The Paleomagnetic Record of Melt Breccia 62235 Yields Consistent Estimates of a Lunar Field of ~100μT at 3.9Ga.

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Introduction: The Apollo era lunar paleomagnetism suffered from a lack of modern instrumentation and data analysis techniques. We have completed a reanalysis of these old Apollo paleomagnetic data using modern techniques of analysis (1,2). The principal result from the mare basalts is that several samples such as 10020, 10017, 10049, 12022, and 70215 appear to be carrying primary natural remanent magnetization (NRM) acquired on the Moon as they initially cooled on the lunar surface, but in almost every case alternating field (AF) demagnetization was not carried out to strong enough fields to isolate this primary magnetization properly. The histories of breccias are more complicated than those of mare basalts and their NRM is harder to interpret. The regolith and fragmental breccias are unlikely in general to give reliable paleointensity estimates. Melt rocks and melt breccias are formed at high temperatures far above the Curie point of any magnetic carriers, have an excellent chance of recording lunar fields faithfully when they cool. This cooling may have taken place in a melt pool in a simple crater, or in a melt layer in a complex crater. Other melt rocks and melt breccias appear to have cooled in ejecta blankets.

Apollo 16 melt breccia 62235 paleomagnetism: We now look in some detail at the paleomagnetic analysis of the Apollo 16 melt breccia 62235. whose age is ~3.9Ga. It is a homogenous KREEP-rich, clast-bearing, impact melt of noritic composition [3]. The clasts are embedded in a much larger fraction of melt, so that in its initial formation it must have been heated far above the Curie points of any possible magnetic carriers.

62235 has been studied by several groups [4,5,6,7], all of which obtained similar results. It is a citically important sample because it may have acquired its magnetization at the proposed time of a strong lunar magnetic field.

Mutually oriented sub-samples gave similar directions of Natural Remanent Magnetization (NRM), including samples analyzed in different laboratories. AF demagnetization consistently revealed a two compenent system with a softer moment generally demagnetized by ~30mT and accounting for >90% of the NRM (fig.1a) [4.5.6]. Thermal demagnetization revealed distributed blocking temperatures also defining a two component system with indications of a change in direction at ~500°C. Above this, there is a poorly defined direction seen in the steroplot by a movement to negtive inclination and in the Zijderveld by a turn near to the origin (fig.1d).

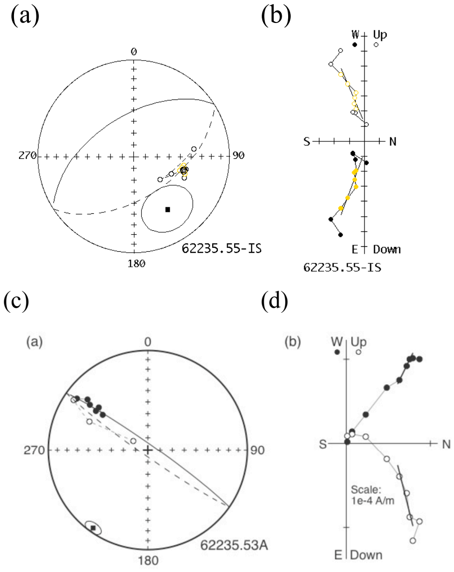

Figure 1. AF demagnetization: (a) stereoplot with fitted great circle and Fisher α95 for interval 5-20mT (b) Zijderveld plot with unconstrained PCA direction for the same interval (5). Thermal demagnetization: (c) stereoplot with fitted great circle.(d) Zijderveld Plot with unconstrained PCA direction for 200 °C to 500 °C (4).

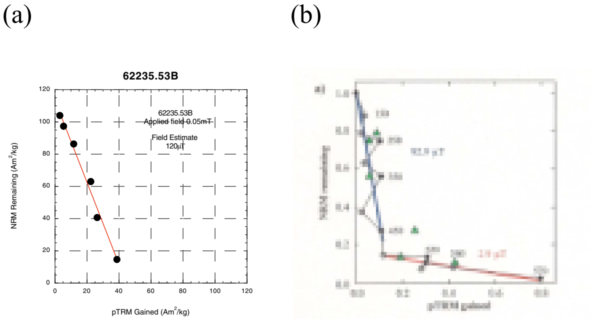

Figure 2. Classical Paleointensity determinations showing the ratio of NRM to pTRM replaced in discrete intervals (a) 62235.53D (4) and 62235.120 (7).

Classical paleointensity work (fig.2) gave field intensuity estimates from ~90-132μT for the lower blocking temperature fraction (4,7). Saturation remanent magnetization nomalization also gave consistent results ~100μT (fig 3a). AF demagnetizatioin characteristics allow comparisons between the behavior of NRM and likely candidates to explain its origin (fig. 3b). Here we see that with the exception of a minor discrepancy in weak fields the curves for NRM and pTRM are similar

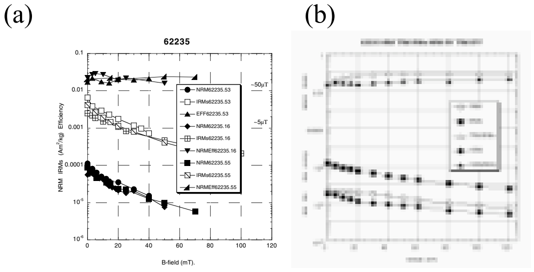

Figure 3 (a) AF Demagnetization of NRM, IRMs and efficiency for three sub-samples of 62235. (b) AF demagnetization characteristics of NRM and pTRM of 62235.120 (7).

We conclude from these observations that there is little disagreement about the raw data and the question is how to interpret them in terms of the history of a melt breccia. The two components of 62235's NRM are (1) a low intensity high temperature magnetization, which is poorly defined directionally, and (2) a hugh intensity lower blocked and softer moment, which gives a well defined direction.

Interpretation and implications of the NRM of 62235: In seeking an interpretation of the paleomagnetism of 62235, the NRM of pyroclastics on earth may afford a useful analogue. Athough the analogy is far from perfect, both pyroclastc flows and impact crater ejecta result in deposition of hot material, which subsequently cools in place, when NRM should be acquired by a TRM or pTRM mechanism. In pyroclastics from Santorini, it has been shown that there is a low temperature magnetization which accurately records the ambient geomagnetic field and a higher temperature moment whose direction is poorly defined (8).

We do not have direct geological evidence that the material in 62235 had a history of ejection, followed by cooling in place analogous to the pyroclastics. However, there is excellent evidence that other lunar samples may have had such a history. Figure 4 shows the layered Apollo 17 Boulder 1 at Station 2. Analyses of the NRM of this boulder and of the boulder cluster at Apollo 17 Station 6 by groups (6,9) working in consortia that considered detailed field, age and petrological evidence advocate just the history, we have outlined for 62235. In such a model, the strong field would haver been recorded as the boulders cooled in layered ejecta blankets. The field value obtained for 72215.262 from that boulder was identical to the result from 62235.120, i.e. 93μT. The Ar/Ar age for the matrix and hence for the formation of the Apollo 17 boulder was also identical with the 62235 age of 3.9Ga. An orthodox interpretation of the data is then that the two samples cooled in eject blankets of the same age and recorded the same lunar field. The origin of the weak higher blocked NRM is not clear.

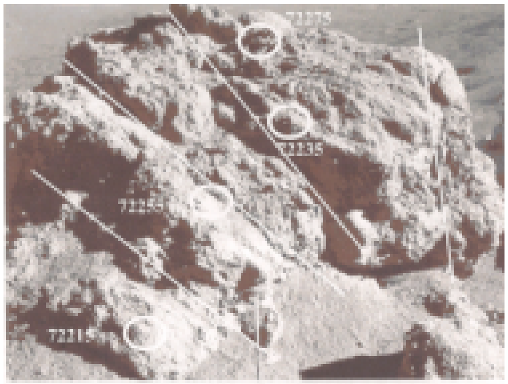

Figure 4. Apollo 17 Boulder 1 at Sation 2.

Conclusion: We conclude that the NRM of 62235 is recording a field of ~100μT acquired as it cooled in an ejecta blanket at ~3.9Ga from ~500°C. This is consistent with a similar determination from 72215. Considered in conjunction with the field intensity of ~60μT from 10020 (11,12), the lunar field may have decreased by 10's of μT between the 3.9Ga age of 62235 and the 3.7Ga age of 10020.

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