

TRACE ELEMENT ZONING IN COEXISTING CHROMITE/ULVÖSPINEL IN APOLLO 12 SAMPLES - ANALYZED BY A PROTON BEAM MICROANALYZER; H. Blank\*, A. El Goresy\*, J. Janicke\*, R. Nöbling<sup>†</sup>, and K. Traxel<sup>‡</sup>, \*Max-Planck-Inst.f. Kernphysik, Heidelberg; <sup>†</sup>Physiologisches Inst. University Heidelberg; <sup>‡</sup>Physikalisches Inst. University Heidelberg.

The partitioning of trace elements among different coexisting phases provides additional information about the behavior of these elements during crystallization in lunar rocks. Measurements were carried out on zoned mineral pairs of chromite/ulvöspinel showing different zoning trends reported by El Goresy et al. (1). The investigation of these spinels shall give information if the behavior of the distribution of trace elements is influenced by the zoning relationships of the major elements. Besides the electron microprobe we used a proton beam microanalyzer (2) for the analysis of the trace elements (3) on the same spots measured by the electron microprobe. Coexisting, zoned chromite/ulvöspinel of an ilmenite basalt were investigated in the Apollo 12 samples 12051,60 and 12051,62. Two different types of spinels were encountered: the bluish-gray Ti-bearing chromite and the brownish Cr-bearing ulvöspinel. They mainly occur in contact with each other with a sharp or gradational boundary from chromite to ulvöspinel. There are also individual idiomorphic grains of early chromite without ulvöspinel rims. Grains with the following different zoning features were investigated:

1. On one side of the grain gradational zoning; on the opposite side a sharp boundary from chromite core to ulvöspinel rim.
2. Only gradational zoning from chromite to ulvöspinel.
3. Chromite and ulvöspinel with a sharp boundary.

Analyses of the early formed, idiomorphic chromite grains show that their  $TiO_2/(TiO_2+Al_2O_3+Cr_2O_3)$  (TAC) ratios slightly vary from 0.1 to 0.15; the  $FeO/(FeO+MgO)$  (FFM)-value lies below 0.9. These grains do not contain any detectable amounts of trace elements (<4 ppm).

Figure 1c shows an analyzed grain with gradational change in TAC-range from 0.1 to 0.25 (points 2 and 1) on the one side and sharp zoning with a TAC-value from 0.13 to 0.62 (points 3 through 8) on the opposite side. According to the TAC-values the FFM-values (Fig. 1b) increase in a small range from 0.96 to 0.97 (points 2 and 1) and in points 3 through 8 from 0.96 to 0.98. This grain contains traces of Zr. The Zr concentration (Fig. 1a) is apparently influenced by the TAC-values which was already observed in the Apollo 15 spinels (3). At high TAC-values (points 6,7,8) the grain has a Zr content from 90 to 105 ppm. In contrast to Apollo 15 chromites, the chromite core (points 2,3) incorporates Zr of up to 50 ppm.

Grain A in Figure 2 shows gradational zoning from chromite to ulvöspinel with a TAC-range from 0.15 to 0.64. The variation in the FFM-values (0.98-0.99) is much narrower in comparison with the variation of the TAC-ratios of the same points (Fig. 2b,c). This grain contains 4-8 ppm of Zr (Fig. 2a) in the chromite core, but up to 50 ppm in the ulvöspinel rim.

Grain B shows a trace element pattern different from the other measured grains. The analyzed points 1 and 2 with low TAC-values (0.15) (Fig. 2c) and low FFM-values (0.92) (Fig. 2b) do not show any detectable Zr (Fig. 2a). Following the abrupt zoning from chromite to ulvöspinel an instantaneous increase of TAC and FFM (point 3) is observed accompanied by the appearance of Zr with a concentration of about 50 ppm. Then the Zr content rises with increasing TAC-values. The zoning features in grain B show similar trace element behaviors as reported from Apollo 15 spinels (3). The results of Fig. 1 appear to be in sharp contrast to the results obtained on grain B (Fig. 2) if only the dependence of the Zr concentration on the TAC-ratios

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is considered. El Goresy et al. (1) reported successive generations of spinels with different initial FFM-ratios, however, with similar zoning trends (Trend II of El Goresy et al., 1976). In other words, spinels with the same TAC-ratios, however, with different FFM-ratios precipitate from the basaltic liquid at different temperatures in the sequence of the crystallization. A low initial FFM-ratio is indicative of an early generation and a high initial FFM-ratio a late one. Zr can always be observed in chromite grains with FFM-values greater than 0.95. Analyses points 2 and 1 in grain B, Fig. 2 show FFM-values of about 0.92 (in Apollo 15 chromite in samples 15065 and 15555 the FFM was less than 0.9). Also the early formed chromites with  $FFM < 0.9$  are without detectable Zr.

A very important result of the present investigations is the fact that the variation in Zr content upon increase in initial FFM-ratios of the spinels of different generations is not comparable. In grain B Zr varies between 50 and 250 ppm, in grain A between 8 and 50 ppm (Fig. 2), and in the grain of Figure 1 between 90-105; although the TAC ranges of these grains are identical. Hence the features observed are not a direct result of the increase in the TAC-ratio of the spinel. The controlling factor is probably the composition of the basaltic liquid and its Zr concentration during growth of the spinels. This concentration must have been different during the growth of the various spinel generations.

#### References

- (1) El Goresy, A. et al. (1976) Proc.Lun.Sci.Conf. 7th, 1261.
- (2) Bosch, F. et al. (1980) Nucl.Sci.Appl., Vol.1, 33.
- (3) Blank, H. et al. (1982) Lunar Planet.Sci. XIII, 49.

Fig. 1a

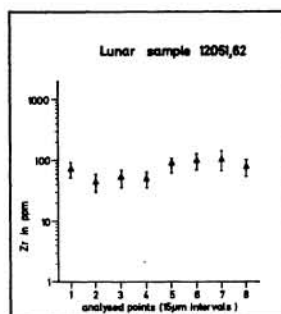


Fig. 2a

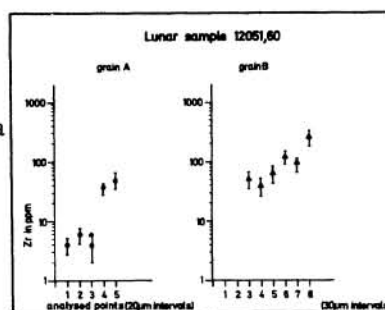


Fig. 1b

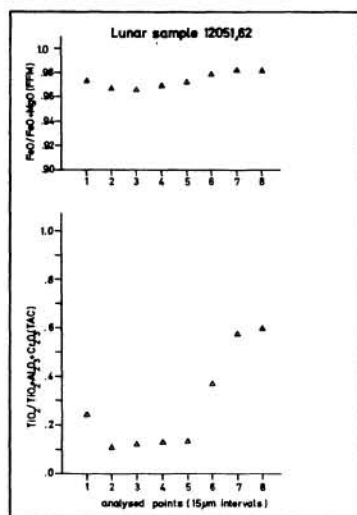


Fig. 2b

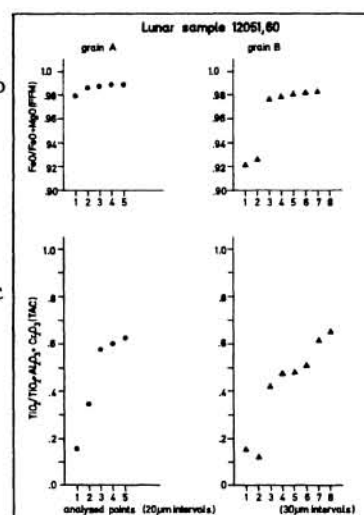


Fig. 1c

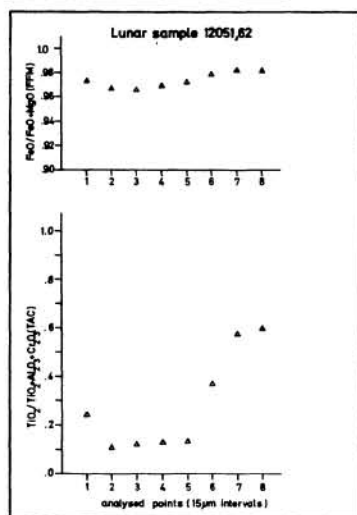


Fig. 2c

