Most highlands rocks are not pristine (of endogenous igneous origin), but polymict (mixtures of different rock types). The latter appear to consist of a few main components; that which supplies the bulk of their incompatible elements is known as KREEP. Although the relative concentrations of incompatibles in the KREEP component are well established, we can only set lower limits on absolute concentrations; large uncertainties are associated with relative and absolute concentrations of major elements. With one exception, pristine samples of KREEPy rocks have incompatible contents lower than those observed in some polymict breccias, and hence, do not appear to be representative samples of primeval KREEP (urKREEP).

There is still vigorous debate regarding the origins of (a) the high-incompatible KREEP component in polymict breccias, particularly those from Apollo-14, and (b) the moderate-incompatible pristine rocks. Some, such as Weill and McKay (1975), advocate partial melting to form the spectrum of incompatible element contents found in pristine and polymict rocks seeing them as a continuum corresponding to varying degrees of melting. In contrast Lipin (1976) maintains that fractional crystallization of a magma "ocean" led to a sequence of KREEPy residual liquids, and Hubbard and Minear (1976) suggest gradual alteration of a residual liquid following crustal formation. We hold that the Hubbard-Minear model is nearest to the truth, but that there is also evidence that the incompatible-rich residual liquid reached the surface at some localities, particularly at Fra Mauro.

Wasson et al. (1977) proposed a new plotting format for illustrating incompatible abundances: normalization to "KREEP" rather than to chondritic abundances. Following a suggestion of Palme and Wänke (1975) we plot the incompatibles in order of decreasing enrichment in KREEP relative to chondrites. For rare earths, this amounts to decreasing ionic radius. The advantages over the traditional chondrite normalization are that small systematic fractionations are readily recognizable, and elements other than rare earths can be assigned their "natural" position in the sequence.

As exemplified by our recent neutron activation data, by isotope dilution data from Hubbard and coworkers, and by neutron activation data from Schmitt and coworkers, KREEP-normalized diagrams for incompatible-rich polymict rocks are flat (Figs. 1-3). Experimental scatter is present but there is no significant deviation from zero slope. Petrogenetically significant deviations should appear as correlated deviations of several adjacent elements. In fact, with the exception of K, single-element aberrations are never replicated by other research groups, and appear to reflect interlaboratory biases. The scatter in K appears to reflect metamorphic redistribution of this volatile element.

We (Wasson and Warren, 1978) conclude that the flatness of these plots holds for samples from all lunar sites providing they contain at least 10 percent of the KREEP component. Such constant covariance over a wide range in concentration for so many elements in samples from such widely separated sites has profound petrogenetic implications. It is impossible to reconcile with
formation of these rocks by varying degrees partial melting. For example, when we assumed the 68415 partial melting protolith derived by Weill and McKay (1975), we found (Fig. 4) that variation in degree of melting (F) of a single source by merely a factor of 2 leads to resolvable non-flat (non-KREEPy) patterns. In the same paper, Weill and McKay estimated F values varying from 0.05 to 0.01 among just four KREEP-rich rocks.

The parallel variation among incompatibles leads to the conclusion that the incompatible element fractionations were generated in one or, at most, a few sources. The high lunar abundance of these incompatible-rich rocks demands that this source be large. The only source capable of producing the high enrichment of incompatibles in such large quantities of materials is the lunar magma ocean proposed to account for the formation of the anorthositic lunar crust. We borrow the German prefix ur- meaning primeval and designate as urKREEP the residual liquid remaining after nearly-complete crystallization of the magma ocean; our (Wasson et al., 1977) KREEP component derived from the most incompatible-rich Apollo-14 breccias gives lower limits on its incompatible element concentrations. With urKREEP it is straightforward to generate semiquantitative models for polymict breccias by the impact mixing of urKREEP with incompatible poor material from the lunar crust or upper mantle. Such a process would dilute but not fractionate the incompatibles. It seems probable that the KREEPy magma extruded in the Fra Mauro region prior to the late heavy bombardment was very similar to urKREEP in composition.

The pristine KREEPy rocks show a range of major element compositions. With one exception these are less incompatible-rich than the Apollo-14 KREEP

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component, thus these rocks are clearly not samples of pure urKREEP. Most can be explained by a model similar to that of Hubbard and Minear (1976), who suggested that some of the "urKREEP" magma-ocean residuum was modified by reaction with material of the lower crust before extrusion, thus accounting for their compositions along the plagioclase-pyroxene cotectic in the system olivine-anorthite-silica (Fig. 5). Assimilation of crustal material can also explain the lower incompatible concentrations. Presumably the assimilated material was so much poorer in incompatibles that the KREEP normalized patterns were unaffected, in agreement with evidence that primary crustal rocks were incompatible-poor anorthositic, troctolitic, and noritic cumulates (Warren and Wasson, 1977). Hubbard and Minear designate their process "hybridization", but in actuality it amounts to a combination of assimilation and "zone refining". Hybridization implies a mingling of two magmas (Carmichael et al., 1974).

With two exceptions, incompatible patterns for pristine KREEPy rocks are as flat as those in polymict KREEPy rocks (Fig. 6). The main exception is 15405c (Nyquist et al., 1978), the only KREEPy pristine rock that is not a basalt, but a quartz monzodiorite plutonic rock. The high incompatible element content combined with the slightly negative slope suggest that this material was produced either by fractional crystallization of a KREEPy magma (Ryder, 1976) or by partial melting of a KREEPy rock. There also appears to be a negative slope to 72275c (Blanchard et al., 1974). Since its incompatibles are relatively low, melting of a KREEP-rich parent is not a possible model, and the negative slope is also not reconcilable to the proposal that 72275c is an intermediate rock type among a continuum which includes mare basalts and still KREEPier basalts (Ryder et al., 1977).

Our siderophile element data on 15386 (at 7 grams the largest pristine KREEPy rock!) confirm petrographic evidence that it is pristine. On the olivine-anorthite-silica pseudoternary (Fig. 5) 15386 and the other pristine KREEP-rich rocks are restricted to an area near the pyroxene-anorthite cotectic. In contrast KREEP-rich polymict breccias, including the so-called low-K Fra Mauro "basalts", occupy a diffuse field near the cotectic between the olivine and anorthite fields. No petrologic significance should be attached to the loose LKFM-cotectic association because it almost certainly results from the fortuitous mixing of components such as urKREEP, anorthosites, troctolites, and SCCRV (Wasson et al., 1977), and not from differentiation controlled by the olivine-plagioclase cotectic surface (Hess et al., 1977).