ANTARCTIC LUNAR METEORITES FROM CRYPTOMARIA OF THE MOON. T. Arai[1], B. Ray Hawke[2], T. A. Giguere[2,3]. [1]Antarctic Meteorite Research Center, National Institute of Polar Research, Kaga, Tokyo, 173-8515, Japan (tomoko@nipr.ac.jp), [2]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI 96822, USA, [3]Intergraph Corporation, P.O. Box 75330, Kapolei, HI 96707, USA.

Introduction: Lunar mare basalts are products of partial melting of the lunar mantle, serving as probes of the composition, structure, and thermal history of the inaccessible lunar interior. Cryptomaria are covered mare deposits that are obscured from view by the subsequent emplacement of ejecta from craters and basins. They are keys to understand ancient mare volcanism, predating the younger volcanism represented by exposed maria sampled by Apollo and Luna missions. Studies by ground-based observations and lunar orbital satellites have revealed that the cryptomaria are widely distributed on the surface of the Moon [e.g. 1]. Yet, their nature is not well defined, due to the lack of the ground truth. Here, we report a group of Antarctic lunar meteorites of cryptomaria origin with reasonable certainty.

Samples description: Four Antarctic lunar meteorites, Yamato (Y) 793169, Asuka (A) 881757, Meteorite Hills (MET) 01210, and Miller Range (MIL) 05035 (YAMM meteorites) are paired low-Ti (~2 wt% TiO_2) mare basalts [2]. MET 01210 is a regolith breccia with mixture of mare and highland components, including a basalt clast 2.7× 4.7 mm in size. The other three are unbrecciated basalt (Fig. 1). They are probably derived from a single basalt flow of >100 m thick [2] extruded at 3870 Ma [e.g. 3], and were simultaneously launched off the Moon at 1 Ma [e.g. 4].

Methods: On the basis of mineralogical data of the above four meteorites [2] combined with the bulk chemistry data, cosmic exposure record, and isotopic age from other studies, a possible source crater of the meteorites was identified, utilizing global maps of FeO, TiO_2, optical maturity (OMAT) image from Clementine UV-VIS camera and Th data from Lunar Prospector gamma-ray spectrometer.

Results and discussions: The low surface irradiation and low maturity of MET 01210, which are similar to those of Apollo 16 regolith breccias, represent ancient regolith residing beneath the surface regolith [5]. As the surface regolith thickness is generally a few meters in mare areas [6], the burial depth of > several meters for the YAMM meteorites clearly indicate that they are originated from regions enriched in mare materials, other than the exposed mare areas. The extremely short exposure time for 3870 Ma-aged YAMM meteorites is in line with the higher turnover rates due to intense meteoroid bombardment, ~3900 Ma [5]. With these grounds, the YAMM meteorites reasonably represent an ancient mare basalt flow, which has little chance to be exposed on the surface, that is, cryptomaria.

While source craters of brecciated lunar meteorites are generally a few km in diameter, those of crystalline ones which are mechanically stronger than breccias tend to be smaller and less than 1 km (i.e. 0.9 km source crater for A-881757) [7]. The size of the source crater which simultaneously ejected crystalline basalts and brecciated basalts would be smaller than a few km.

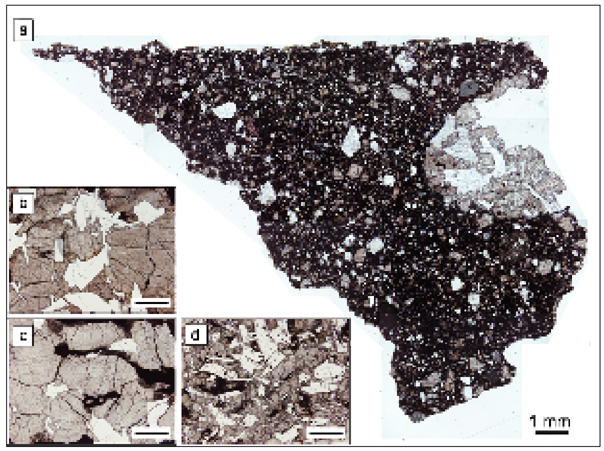

Fig. 1. Photomicrographs of polished thin sections of (a) MET 01210, (b) MIL 05035, (c) A-881757, and (d) Y-793169.
extremely young with bright ejecta around the crater.

Regolith breccias at a given site are broadly similar to the regional soils within locations of a few km [8]. Thus, their compositions provide clues to specify the source location. Regolith breccia MET 01210 is a product of thorough mixing of mare and highland components. The result of a two-component mixing model indicated that the source region of the YAMM meteorites contains 68% mare material. Given that ratio, the 0.9 ppm Th of MET 01210 [9] was decomposed into 0.58 ppm Th from mare components and 1.58 ppm Th from highland components. The bulk-rock Th of MET 01210 is close to the lower Th range of the nearside regoliths and regolith breccias, i.e. 0.4 – 0.9 ppm Th at Luna sites [9]. The incorporation of KREEP (K, Rare Earth Element, and P)-rich materials inferred from the relatively elevated Th content (1.58 ppm) in the highland component clearly indicate the nearside origin.

Our detailed knowledge of the YAMM meteorites listed below allowed us to identify their provenance; (1) cryptomare basalt erupted at 3870 Ma and impacted at 3800 Ma, (2) basalt composition with ~

2.0 wt% of TiO_2, (3) basalt thickness >100 m, (4) mare-highland mixing ratio of 68 : 32, (5) surface composition with 16.4 wt% FeO and 0.9 ppm Th, (6) lack of pyroclastics, and (7) extremely young (~1 Ma) and small (< a few km in diameter) crater. With these constraints combined with Clementine Fe-Ti maps, multispectral images and Lunar Prospector Th map, we successfully specified their derivation amongst the nearside cryptomare regions. The most likely source is the Schiller – Schickard region near the extreme southwestern limb, which contains major expanse of cryptomaria (Table 1). The cryptomaria in this region are covered by ejecta materials of Orientale basin and local craters [e.g. 10]. The cryptomare deposits detected on the floors of Schiller and Schickard craters [10] are in excellent agreement with YAMM basalts in multiple aspects: Pre-Orientale eruption age (>3.8 Ga), mixing ratio of mare materials (40 – 70 %), basalt thickness (1 – 3 km), TiO_2 content (0.4 – 2.6 wt%) of the buried basalt [11], surface composition with FeO content (9.0 – 16.0 wt %) [12] and Th content (0.5 – 1.0 ppm) [13], and no pyroclastic deposit detected [14]. The only crater young and small enough to be the source in this region is an unnamed 1.4 km-diameter crater on the floor of Schickard crater (53°W, 44.5°S) (Fig. 2). The mixing ratio (68%) of mare component and FeO value (14.0 - 16.2 wt%) for the ejecta of this crater remarkably coincide with the composition of MET 01210. Based on the optical maturity index [15] which is an indicator of degree of collective space-exposure effects, the ejecta material around that crater is less mature and younger than that of 2 Ma-aged South Ray crater [16] near the Apollo 16 site. Hence, the age of the crater could be reasonably 1 Ma. With all the data above, we conclude that the 1.4 km crater on the floor of Schickard crater is the most likely source for the YAMM meteorites.

The low $^{238}U/^{204}Pb$ (μ) value (10–22) of YAMM basalts [3, 17] and of Luna 24 basalts (~12 - 15) [18], compared with the high-μ value Apollo basalts (100–300) [19], indicates that the heat source should not be related to KREEP. The thermal evolution may be distinct between the PKT and the non-PKT regions.

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References:

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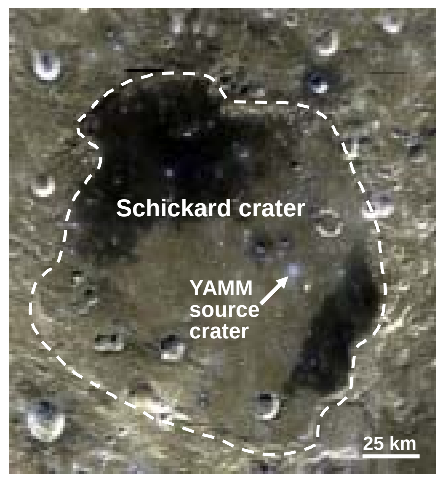

Fig.2. Clementine albedo map (http://pdsmaps.wr.usgs.gov) showing a proposed source crater (53°W, 44.5°S) for YAMM meteorites on the floor of Schickard crater. The crater is 1.4 km (dia.) and extremely young with bright ejecta around the crater.

Table 1. Cryptomaria for potential source of YAMM meteorites.

Constraints from YAMM meteorites		Schiller-Schickard (48ºS, 50ºW)	Balmer-Kapteyn (15ºS, 70ºE)	Mendel-Rydberg (50ºS, 95ºW)	Lomonosov-Fleming (19ºN, 105ºW)
Surface composition					
Th (ppm)	0.9	<1.5	1.2 – 2.2	<1.0	<0.5
FeO (wt%)	16.4	9.0 – 16.0	9.0 – 15.0	8.0 – 14.0	8.0 – 14.0
Mixing ratio (%) of mare	68	40 – 70	30 – 53	<40	21 – 50
Basalt composition					
TiO_2 (wt%)	2.0	0.4 – 2.6 (Pre-Orientale)	1.0 – 2.5	N/A	0.5 – 4.5
FeO (wt%)	<22.2	16.5 – 19.0	16.8 – 18.0	N/A	15.0 – 18.1
Eruption age (Ma)	3870	Pre-Orientale & Post-Orientale	Early Imbrian, Pre Nectarian	Pre-Orientale	Imbrian, Pre Nectrarian
Pyroclastics	No	No	No	No	No