In an earlier paper (Pearce et al., 1974) we have suggested that the ratio $\frac{Fe^0}{Fe^{++}}$ may be an indicator of the time and severity of exposure of lunar regolith material to meteorite bombardment at the Moon's surface. Meteorite impacts cause heating in their vicinity. The lunar surface environment is highly reducing as a result of absorption of solar wind matter in the regolith. Thus, impacts lead to reduction of iron out of silicates and oxides in the affected material. Since oxidation is uncommon on the lunar surface, the reduced iron tends to stay once it is produced. Reduction of ferrous iron to metal, then, can be expected to be a cumulative process over the life of the regolith and may be indicative of its exposure history. Magnetic measurements are a simple, quick, non-destructive method for obtaining the ratio of reduced iron to ferrous iron ($\frac{Fe^0}{Fe^{++}}$) fairly accurately ($\pm 10\%$ for 10-20 mg soil samples). Hence, we have previously and in this present note, studied iron reduction in lunar samples by means of magnetically determined $\frac{Fe^0}{Fe^{++}}$ values for these samples and attempted to apply the results to the problem of regolith formation and development. The method has been described in earlier papers (Pearce et al., 1973; 1974).

The iron reduction ratio $\frac{Fe^0}{Fe^{++}}$ for a number of soils has been plotted (Fig. 1) against the mean grain size of the soils - a parameter thought to be an expression of exposure of soil material to surface conditions. Most of the $\frac{Fe^0}{Fe^{++}}$ values are taken from Pearce et al. (1974). A value for 14259 was obtained by combining $%Fe^0$ as determined by Nagata et al., (1972) with a chemically determined $%Fe^+$ (PET, 1971). Values of .066 for 15021, 21 and .057 for 15271,25 are reported in the present note. Soil grain size data is from Butler et al. (1973), King et al., (1972) and Lindsay (unpublished data). The two quantities are very well correlated with each other. Another parameter called on to describe the exposure age of the various Apollo sites is regolith thickness as obtained from seismic data and crater profiles (Watkins and Kovach, 1973). If average $\frac{Fe^0}{Fe^{++}}$ for all measured soils at each site is plotted (Fig. 2) against this parameter, a linear relation is obtained. The consistent correlation between these three disparate measurements is strong evidence they do indeed vary as a function of the age and severity of weathering at and in the vicinity of these sites. Measurements on vertical sections at these sites—the deep drill cores may determine the nature of the relation between these parameters.

With this in mind, we have recently begun a set of measurements on the Apollo 15 deep core samples, 15001, 15002 and 15003. The samples have previously been sieved and thus we can determine the distribution of reduced iron throughout the various size fractions. We wish here to report on measurements of $\frac{Fe^0}{Fe^{++}}$ in three complete size fraction sequences from 15001, in $<45\mu m$ fractions from 15001 and 15002. The results are plotted in figures 3 and 4 respectively.

Of the samples in Figure 3, two (148 and 164) have relatively average mean grain sizes (graphic means are 3.65\(\mu\)m and 3.96\(\mu\)m respectively) whereas 193 is a coarse grained sample (graphic mean 2.69\(\mu\)m). In all three samples...
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The finest fraction is the most reduced. This would be expected since much of the finest material has probably been reworked a number of times and thereby has had a chance to become more reduced. The coarse grained sample 164 is much less reduced than the finer soils particularly in the larger size fractions. In fact, some of these do not differ greatly from the Fe\(^0\)/Fe\(^{++}\) ratios typical of Apollo 15 igneous rocks (ave .0040, Pearce et al., 1973). Thus, this soil sample appears to be composed primarily of crushed, but unaltered igneous material. The coarser size fractions of the finer soils must contain appreciable proportions of reduced material such as glass, agglutinates, agglutinate debris and microbreccia fragments.

The sub 45\(\mu\)m sample measurements are plotted against depth in figure 4. There is rather small variation of Fe\(^0\)/Fe\(^{++}\) throughout the core and it is difficult to correlate these variations with the stratigraphic units identified throughout this length of the core. The average (.036) is somewhat lower than that obtained for four \(<1\)mm surface soils from Apollo 15 (.050) although the difference may not be significant. The buried soils would be expected to be less reduced on the average since they have been removed from the possibility of further reduction since their burial, assuming this burial to have occurred a significantly lengthy time ago.

Thus the ratio Fe\(^0\)/Fe\(^{++}\) appears well correlated with other parameters suggestive of surface exposure history of lunar regoliths. Areas with thick regolith coverings have more severely reduced soils, and at any particular site the finer grained, more mature soils tend to be more reduced. The finest fractions of the soils in part of the Apollo 15 deep core vary little in their Fe\(^0\)/Fe\(^{++}\) ratios, although for three there is a considerable variation in the coarser size fractions. The former observation may indicate some saturation process. The latter suggests that measurement of Fe\(^0\)/Fe\(^{++}\) in coarse fractions (i.e. \(>100\mu\)m) of soils may be a very sensitive and quick method of estimating the severity of their surface exposure.

References

PET (1971), Science, V. 173, 681.
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Fig. 1

Fig. 2

Fig. 3

Fig. 4

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