

INITIAL FINDINGS OF A STUDY OF CHEMICAL COMPOSITION AND CRYSTAL FIELD SPECTRA OF SELECTED GRAINS FROM APOLLO 14 AND 15 ROCKS, GLASSES AND FINE FRACTIONS (less than 1 mm), P. M. Bell and H. K. Mao, Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C. 20008

#### Composition

Olivine phenocrysts in a section (#A-14306,6) of breccia range in composition widely between Fo<sub>70</sub> and Fo<sub>90</sub> (Table 1), in contrast with those from Apollo 11 and 12 rock samples which ranged between Fo<sub>70</sub> and Fo<sub>75</sub>. However, the iron-poor olivines of this rock contain relatively high concentrations of Cr (approximately 0.3 weight per cent Cr<sub>2</sub>O<sub>3</sub>) attesting to their having crystallized under similarly low oxygen fugacities. These data suggest the existence of precursor rocks, which were lower in iron, and perhaps were more primitive differentiates than those of Apollo 11 and 12. Further data on selected crystals will be needed to confirm this interpretation.

Large, subhedral olivine phenocrysts from Apollo 15 rock 15555 are more Fe-rich than Apollo 11, 12, and 14 phenocrysts. Previous compositional measurements on lunar olivine phenocrysts have indicated normal chemical zoning of Fe and Mg, with Mg/Fe decreasing at the grain margins or remaining constant, but several grains in the section studied (#15555,37) are reversely zoned. Relatively Fe-rich cores (Fo<sub>40</sub>) of these abnormal phenocrysts grade into Mg-rich margins (Fo<sub>60</sub>). Other smaller olivine phenocrysts in the rock are euhedral and are not zoned. It is very likely that both types of olivine phenocryst in this rock crystallized on or immediately below the liquidus, but the compositional differences would imply that the reversely zoned crystals were inherited from an earlier stage of the process. A process of adiabatic release of pressure of 1-10 kilobars, or of a temperature rise from the enthalpy of crystallization at the lunar surface, could have caused the observed zoning. Two stages of crystallization are implied--one for the large reversely zoned olivines, the other for the smaller euhedral ones.

#### Spectra

The crystal field spectra of Fe<sup>2+</sup> in crystals of olivine and pyroxene from breccias, rocks, and fine fractions (less than 1 mm) of Apollo 12, 14, and 15 samples are typical of Fe<sup>2+</sup> bands in octahedrally coordinated sites (Figures 1, 2, 3). However, unusual bands are observed at energies between 25,000 and 15,000 wave numbers. These are thought to be caused by Ti<sup>3+</sup> and Fe<sup>3+</sup>. Although the calculated assignments do not provide unique solutions, they support the chemical evidence for the existence of these species in lunar crystals.

The glass particles which are colored green, yellow, and red, behave differently than the crystals, in that the Fe<sup>2+</sup> bands are nearly identical, regardless of color. The colors are caused by strong absorption in the ultraviolet, the sloping edge of which converges toward the visible range with

variable intensity. The remarkably constant infrared absorption and the effects of the ultraviolet absorption edge of these glasses may contribute to the uniform radiative and albedo properties of the lunar surface.

Figure 4 shows absorption spectra for a nearly colorless glass spheroid, low in both Fe and Ti. Figure 5 shows a green glass particle with a high Fe content, and Figure 6 a red fragment with both high Fe and Ti. Intermediate amounts of Ti cause brown colors.

The absorption coefficient for the strong  $\text{Fe}^{2+}$  band centered slightly above 1000 nm is plotted against weight per cent FeO for several glasses in Figure 7. The correlation is sufficient to provide a good basis for spectral interpretation.

Plotted in Figure 8 is the wavelength ( $\lambda$ ) of the absorption minimum between the Ti edge and the Fe band, versus the weight per cent  $\text{TiO}_2$ . The scale factors were chosen so as to spread the vertical axis. The scatter is related to the  $\text{Ti}^{3+}/\text{Ti}^{4+}$  ratio, a limiting value for a lunar oxygen fugacity being given approximately by the dashed line. A family of curves, each for a fixed oxygen fugacity, could be superimposed if they were known. A line close to the vertical axis would correspond to all Ti as  $\text{Ti}^{3+}$ . The estimated range of oxygen pressures for these glasses is  $10^{-7}$ - $10^{-14}$  atmospheres.

Table 1. Olivine Crystals from Breccia 14306 (Analyses by electron microprobe)

Weight percent	Grain Designations								
	15	6	1	10	2	4	12	9	3
FeO	10.05	11.37	24.67	15.57	18.76	18.36	26.30	10.43	20.44
MgO	48.46	47.42	36.70	43.67	40.73	41.55	34.39	46.11	39.21
$\text{SiO}_2$	42.19	41.72	38.86	40.75	39.84	40.12	38.26	41.13	39.71
$\text{Cr}_2\text{O}_3$	0.40	0.42	0.35	0.32	0.33	0.31	0.33	0.37	0.34
Total	101.1	100.93	100.58	100.31	99.66	100.34	99.28	98.04	99.70

Figures 1-8. Optical values (see text for discussion).

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