MICROSCOPIC AND THERMOMAGNETIC ANALYSIS OF APOLLO 17 BRECCIA AND BASALT: FEASIBILITY OF OBTAINING MEANINGFUL PALEOINTENSITIES OF THE LUNAR MAGNETIC FIELD.

Watson, D. E., U.S.G.S., Boulder, Colorado 80302; Larson, E. E., CIRES, Univ. of Colorado/NOAA, Boulder, Colorado 80302; Reynolds, R. L., CIRES, Univ. of Colorado/NOAA, Boulder, Colorado 80302

Two specimens of metabreccia (#73235) and two of basalt (#71055) from the Apollo 17 mission were studied by means of (a) thermomagnetic analysis (J_s vs T) and (b) transmitted- and reflected-light microscopy (at 500X magnification) in an attempt to identify magnetic carriers and their behavior during thermal experiments, including paleointensity determinations. The heating experiments were conducted in a controlled-oxygen environment ($fO_2 \leq 10^{-25}$ atm. at 700° C) to minimize alteration (1).

In the basalt, nickel-free iron was the only identifiable carrier of natural remanence. The iron occurs as crystals up to 25μ and is most commonly associated with troilite which occurs in grains up to 40μ. The troilite-iron grains are in general closely associated with either ilmenite or ülvospinel crystals. The average iron content, estimated from saturation magnetization measurements, is about 0.14% by weight. The average natural remanent magnetization (NRM) of the two basalt specimens is 2.0×10^{-5} emu/gm. During thermal cycling up to 800° C (less than one hour/cycle), some troilite breaks down to produce additional iron (Fig. 1). In some cases the content of free iron is increased by as much as 60% over the initial amount after completion of only two heating cycles.

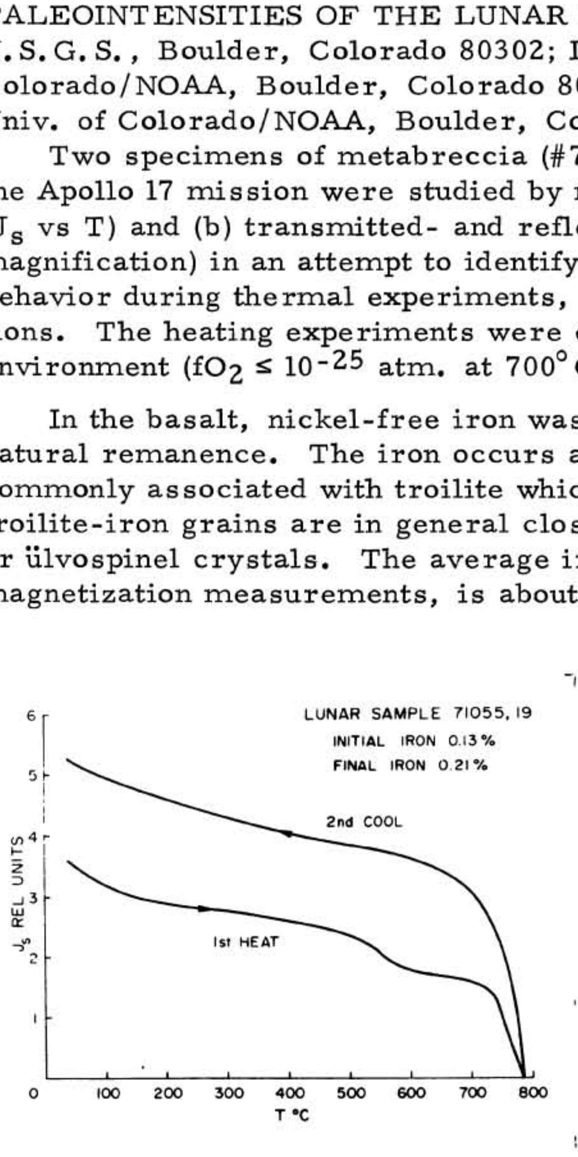

Fig. 1 J_s vs. T curve of basalt for two thermal cycles showing production of iron by reduction of troilite. Curie temperature at 580°C indicates partial oxidation of iron to magnetite; Curie temperature at 770° C represents that of pure iron.

In the metabreccia, the principal ferromagnetic material is also iron; however, some iron is nickel-free whereas some contains up to 6% nickel (see Fig. 2). The latter apparently resulted from incorporation of meteoritic debris. Total free iron averages about 0.31% by weight which is about 2.2 times

THERMOMAGNETIC ANALYSIS

Watson, D. E.

greater than that in the basalt specimens. However, the average NRM of the breccia specimens is only about 6×10^{-6} emu/gm, which is less than one-third the average moment of the basalts. The iron in the breccia is generally more fine-grained than that in the basalt; in fact so fine-grained that it is impossible to inhibit its partial oxidation to Fe_3O_4 at temperatures below 550°C even in an atmosphere in which $fO_2 \approx 10^{-22}$ atm (see Fig. 3). The iron in the breccia is less commonly associated with troilite than in the basalt and generally occurs as blebs within and marginal to breccia glass fragments. Since free Fe is consistently more abundant in the lunar breccias than in the basalts (2), it appears that the formation of additional iron is related to the brecciation process. Some of the "newly formed" iron, as demonstrated by Pearce, and others (3), probably came from the thermal breakdown of an iron-rich glass under reducing conditions. In addition, some iron undoubtedly formed by the reduction of troilite (FeS) (particularly that of very small grain size) during and shortly after meteorite impact. As a result, short-time thermomagnetic experiments produce little or no additional decomposition of troilite, thereby leading to nearly reversible J_s-T curves (see Fig. 3).

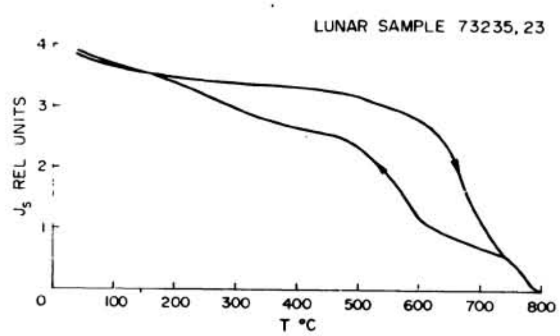

Fig. 2 J_s vs. T curve of metabreccia containing both pure iron and iron with about 6% Ni.

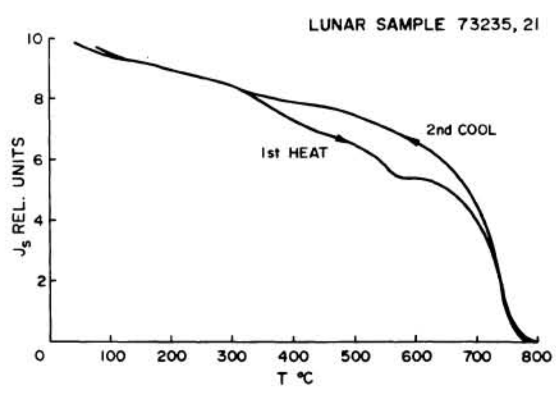

Fig. 3 J_s vs. T curve for metabreccia containing pure iron during two thermal cycles. Note formation of magnetite (T_c = 580° C) by oxidation during heating.

THERMOMAGNETIC ANALYSIS

Watson, D. E.

Transmitted- and reflected-light microscopic observations indicate that the breccia has been heated to temperatures sufficient to cause skeletal crystallization of ilmenite and partial recrystallization of silicate glass. This observation, the fine-grained nature of the iron in the breccia, and the reversible nature of the J_s-T curves for the breccia leads us to conclude that the breccia is more suitable than the basalt for paleointensity experiments. A similar conclusion was reached by Gose and others (2).

Based on an analysis of the higher temperature iron components for the lunar breccia, a tentative result for the strength of the lunar magnetizing field is 1100 gammas. A value about twice this one was obtained by Gose and others (4).

References

(1) Larson, E. E., Hoblitt, R., and Watson, D. E., (1974) Gas-controlled thermomagnetic analysis, Geophysical Jour., in press.

(2) Gose, W. A., Pearce, G. W., Strangway, D. W., and Larson, E. E., (1972) On the applicability of lunar breccias for paleomagnetic interpretations, The Moon, V. 5, pp 106-120.

(3) Pearce, G. W., Williams, R. J., and McKay, D. S., (1972) Magnetic properties and morphology of iron produced by subsolidus reduction of synthetic Apollo 11 glasses, Earth Plan. Sci. Lett., V. 17, pp 95-104.

(4) Gose, W. A., Strangway, D. W., and Pearce, G. W., (1973) A determination of the intensity of the ancient lunar magnetic field, The Moon, V. 7, pp 196-201.