke, Fabbroni, and Gardner, provided the best compositional matches with the sample with respect to its compositional mix of highland and mare-like material. Comparing the results of the ejecta mixing model [7] shows that the rocks excavated from those craters most likely consisted of material derived from the Serenitatis, Imbrium, and Crisium basin (Fig. 1, Table 1). The typical ~3.92 Ga age of the Imbrium event has not been identified in 77017 so far, so the sample is probably unrelated to that event. Thus, Serenitatis basin appears to be the most convincing candidate to have created the metamorphic overprint of the sample, which would support the notion that this basin formed at ~4.2 Ga [12].

Conclusions: Hybrid studies such as this one, including geological and spectral analysis, ejecta modelling, and isotopic dating, can be used to narrow down the origin of collected samples. Such studies will eventually further our understanding of the lunar history and help to develop a more accurate stratigraphic time scale of the Moon.

Further Work: In future, we will use crater size-frequency distribution (CSFD) measurements to find absolute model ages (AMAs) of the craters that have consistent mineralogical concentrations in spectral data with sample data.

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