

U-PB ISOTOPE SYSTEMATICS OF SHERGOTTITE QUEEN ALEXANDRA RANGE 94201: SEEING THROUGH TERRESTRIAL LEAD CONTAMINATION TO IDENTIFY AN EVEN LOWER-MU SOURCE ON MARS. Amy M. Gaffney¹, Lars E. Borg,¹ and James N. Connelly², ¹Institute of Meteoritics, University of New Mexico, Albuquerque, NM, 87131, ²The Jackson School of Geosciences, The University of Texas, Austin, TX 78712

Introduction: Basaltic shergottite Queen Alexandra Range 94201 originated from an extremely depleted mantle source, and has the highest initial ϵ_{Nd} ($+47.6 \pm 1.7$) and the lowest initial $^{87}Sr/^{86}Sr$ (0.701298 ± 14) measured for any martian meteorite to date [1]. Rb-Sr and Sm-Nd isochrons for this sample yield concordant crystallization ages of 327 ± 12 Ma and 327 ± 19 Ma, respectively [1]. Knowledge of the crystallization age provides a context in which to discuss new evidence for a very low $^{238}U/^{204}Pb$ (μ') source in the martian mantle, as well as the effects of terrestrial contamination on U-Pb and Pb-Pb isotope systematics in martian meteorites.

Analytical techniques: We were allocated a 325 mg fraction of QUE 94201, a martian meteorite collected in Antarctica. Initial sample preparation and leaching were completed at University of New Mexico, and sample digestion, column chemistry and mass spectrometry were completed at The University of Texas. The sample was crushed in a sapphire mortar and pestle, and the coarsest (74-150 μm) grain size fraction was separated into pure (>99%) mineral separates and reject mineral fractions by a combination of magnetic separation and hand-picking. All fractions were washed with 0.5 M acetic acid followed by QD water. All fractions were leached for 10 minutes at room temperature in HCl (2N for the silicates and 1N for the oxides), and rinsed with QD water. The HCl leachates + final water rinse were combined, processed and analyzed for U and Pb isotopic compositions. The mineral fractions were dissolved with HF+HNO₃+HCl. Pb was purified on anion resin columns using HBr and HCl. U was purified with UTEVA U-specific resin and HNO₃. Samples were run on a Finnegan 261 thermal ionization mass spectrometer, in static mode and using all Faraday cups. Procedural blanks for dissolution + column chemistry are less than 2.5 pg Pb, and sample-blank ratios range from 135 to 3260 for the mineral fractions. Total uncertainties on the Pb isotopic compositions reflect the combination of uncertainties determined for the internal analytical precision, and corrections for mass fractionation and laboratory blank, and are typically less than 0.1% for $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$, and are less than 0.05% for $^{207}Pb/^{206}Pb$.

Results: The Pb isotopic compositions of the leached silicate fractions are very unradiogenic and define a narrow range ($^{206}Pb/^{204}Pb = 11.16-11.61$,

$^{207}Pb/^{204}Pb = 11.47-11.72$). In contrast, the oxide mineral fractions and leachates have Pb isotopic compositions significantly more radiogenic and variable than the leached silicate mineral fractions. On a conventional uraniumogenic Pb-Pb diagram (Fig. 1), all the data define a single linear array, the slope of which corresponds to an age of 4325 ± 19 Ma. The data also define a single linear array in $^{208}Pb/^{204}Pb$ - $^{206}Pb/^{204}Pb$ space. However, the composition of Pb in Antarctic ice falls on both these arrays. We interpret these arrays to be the result of contamination by Antarctic ice, and therefore assign no age significance to the uraniumogenic Pb-Pb array. The mineral fractions have $^{238}U/^{204}Pb$ compositions that are both very low and quite limited (1.2 – 4.3), so that minimal quantities of ^{206}Pb and ^{207}Pb have been produced by radioactive decay since the rock crystallized at 327 Ma. Thus, the mineral fractions effectively represent a single point in Pb-Pb space. Variable amounts of contamination of these mineral fractions by terrestrial Pb results in a 2-component mixing line. Furthermore, this sample contains exceedingly low abundances of Pb (WR(R) + WR(L) has 0.16 ppm Pb), and thus is particularly susceptible to contamination. Simple binary mixing models are consistent with 2-7 % Antarctic contamination in the pure silicate fractions, and 6-87 % contamination in the other mineral fractions and leachates.

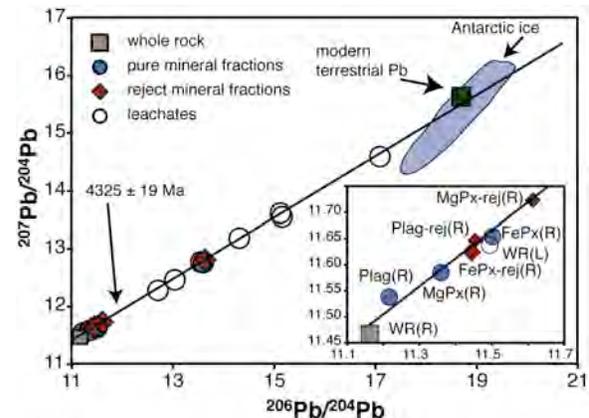


Figure 1: $^{206}Pb/^{204}Pb$ - $^{207}Pb/^{204}Pb$ diagram of all fractions analyzed. (R) denotes leached residue, (L) denotes leachate. Age calculated using IsoPlot [5].

The ^{238}U - ^{206}Pb and ^{235}U - ^{207}Pb isochron plots show considerably more scatter than the Pb-Pb plot shows (Fig. 2). This is expected, given the minimal variation in $^{238}U/^{204}Pb$ in the mineral fractions and the magni-

tude of terrestrial contamination. Additionally, the mineral-reject fractions contain impact melt. Martian contamination introduced to the sample during the impact event, and concentrated in the impact melt, may cause the mineral-reject fractions to fall off any U-Pb isochron representing a crystallization age. In the ^{238}U - ^{206}Pb system, the WR(R), Plag(R) and MgPx(R) fractions define a line corresponding to an age (397 ± 21 Ma) that is closest to the crystallization age for QUE 94201 (327 Ma, [1]). These three fractions are the least contaminated fractions analyzed (2-5% maximum contamination). Furthermore, small amounts of contamination in these fractions are consistent with an artificially old age. As expected, no age information is preserved in the ^{235}U - ^{207}Pb system, given the minimal amounts of ^{207}Pb that have been produced since 327 Ma.

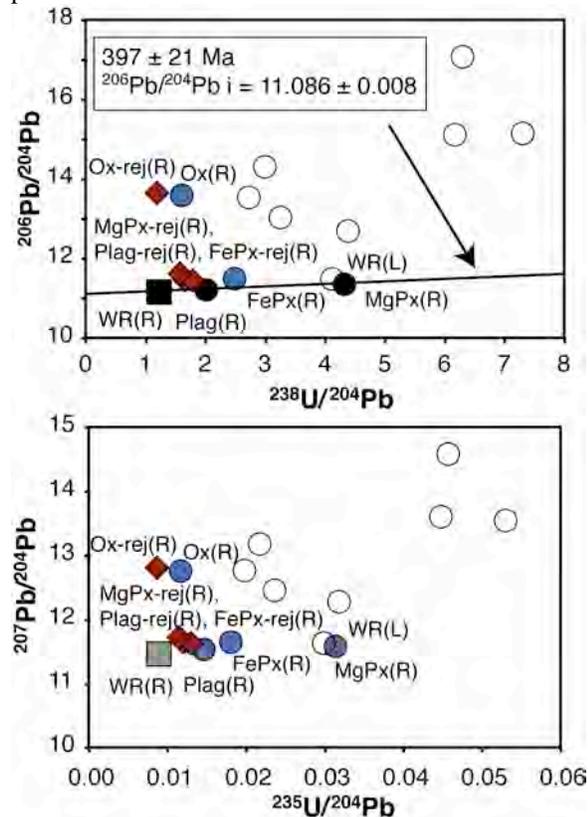


Figure 2: U-Pb isochron diagrams. Symbols as in Fig. 1. Black symbols only included in calculation of ^{238}U - ^{206}Pb age. Age calculated using Isoplot [5].

U/Pb in Martian basalt source regions: When interpreted in the context of the 327 Ma crystallization age, the Pb isotopic data yield information that expands our understanding of U-Pb geochemistry of martian basalt source regions. We employ three methods to estimate the initial $^{206}\text{Pb}/^{204}\text{Pb}$ of QUE 94201, and, from this, the $^{238}\text{U}/^{204}\text{Pb}$ of its mantle source. A maximum μ value is estimated by assuming that the composition of the least radiogenic min-

eral fraction (WR(R)) represents the maximum possible initial $^{206}\text{Pb}/^{204}\text{Pb}$ (11.163 ± 0.005). Assuming radiogenic Pb growth from 4.558 Ga to 327 Ma, starting from CDT, the μ value of the source is 1.90 ± 0.01 . In a second approach, the initial Pb composition is represented by the point of intersection of the geochron at 327 Ma and the array defined by the mineral fraction and leachate data. This method returns an estimated initial $^{206}\text{Pb}/^{204}\text{Pb}$ of 11.010 ± 0.024 , and source a source μ of 1.75 ± 0.03 . Lastly, the initial $^{206}\text{Pb}/^{204}\text{Pb}$ calculated from the three-point ^{238}U - ^{206}Pb isochron (11.0862 ± 0.0075) corresponds to a source μ of 1.82 ± 0.01 . These three very different approaches yield the same estimate for the QUE 94201 source μ to within $\sim 8\%$.

The estimated QUE 94201 source μ of 1.8-1.9 is lower than determinations of source μ values of ~ 4 for Zagami and Shergotty [2-4]. This new observation of an extremely low- μ source region for QUE 94201 means that the bulk Mars μ value is probably even lower than previously estimated. A low (< 4) bulk μ value for Mars reflects the volatile-rich nature of this planet in comparison to Earth or the Moon. The μ values for martian mantle sources vary by (at least) a factor of two, whereas the total range of μ values for terrestrial mantle sources varies by a factor of ~ 1.2 , and the μ values of lunar sources may vary by a factor of 10 or more. This suggests fundamental differences in the processes that govern U-Pb fractionation and/or their degree of progress on these three bodies.

Low initial ϵ_{Nd} and high initial $^{87}\text{Sr}/^{86}\text{Sr}$ of Shergotty and Zagami indicate that these samples came from mantle sources that experienced long-term enrichment in very incompatible trace elements relative to less incompatible trace elements. In contrast, initial ϵ_{Nd} and $^{87}\text{Sr}/^{86}\text{Sr}$ compositions of QUE 94201 indicate that it originated from the most depleted martian mantle source yet observed. Dar al Gani 476 also has high initial ϵ_{Nd} and low initial $^{87}\text{Sr}/^{86}\text{Sr}$, and, from its whole rock $^{206}\text{Pb}/^{204}\text{Pb}$ composition [4], is also inferred to have formed from a source with very low μ . The correspondence of high source μ values to high initial $^{87}\text{Sr}/^{86}\text{Sr}$ and low initial ϵ_{Nd} , and the contrasting correspondence of low source μ values to low initial $^{87}\text{Sr}/^{86}\text{Sr}$ and high ϵ_{Nd} , infers that U-Pb fractionation occurred during the same igneous events that resulted in Rb-Sr and Sm-Nd fractionation.

References: [1] Borg L. E. et al. (1997) *GCA*, 61, 4915-4931 [2] Chen J. H. and Wasserburg G. J. (1986) *GCA*, 50, 955-968 [3] Borg L. E. et al. (2005) *GCA*, 69, 5819-5830 [4] Bouvier A. (2005) *EPSL*, 240, 221-233 [5] Ludwig K L (2001) *Berkeley Geochron. Ctr. Spec. Pub.* 1a.