

EPISODIC LUNACY - V: ORIGIN OF THE EXOTIC COMPONENT. N.M. Evensen, V. Rama Murthy and M.R. Coscio, Jr., Dept. of Geology and Geophysics, Univ. of Minnesota, Minneapolis, Minnesota 55455.

We have previously reported on trace element and isotopic analyses of grain size fractions of regolith samples from Apollo missions 11, 14, 15 and 17. These investigations have been directed primarily toward characterizing the "exotic" component present ubiquitously in the lunar soils. The exotic component is required to account for differences in trace element concentrations and isotopic systematics between coexisting rocks and soils at various sampled sites. It is inferred to be enriched with respect to major basalt and anorthosite rock types in a number of trace elements, including K and Rb, and to have a Rb-Sr model age of the order of 4.5 AE. This material is thus probably very similar chemically and isotopically to KREEP; however KREEP has been defined petrologically and chemically by examination of distinguishable rock fragments, while the characteristics of the exotic component have been inferred only indirectly from studies on mixtures of exotic component and locally derived soil, too fine grained to permit identification of specific mineralogic and petrologic components. We therefore tentatively retain the distinction.

Where large proportions ( $\geq 10\%$ ) of exotic components are present, they can readily be demonstrated by direct comparison of rock and soil compositions. Measurements of K, Rb, Sr and Ba concentrations in various soil size fractions from 4 to 1000  $\mu$  at such sites (e.g., Apollo 15 soil 15531) show progressive increase in trace element content, particularly K and Rb, with decreasing grain size. Also, progressively finer size fractions plotted on a Sr evolution diagram deviate increasingly from the typical local rock isochron, in a direction indicating addition of material with high Rb/Sr and  $\sim 4.5$  AE model age. Similar, though less marked trends are seen in soils differing less noticeably from local rock compositions and therefore presumably containing a lower proportion of exotic component (e.g., Apollo 17 soils 71501, 75081). We conclude that the exotic component tends to be finer grained than the locally derived soil, and hypothesize that this difference is a consequence of transport of exotic component from a distant source, resulting in increased mechanical breakup of material. It is of interest to note that plagioclase separates obtained from individual size fractions of soil 10084 tend to mirror the trend of increasing trace element content with decreasing grain size, while ilmenite concentrates from the same fractions show no tendency to increase. Plagioclase is a common lunar mineral and could well be partially exotic in origin, while the ilmenite is probably almost entirely derived from the local very ilmenite-rich Apollo 11 rocks.

The orbital gamma ray spectrometry experiments have shown that high K, U, Th concentrations are present at several areas in the Mare Imbrium region. One of these, Fra Mauro, has been directly sampled by Apollo 14 and contains material chemically and isotopically similar to the inferred exotic component. If the Imbrium area were the sole source of such material on the lunar surface, a strong correlation between distance from the source and proportion of exotic component should be seen. Using comparison of rock and soil compositions to estimate the percentage of exotic component, and taking Fra

## EPISODIC LUNACY \_V: ORIGIN OF THE EXOTIC ...

Evensen, N.M. et al.

Mauro as a hypothetical source area, such a correlation appears to exist, ranging from ~35% exotic component at the Apollo 12 site, 300 km from Fra Mauro, to ~1% exotic component at the Luna 16 and 20 sites, >2000 km from Fra Mauro. Of course the actual source would be a more diffuse area, but this does not strongly affect the correlation, especially for more distant sites. Apollo 14 soils 14149 and 14259 show none of the grain size effects which we have attributed to transport and are therefore consistent with this model.

The regolith at Fra Mauro, and presumably the other high K, U, Th material in the Imbrium region, is believed to be derived from the excavation of the Imbrium basin at ~4 AE ago. Since Imbrium has the largest and deepest of the circular mare basins, its excavation may have brought up material from deeper in the lunar interior than is accessible from any other source. Such material would initially be found as ejecta surrounding the Imbrium basin, but over the subsequent 4 AE would diffuse outward into surrounding regolith at a rate controlled by the nature of lunar transport processes. Such processes are reasonably effective at, for example, transporting anorthosite and other exotic fragments into mare regions, and would presumably transport proportionately more fine grained material. Imbrium ejecta which landed on younger mare basins would be covered over by subsequent mare filling.

In view of the chemical and isotopic similarities between KREEP and the exotic component, as well as the general correlation between abundance of exotic component and the proportion of identifiable KREEP fragments in the soil, it is tempting to speculate that KREEP has a history similar to that hypothesized above, particularly since no evidence of localized reservoirs of KREEP-like material has been found. The lunar regolith would then be pictured as locally derived material dominated by the mare basalt-highland anorthosite bimodal tendency, overprinted with distance dependent KREEP-exotic component, with additional vertical and lateral mixing provided by lunar gardening and transport processes. If the major portion of trace element enriched lunar material were derived from the deep lunar interior by an essentially unique event, considerable implications regarding the moon's differentiation history and present structure would arise. Although such a hypothesis must remain tentative at best in the present state of our knowledge, some of these implications might be of interest to explore further.