^{176}Lu-^{176}Hf Isochron Dating of Strongly Cosmic Ray Exposed Samples – A case study on Apollo 14 Impact Melt Rock 14310

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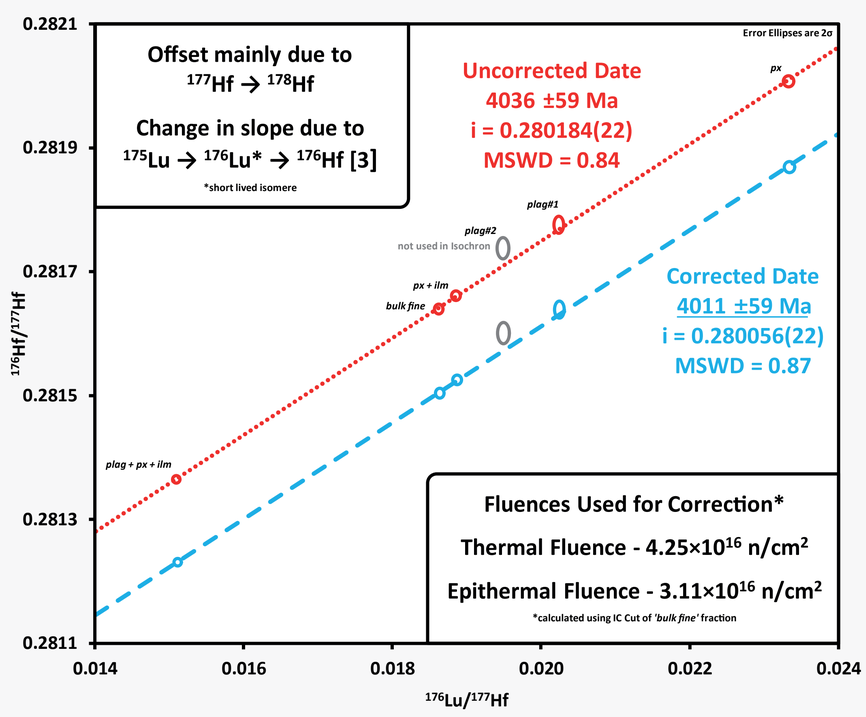
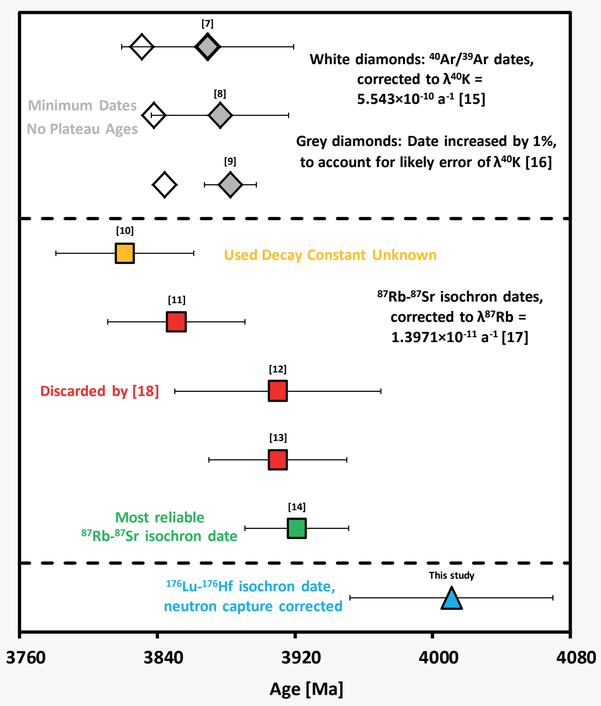
1. Introduction

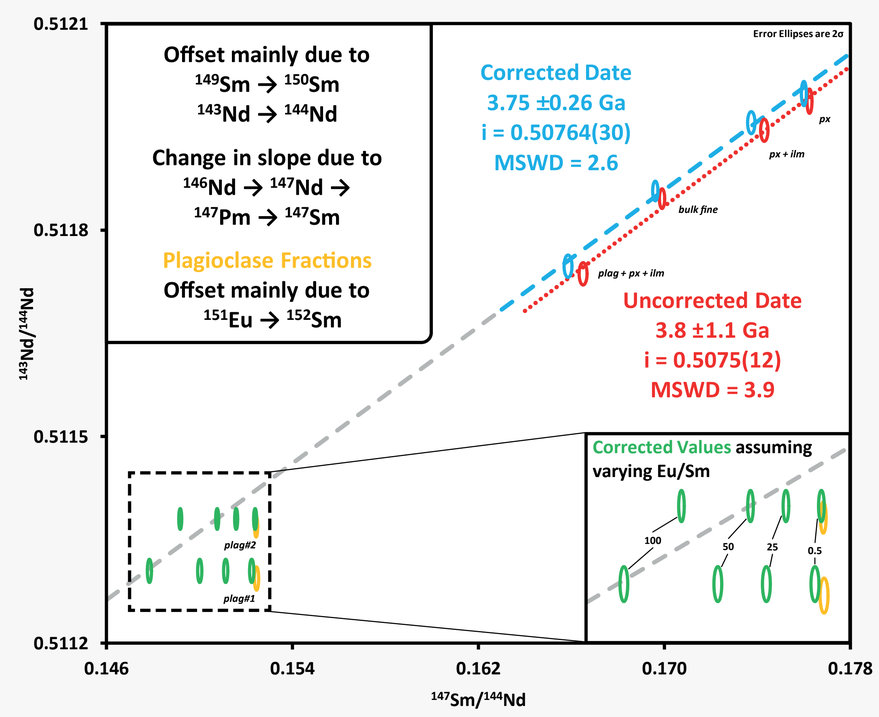
The determination of precise and accurate isotopic ages of lunar impact melt rocks is crucial for calibrating the lunar crater chronology function [1]. The ^{176}Lu-^{176}Hf system promises to be a powerful tool for ***dating the crystallization of lunar impact melt rocks*** because it has a high closure temperature [e.g., 2] and strong elemental fractionation results in a large range in Lu/Hf among minerals, potentially allowing higher precision on internal isochrons as compared to Sm-Nd. Additionally, it is possible to simultaneously analyze other geochronolgical systems such as ^{147}Sm-^{143}Nd and ^{87}Rb-^{87}Sr on the same mineral fractions. However, both Lu-Hf and Sm-Nd can be heavily affected by ***neutron capture (NC) effects***, which need to be properly corrected [3, 4] for accurate dating.

2. Sample and Method

Sample ***14310*** is a holocrystalline, clast-free impact melt rock with a fine-grained, subophitic texture [5, see also Poster #3]. Its long exposure on the lunar surface (210 to 347 Myr, [5]) means that it was subjected to ***significant neutron fluxes***. Five mineral fractions (63-125 µm, separated from a ~1 g split: 14310,115 using magnetic and density methods) and a bulk fine fraction were spiked and processed through a modified version of the chemical separation scheme of [6] (cation column separation of HFSE, Lu, LREE; Ln-Spec column separation of Hf from other HFSE; HDEHP Kel-F column to separate Sm from Nd). The isotope compositions of Lu, Hf, Sm, and Nd were measured on a ***Neptune Plus MC-ICP-MS***. An unspiked aliquot of the 'bulk fine' fraction was also analyzed to characterize the neutron fluence for this sample.







3. Results

Lu-Hf: The analyzed fractions contain 0.16–4.3 ppm Lu and 1.2–41 ppm Hf. The uncorrected ^{176}Lu/^{177}Hf and ^{176}Hf/^{177}Hf data of five of the six fractions yield a 4036 ±59 Ma (MSWD = 0.84) isochron. Plagioclase fraction #2 lies above the isochron. The neutron fluences that affected the sample were calculated using the Hf and Sm isotopic composition of the unspiked 'bulk fine' fraction [3, 4]. Correcting for NC effects changes the date to ***4011 ±59 Ma*** (MSWD = 0.87).

Sm-Nd: The analyzed fractions contain 2.5–43 ppm Sm and 8.9–156 ppm Nd. The uncorrected ^{147}Sm/^{144}Nd and ^{143}Nd/^{144}Nd data of four fractions (excluding plag #1 & #2) yield a 3.8 ±1.1 Ga (MSWD = 3.9) date. Correcting for NC changes this date to 3.75 ±0.26 Ga (MSWD = 2.6).

4. Discussion and Conclusion

Our ^{176}Lu-^{176}Hf data yield the ***oldest date*** reported for sample 14310. Owing to the high resistance of Lu-Hf to later (shock-induced) heating events [19], this date is more likely to represent the ***actual crystallization age*** of this sample than ^{40}Ar/^{39}Ar or Rb-Sr dates. Our ^{147}Sm-^{143}Nd date is indistinguishable from the Lu-Hf date. To improve the precision of the former, the Eu/Sm of the plagioclase has to be determined to improve the correction for NC effects on Eu.

According to [20], 14310 pre-dates the Imbrium event. On the basis of the young Rb-Sr and ^{40}Ar/^{39}Ar ages of the sample, those authors argued for a young age (3770 ±20 Ma) of the Imbrium event. The older Lu-Hf date from our present study allows for a significantly older age of the Imbrium event of up to ~4 Ga.

Sources: [1] Neukum G. and Ivanov B.A. (1994), *In: Hazards Due to Comets and Asteroids*, 359-416. [2] Scherer E. E. et al. (2000) *GCA 64*, 3413-3432. [3] Sprung et al. (2013) *EPSL 380*, 77-87. [4] Sprung et al. (2010) *EPSL 295*, 1-11. [5] Meyer (2009) *LSC* #14310. [6] Bast et al. (2015) *JAAS 30*, 2323-2333. [7] York D. et al. (1972) *LPS III*, 1613-1622. [8] Turner G. et al. (1971) *EPSL 12*, 19-35. [9] Stettler A. et al. (1973), *LPS IV*, 1865-1888. [10] Tatsumoto M. et al. (1972), *LPS III*, 1531-1555. [11] Papanastassiou D. A. and Wasserburg G. J. (1971) *EPSL 12*, 36-48. [12] Compston W. et al. (1972), *LPS III*, 1487-1501. [13] Murthy V. R. et al. (1972), *LPS III*, 1503-1514. [14] Mark R. K. et al. (1974), *GCA 38*, 1643-1648. [15] Steiger R. H. and Jäger E. (1977), *EPSL 36*, 359-362. [16] Jourdan (2012) *AJES, 59*, 199-224. [17] Rotenberg E. et al. (2012), *GCA 85*, 41-57. [18] Snape J.F. et al. (2016), *GCA 174*, 13-29. [19] Bloch E. and Ganguly J. (2014), *EPSL 395*, 173-183. [20] Deutsch A. and Stöffler D. (1987), *GCA 51*, 1951-1964.

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