LITHIUM AS A CORRELATED ELEMENT AND ON THE BULK COMPOSITION OF THE MOON AND THE PARENT BODY OF THE EUCRITES.

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In our previous Apollo papers[1,2] we have reported on the identification of primary matter in the lunar highlands. There is little doubt that most highland samples are mechanical mixtures. One of the components of these mixtures is a Mg-rich component which according to our interpretation represents primary matter of the last accumulation stage of the moon and which never underwent large scale magmatic fractionations. We have shown that all highland samples fit very well in a two-component-mixing model with the lunar anorthosites and the Mg-rich primary component as endmembers. The primary component was computed from the composition of the mixtures (the highland samples with their varying chemical composition) with the only assumption that the Ca/Al ratio in the primary matter has a value of 1.08. The KREEP-rich samples fit equally well to such a mixing diagram, if one assumes that there exists a trace element rich third component which major element composition does not significantly influence the bulk chemistry of these samples.

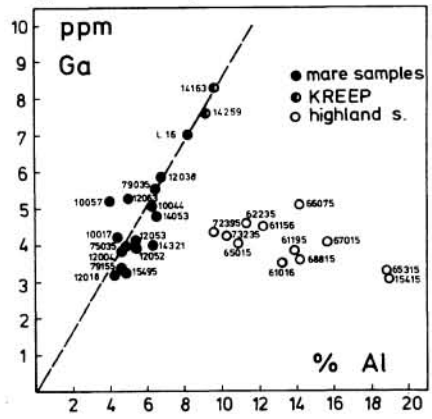

Fig. 1

The constant Al/Ga ratio (Fig.1) of all mare samples and the KREEP-rich samples indicate the genetic relation of the feldspars from mare basalts and KREEP (see also abstract Palme and Wänke). The different Al/Ga ratio in the anorthosite-rich samples seems to exclude a significant admixture of these anorthosites to the KREEP-rich samples (14163 etc.). In the case of the mafic elements Fe-Sc and Mg-Cr both KREEP-rich and KREEP-poor highland samples have identical ratios differing considerably from those in the mare basalts (Figs. 2 and 3). We assume that the Fe/Sc and the Mg/Cr ratios, both in KREEP-rich and KREEP-poor highland samples are defined by

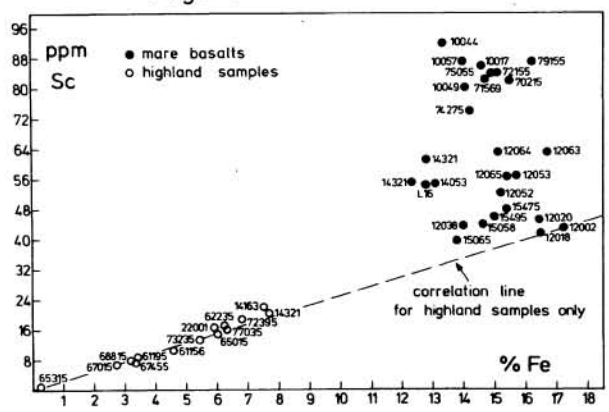

Fig.2

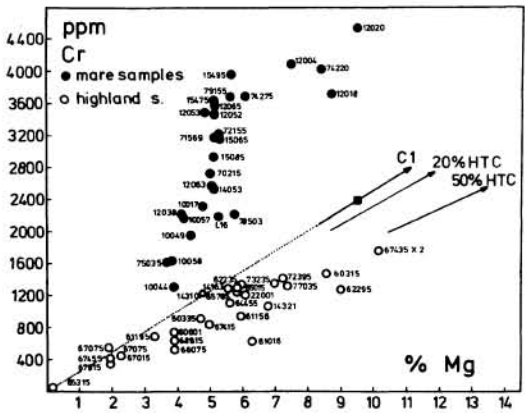

Fig.3

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the admixed primary component.In this way, the high Mg/Fe ratio in KREEP-rich samples is explained satisfactorily also.Nevertheless the trace element rich component (pure KREEP) seems to have been added to all highland samples together with a constant proportion of mafic elements from the primary component.

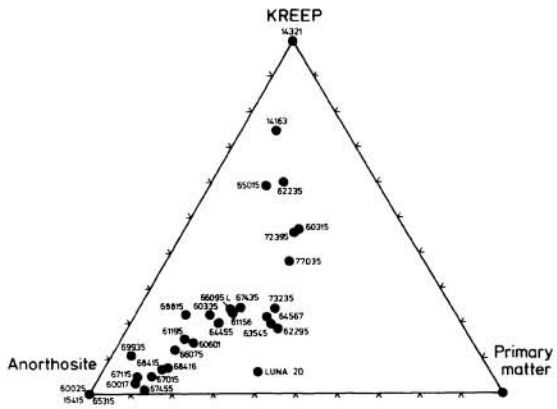

Fig. 4

The last point is indicated by the fact that all highland samples fit also very well into a ternary mixing diagram with anorthosite, KREEP (14321) and primary component as endmembers.The proportions of these endmembers in the various highland samples are shown in Fig. 4. The computation was again based on the composition of the mixtures only.The fact that such a three-component-mixing computation gives satisfactory results probably indicates that KREEP was admixed to most highland samples collected so far by one single event, the Imbrium collision.In the resulting ejecta a rather constant ratio of an extreme lunar differentiate very rich in incompatible elements and the unfractionated primary matter seems to have been established.

In our last papers[1,2] we have also tried to calculate the bulk chemical composition of the moon from observed correlations of various pairs of elements in light of the present knowledge about the condensation sequence in the solar nebula.There seems to exist the general agreement that the moon[3-5] is enriched in refractory elements and depleted in volatile elements relative to the Mg-silicates.The total fractionation factor appears to be fairly well known from the K/La ratio which is very constant for all lunar samples but about a factor of 30 below the C 1 ratio, while the ratios of two correlated refractory elements in lunar samples are always identical to the C 1 ratios.Lanthanum is certainly a good reference element for the whole group of refractory elements, however, the depletion factor of K relative to the Mg-silicates can only be crudely estimated. We have recently realized that Li correlates very well with Be in lunar samples (Fig.5 exclusively based on data from Dr.Rose's group[6]). Unfortunately, there exist only very few data on Be. Beryllium should certainly belong to the refractory elements and should have been enriched therefore in the high-temperature condensates (HTC) by about a factor 22, but no direct measurements in Allende inclusions were carried out so far.The good correlation with Yb and the identity of the lunar Be/Yb ratio with the C 1 value (Fig.6) can, however, be taken as experimental evidence of an identical enrichment of the REE and Be in the moon and in the HTC.

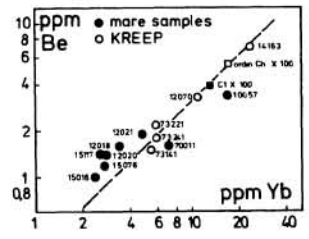

Fig. 5

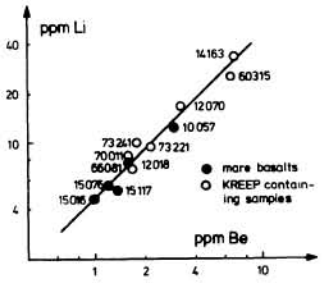

Fig.6

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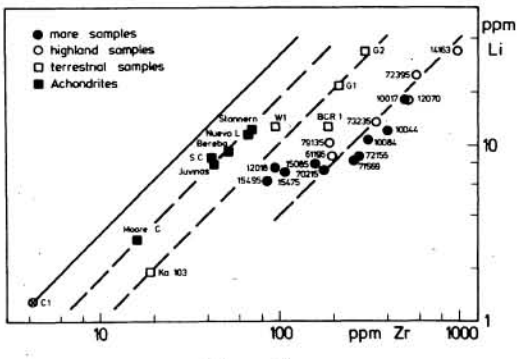

Fig. 7

A similar correlation of Li with Zr besides that for the lunar samples also holds for eucrites and might even extend to terrestrial samples (Fig.7). Both the Li/Be and Li/Zr ratios for lunar samples are about a factor of 8 below the chondritic ratio.From thermodynamic data as well as from volatility experiments we can be certain that during condensation Li does not follow the other alkali elements being far less volatile.On the other hand, we have analyzed three Allende inclusions showing high enrichment factors for all refractory elements but found Li concentrations below the chondritic level.We can therefore quite safely assume that Li does not belong to the group of refractory elements either,but in the condensation sequences follows the Mg-silicates.Hence, we can use Li as reference element for the Mg-silicates,the most abundant compound among the condensable elements.

The Li/Be ratio yields for the moon a contribution of 39 % HTC,while from the Li/Zr ratios values of 41 %, 13 % and 22 % HTC are found for the moon, the eucrites and the earth,respectively.The value for the bulk earth comes down to 14 %, assuming a core of a mass of 35 % which does not affect the Li/Zr ratio.For the moon the HTC content of 40 % is slightly below our previous estimates[1],in which (based mainly on the K/La ratio) values between 40 % and 54 % were obtained.The new value gives the following bulk composition of the moon:

O	41.6%	Si	19.2%	Fe(FeO)	8.2%	Na	0.18 %	Sc	51 ppm
Mg	13.9%	Ca	7.2%	Fe(met)	1.8%	K	0.014%	La	2.0ppm
Al	6.8%	Ti	0.4%	Ni	0.1%	Cr	0.24 %	U	0.048-0.072ppm

The Al and Ca contents are still considerably above the range which seems permissible from petrologic experiments assuming the mare basalts to reflect the lunar bulk chemistry[7].We have already suggested an inhomogeneous moon with a considerable decrease of HTC elements towards the surface.We suppose that the major element chemistry of the mare basalts is merely determined by the chemistry of the outer region of the moon,while the incompatible trace elements brought to the surface regions by partial melting of the whole moon allow a better estimate of the bulk composition.

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