EARLY DIFFERENTIATION, LATE MAGMATISM, AND
RECENT BOMBARDMENT ON THE SHERGOTTITE PARENT PLANET
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Rb-Sr ages (T) and initial $^{87}\text{Sr}/^{86}\text{Sr}$ (I) for the shergottites, Shergotty and Zagami, and for the related achondrite ALHA 77005 are:

- **Shergotty**: $T = 165 \pm 12$ m.y., $I = 0.72261 \pm 13$;
- **Zagami**: $T = 184 \pm 8$ m.y., $I = 0.72139 \pm 5$;
- **ALHA 77005**: $T = 183 \pm 12$ m.y., $I = 71039 \pm 5$.

The equality of these ages and the occurrence of maskelynite in these meteorites, coupled with older $^{39}\text{Ar}/^{40}\text{Ar}$ and Sm-Nd ages of Shergotty, imply that the Rb-Sr ages were reset by a single major impact on the shergottite parent body.

A pyroxene-whole rock Sm-Nd age of $620 \pm 170$ m.y. and a maximum whole rock $^{39}\text{Ar}/^{40}\text{Ar}$ age of $626 \pm 15$ m.y. are probably good estimates of the crystallization age of Shergotty Sm-Nd model ages relative to an eucritic initial $^{143}\text{Nd}/^{144}\text{Nd}$ of 3.6, 3.5, and 2.8 g.y. for Shergotty, Zagami, and ALHA 77005, respectively, are upper age limits. Sm-Nd and Rb-Sr whole rock isochrons ($\sim 1.2$ g.y. and $\sim 5$ g.y., respectively) are discordant and show that the meteorites cannot be comagmatic. An early differentiation of the Shergottite parent body is indicated by BABI Rb-Sr model ages of 4.8-5.1 g.y. for the three meteorites. A two-stage model yields $(\text{Sm/Nd})_r/(\text{Sm/Nd})_s > 1.27, 1.33,$ and $1.68$ for Shergotty, Zagami, and ALHA 77005, respectively, for $T_x > 0$ where $r$ = rock, $s$ = source, and $x$ = crystallization. For $(\text{Sm/Nd})_r/(\text{Sm/Nd})_s \leq 2.2$, the upper limit achievable via pyroxene accumulation, the model yields $T_x \leq 2.8, 2.6,$ and $1.2$ g.y., respectively. Corresponding $(\text{Rb/Sr})_r/(\text{Rb/Sr})_s$ are 0.80-0.96. Thus, the two-fold variation in Rb/Sr between ALHA 77005 and the shergottites is inherited from distinct sources which were established early in the parent body’s history. Early differentiation plus late magmatism imply a sizable parent planet. A portion of the planet’s surface must be young. Mars fits these criteria.

ISOTOPIC CONSTRAINTS FOR THE
EARLY EVOLUTION OF THE MOON


A synthesis of the early evolution of the moon and of the lunar highland crust is made on the basis of U-Th-Pb, Rb-Sr, K-Ar and Sm-Nd isotopic data from lunar highland breccias. These data indicate that most of the lunar highland rocks were metamorphosed during a short period of giant
impacts at 3.8-4.0 AE (Terminal Lunar Cataclysm). The existence of an older major impact event at 4.17 AE is documented by precise, identical U-Pb and \(^{40}\)Ar-\(^{39}\)Ar ages obtained from breccia 78155. This older event may be connected with the formation of a basin on the eastern part of the earth-facing side of the moon or on the lunar far-side.

Both 3.9 and 4.17 AE old breccias yield nearly identical primary U-Pb ages of 4.46 and 4.51 AE suggesting that the moon differentiated on a planetary scale at that time. Derivation of the highland breccias from \textit{differentiated} sources is indicated by variations of initial Sr, Nd and Pb isotopic ratios at the times of impact metamorphism.

Rb-Sr model ages for KREEPTh-rich breccias require Rb/Sr fractionation at times \(\leq 4.2\) AE. Most likely the fractionation occurred during the cataclysm at \(\sim 3.9\) AE. A volatile/refractory element fractionation mechanism does not appear to be the principal process involved. It is most plausible that the KREEP component was generated by partial melting of a source with high Rb/Sr.

**CORRELATED ANOMALIES OF TELLURIUM AND XENON IN ALLENDE**

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The relative abundances of \(^{120}\)Te, \(^{122}\)Te, \(^{123}\)Te, \(^{124}\)Te, \(^{126}\)Te, \(^{128}\)Te and \(^{130}\)Te in carbon- and spinel-rich fractions of Allende’s acid etched residues have been redetermined by neutron activation and \(\gamma\)-ray spectrometry. Changes from the procedure described by Ballad \textit{et al.} (1979) are (i) irradiation to a higher neutron fluence, (ii) analysis of Te from a sample of natural sylvanite, Cripple Creek, CO, (iii) use of the ingrowth activity of \(^{131}\)I to monitor levels of \(^{131}\)Te in the irradiated samples and monitors, and (iv) use of a computerized peak-stripping program for data reduction. No differences were observed between the isotopic compositions of Te in the monitor of purified TeO\(_2\) and the sample of sylvanite.

The spectra of even mass Te isotopes in the carbon- and spinel-rich fractions of Allende are shown in Figure 1, normalized to the second lighest stable isotope, \(^{122}\)Te.

\[ g_{122} = \left(\frac{^{122}\text{Te}}{^{122}\text{Te}}\right)_{\text{Sample}} / \left(\frac{^{122}\text{Te}}{^{122}\text{Te}}\right)_{\text{Monitor}} \]  

In addition to the six isotopes shown there, the activity produced by double neutron capture on \(^{123}\)Te indicates values of \(g_{122}^{123} = 2.5 \pm 0.8\) and \(-0.6 \pm 0.8\) for the carbon and spinel fractions, respectively.

To illustrate similarities in the anomaly patterns of Te and Xe in these residues, the Xe spectra reported by Ballad \textit{et al.} (1979) have been