Implications for Lunar History from Ancient Basalts of the Secondary Crust.
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Introduction & Overview
Ancient volcanism (~4.35 Ga) on the Moon confirmed
• Recently, Kalahari 009 and Miller Range 13137 by SIMS Pb-Pb (isotopic) [1].
• Previously, Apollo 14 Alumunium Meteorites, then Kal 009
• Here: Extend and expand our report on Kal 009 [4].
  • Kal 009 in the context of "secondary lunar crust"
  • A concept introduced by Head and Wilson [5] and continued recently by Whetten and Head [6,7].
• Here we mean the "original" secondary crust volcanically produced prior to the currently identified lunar basins.

Important: because the timeline for secondary crust formation may not follow the usual paradigm.
• Formation of LMO then LHT/LVT "crust" then Impact Basins then Mars volcanism into the impact basins?

When, where, how could such a crust begin forming?
Will borrow heavily from prior work on this topic (i.e., Kal 009 in the context of "secondary lunar crust"
• Here we mean the "original" secondary crust volcanically produced prior to the currently identified lunar basins.

—Serendipitous "IBC" from [16]:
• Formation of LMO then LHT/LVT "crust" then Impact Basins then Mars volcanism into the impact basins?

Lunar Mare Basalt Source Formation

- Ages of Kalahari 009 Mare Basalt
- Kalahari 009, LVT and A14 Alumunium Mare Basalts
- Time before Present (Ga)
- Average Province Cratering Age (Ga)
- Lunar Mare Basalt Meteorite - Kalahari 009
- Lunar Mare Basalt Source Formation

Table 1. Candidate sources of Kal 009 & MIL 13317

Summary and Conclusions
• Lunar cryomantlas are characterized mostly by LVT basalt compositions.
  • Variations in LVT basalt ages are apparent both photo-geo logically and in sample data.
  • The variations in age suggest the "secondary lunar crust" probably formed rather continuously in early lunar history.
  • The Schlumberg-Schickard (SS) region is a type example of a cryptomaria, but the older, more heavily obscured Lomonosov-Fleming remnant lies farther from a source for the oldest LVT basaltises like Kal 009.
  • Principal Components Analysis (PCA) is a useful method to compare the compositions of samples with those of geo logical provinces.
  • See Smith et al. (1985), Bislett et al. (1995), Chevrel et al. (2006), etc.
  • But, interpretations of PCA are "non-absolute".
  • A patchwork of data suitable for "absolute" comparisons persists.
  • Remotely sensed Th abundances are systematically higher than laboratory values for corresponding samples.
  • Remotely sensed surfaces may be contaminated with high-Th ejecta.
  • One or more additional parameters remotely determined with "good" analytical and spatial resolution are needed.
  • Careful evaluation of Al/Fe ratios from spacecraft gamma ray spectrometry instruments may be useful.

References: