A 8.2 MA AGE FOR THE LUNAR CRATER GIORDANO BRUNO? J. Fritz Museum für Naturkunde, Leibniz Institut an der Humboldt Universität zu Berlin, Invalidenstr. 43, 10115 Berlin, Germany (joerg.fritz@mfn-berlin.de).

Introduction: The 22 km ∅ crater "Giordano Bruno" is the youngest lunar crater of its size or larger [1]. The crater is located at 36N / 103E in the Th-poor lunar highlands and has a prominent ejecta ray system. According to urban ledgend formation of the Giordano Bruno crater was observed by medieval monks on June 18, 1178 A.D [2]. However, formation of a 22 km sized crater on the Moon would have resulted in an intense storm of lunar meteorites onto Earth [3]. An intense meteor shower is not recorded in the historical chronicals around the world, and thus Withers [3] concluded that the crater was not formed in 1178 A.D. For an efficient delivery of lunar impact ejecta to Earth, and the similar number of lunar (134) and matian (94) meteorites [4], it was previously argued that Giordano Bruno crater is certainly older than 1 Ma [5]. This interpretation was recently confirmed by crater statistics that assigned an 1 - 10 Ma age for the emplacement of the Giordano Bruno ejecta blanket onto the lunar surface [1]. Considering that the Giordano Bruno crater is the largest crater that formed during the last 10 Ma, and hence ejected the greatest amont of material from the Moon, it appears likely that fragments of that ejecta are present in our collection of lunar meteorites. In addition, it is discussed the likelyhood that the Giordano Bruno crater delivered suficient ^{3}He-rich lunar material to Earth to produce a significant spike in the extraterrestrial ^{3}He-record of Earth's sediments [6].

Lunar meteorites represent rock fragments impact-ejcted from the Moon and subsequently delivered to the Earth. The time of impact ejection can (besides problems related with a complex exposure history) be determined by measuring cosmogenic nuclides (Fig. 1 & 2) The ejection age is the sum of the space residence time (4π cosmic ray exposure history) and the terrestrial residence time. An efficient delivery of lunar and martian rock fragments to Earth is documentd because frequent and thus small impact events are capable of sending enough rock fragments into space to explain the suite of lunar and martian meteorites recovered on Earth [i.e. 7, 8]. Apparently, projectiles as small as ~30 m and 200 m can produce lunar and martian meteorites, respectively and the resulting crates are small in size (1 and 3 km ∅ on Moon and Mars, respectively), thus substantially smaller than the 22 km ∅ of Giordano Bruno). For comparison a 22 km ∅ crater forms on average once every ~10 Ma on the lunar surface [9].

A cumulative plot of the meteorite space residence time (T_{space}) shows the differences in the delivery of lunar and martian meteorites (Fig. 1). A lunar impact delivers the majority of meteorites on quasi-geocentric orbits to Earth during the initial 0.5 to 1 Ma [10] (Fig. 1 & 2). In contrast, a martian impact provides a 10 to 20 Ma lasting steady flux of meteorites that travel on helicentic orbits to Earth. Note that on average the terrestrial age of lunar and martian meteorites is <0.5 Ma. Because of the high efficiency to deliver and recover lunar meteorites ejected from craters younger than 1 Ma, the similar number of lunar and martian meteorites clearly documents that the 22 km sized lunar crater Giordano Bruno formed NOT during the last 1 Ma.

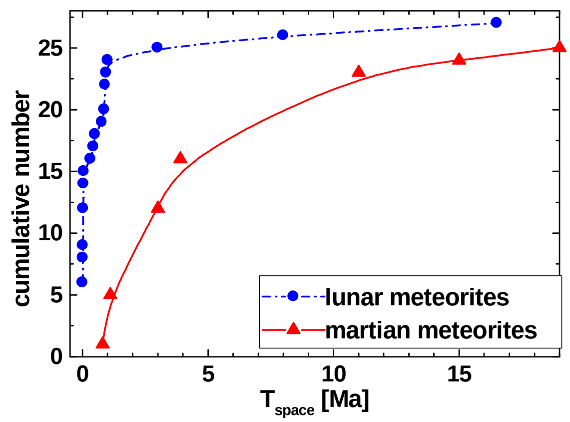

Figure 1: Cumulative space residence time of lunar and martian meteorites. Literature data for martian meteorites from references within [7] and lunar meteorites (see Figure 2).

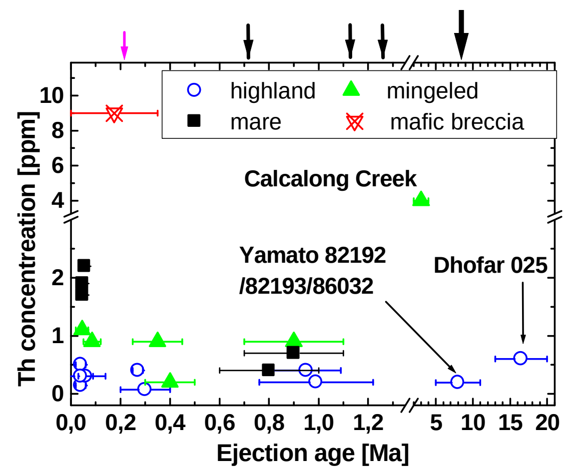

Figure 1: Compilation of ejection ages vs. Th-concentrations in lunar meteorites. Ejection ages (4πi exposure age + terrestrial residence age) from [11-14; 17-26] and Th concentrations from [27]. The petrologic types are indicated by different symbols. The small pink arrow marks a minor ^{3}He excursion in marine sediments and the black arrows show those excursion identified as spikes in the ^{3}He burial flux at 714, 1137, and 1265 ka ago by [15]. A major ^{3}He spike was identified at 8.2 Ma ago [16].

However, it is likely that some of the lunar meteorites that arrive on less efficient heliocentric orbits to Earth (T_{space} >1 Ma) actually derived from the largest crater that formed in the last 10 Ma. A compilation of petrology, Th-concentration and ejection ages of lunar meteorites is presented (Fig. 2) to discriminate the different ejection events and to constrain the sampled source regions. Giordano Bruno crater is situated in the Th-poor lunar highlands on the northern limb of the Moon [1]. Thus, the Th-rich mingled (basalsts and highland rocks) breccia Calcalong Creek, that was ejected 2-4 Ma ago [11], presents a poor petrological match. The Th-poor highland rock Dhofar 025 was ejected 14-20 Ma ago [12] and, thus, is barely in agreement with the formation age of 1 to 10 Ma as constrained by crater statistics [1]. Thus, the Th-poor lunar highland rocks Yamato 82192/82193/86032 ejected 5 - 11 Ma ago [13, 14] from the Moon presents the only lunar meteorite that matches both the geochemical constrains of the source region and the temporal requirements as discussed before.

Lunar ^{3}He in marine sediments: An efficient delivery of ^{3}He-rich lunar impact ejecta into Earth's sediments was first proposed by [6] to resolve puzzling aspects related to the late Eocene projectile shower to the Earth-Moon system. It was argued that a bombardment of the Moon by meter to hundered meter size projectiles provides a somehow steady flux of ^{3}He-rich lunar ejecta contributing to the extraterrestrial ^{3}He measured in Earth's sediments. An efficient delivery of ^{3}He-rich lunar material to Earth's sediments implies a general spikiness of the terrestrial ^{3}He record. Random lunar impacts large enough (the minimum size being related to the temporal frequency of the ^{3}He-spikes) should produce brief (~10ka) ^{3}He anomalies. Indeed, detailed ^{3}He-profiles of the last 1.8 Ma [15] report three brief spikes in the ^{3}He burial flux at ~0.714, ~1.137, and ~1.265 Ma ago (Fig. 2). The lunar impact scenario argues that a relatively small amount of ^{3}He-rich lunar ejecta (small compared to the total mass of IDPs arriving on Earth) substantially contributes to the volume of ^{3}He measured in Earth's sediments [6]. In contrast, a purely asteroidal or cometary origin of the ^{3}He-rich particles in Earth's sediments (prevailing ^{3}He-agents [15,16]) implies that the background flux of interplanetary dust particles (IDPs) frequently increases by 3 to 5 times. Thus assuming that **1)** the three ^{3}He-spikes truly document brief and frequent increases in the ^{3}He burial flux [15], and **2)** the last 1.8 Ma are not characterised by a series of unusual events advocates the interpretation that lunar impact ejecta substantially contributes to the ^{3}He-budget of Earth's sediments.

An 8.2 Ma age for Giordano Bruno: An nine-fold increase above background in the ^{3}He burial flux was identifyed at 8.2 Ma ago [16] and attributed to the collision that formed the Veritas asteroid family [16]. Alternatively the ^{3}He-spike in 8.2±0.1 Ma old sediments on Earth represents the ^{3}He-rich ejecta from Giordanoi Bruno, and thus provides the precice formation age for this lunar crater.

Testing the theory: The two scenarios can be discriminated by measuring Platinum Group Elements (PGEs) and ^{3}He concentrations in the marine sediments. Both PGEs and ^{3}He concentrations should increase if the ^{3}He-spike resulted from "chondritic" IDPs that derived from the break up of the Veritas family [16]. In contrast ^{3}He-rich (and PGE poor) lunar ejecta from the Giordano Bruno crater would result in an increase in the ^{3}He concentrations but not in PGE concentrations. The inferred connection between Yamato 82192/82193/86032 and the Giordano Bruno crater can be tested by comparing the geochemical data of the meteorites and orbital data from the lunar surface.

Relevance of testing the theory: 1) Pinpointing the source region of lunar meteorites potentially provides lunar samples from a well constrained locality on the Moon distant from the Apollo and Luna landing sites.

2) A precisely dated Giordano Bruno crater would present a landmark for the lunar crater production rates. The ejecta blancket is almost unaffected by secondary craters since it is the youngest sizable lunar crater. In addition it would present the most precicely dated ejecta blanket beside North Ray, South Ray and Cone crater.

3) Using a simple telescope, the Giordano Bruno crater can be seen from all around the world. Thus, Earth's sediments including the lunar impact layer would qualify as an ideal geocite for planetary science.

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