GRAIN GROWTH OF IRON: IMPLICATIONS FOR THE THERMAL CONDITIONS IN A LUNAR EJECTA BLANKET. Thomas M. Usselman, NASA Johnson Space Center, Houston, TX 77058 and G. W. Pearce, University of Toronto, Toronto, Canada.

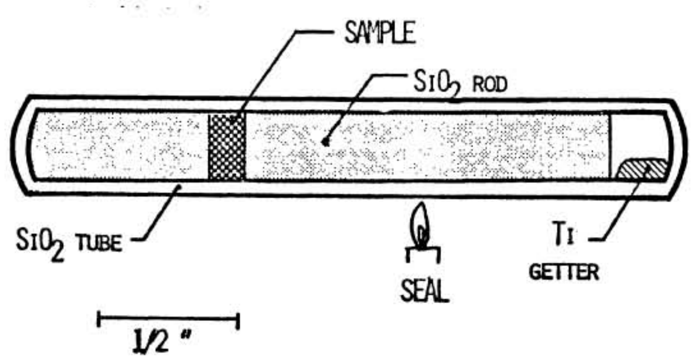
The grain size of iron particles in lunar breccias correlates with their degree of metamorphism (1) and thus with mineral reequilibration (2). Breccias and soils typically contain an order of magnitude more iron than igneous rocks (3). If iron grain size is indicated by the magnetic division into superparamagnetic (SP; <150Å diameter) single domain (SD; 150-300Å), and multidomain (MD; >300Å), soils are found to have predominantly SP and SD grains, breccias exhibit grain sizes from SP to MD, while igneous rocks generally only have MD iron (3). Breccias and soils are thought to be enriched in iron either by subsolidus (4) or shock induced (5) reduction or both. While reduction of metallic iron may occur during the formation of breccias, the dominant process affecting the iron particles is grain growth during heating and cooling of an ejected mass. Thus, the times and temperatures of experimentally determined iron growth may indicate the temperatures and cooling rates of the breccias in an ejecta blanket.

Samples of a synthetic Apollo 11 basaltic glass, which had been reduced to form SP and SD iron under controlled conditions (4), were placed in a silica glass tube (Fig. 1), evacuated, and sealed. A titanium getter removed any oxidizing agents from the charge. The following procedure was used: 1) the sample was heated at 750°C. for 15 minutes, 2) the titanium foil was isolated from the charge by sealing the silica glass tube between the foil and the charge, and 3) the isolated charge was heated at 750°C. until a constant magnetic moment was achieved, indicating equilibration of the quantity of metallic iron in the system. At this point the metallic iron content and relative grain size served as the starting point for the grain growth experiments. The isolated charges in the silica tubes were placed in a furnace at the desired temperature. After a given time, the sample was quenched and measured on the magnetometer. After measurement, the charge was reheated to the same temperature, and the procedure repeated until the iron was essentially all multidomain or until the run times became excessively long.

The charges in the silica glass tubes were examined directly in a vibrating sample magnetometer. The Jrs/Js*ratio and the shape of the

*Saturation remanence/saturation magnetization

Figure 1. Illustration of the silica glass tube used. The small flame indicates where the charge was sealed.



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magnetization curves were used to give the grain size range of the metallic iron (4). Curie point measurements indicated that the material being measured was indeed metallic iron.

A Jrs/Js representative of multidomain iron (determined by heating a sample at 1000°C. until the Jrs/Js reached a constant minimum value) was subtracted from the measured Jrs/Js of each point. The experimental data are shown on Fig. 2, where the percent of the initial Jrs/Js is representative of the fraction of iron remaining in the single domain grain size range. The intercept of the curves with the time axis indicates the maximum time in which SD iron can survive at a given temperature (Table 1 and Figure 3).

The results suggest that iron grain size may be an effective time dependent geothermometer for lunar surface processes in the range of 600°-1000°C. with limited applicability outside this range. For sites like Apollo 14 and 16 where breccias with widely differing iron grain size range are found, it can be concluded that time scales of the order of days to weeks were required to produce such a variety. This time scale, similar to those found by other methods (6), is consistent with models of base surge ejecta deposits, while being too slow for impact and ballistic deposits and too fast for deep-seated thermal metamorphism.

Table 1. Time required to eliminate all SD iron particles in lunar breccias.

Temperature, °C.	Time, hours
1100°C.	0.01*
975	5.25 ± 0.1
900	430 ± 25 (18 days)
810	7600 ± 2000 (320 days)
700	(10 ± 4) x 10^6 (1,100 years)
500	∿10^{12} (115 million years)*

* Extrapolated from Fig. 3.

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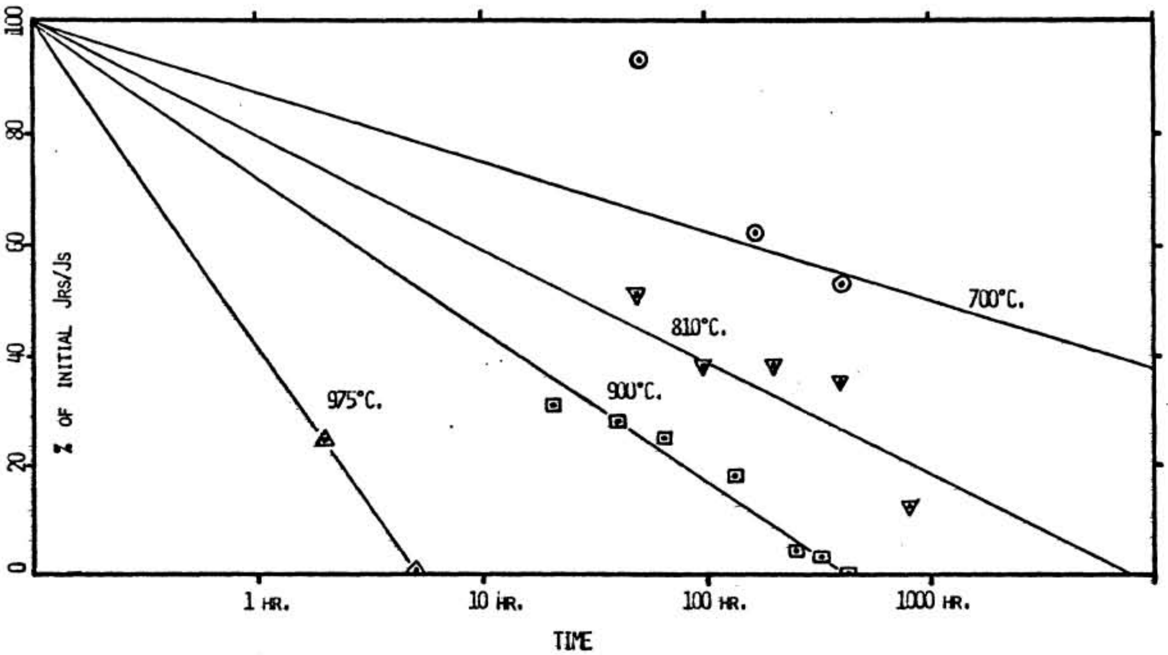

Figure 2. Plot of the measured % of the initial Jrs/Js versus log time for different temperatures.

Figure 3. Plot of the intercept of the time axis from Fig. 2. The two lines indicate the maximum and minimum values.