ANTIFERROMAGNETIC (NÉEL) TRANSITIONS IN LUNAR GLASS AND ILMENITE,

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The existence of antiferromagnetic minerals such as ilmenite, ferrosilite, and ulvospinel in lunar rocks has been well established. Pickart and Alperin (1) observed antiferromagnetic ordering in their neutron-diffraction studies of some Apollo 12 rock specimens. Nagata et al.(2) found two antiferromagnetic transitions at 41 K and 56 K on the bulk fines of Apollo 14 and 15 rocks (3), but were unable to observe an antiferromagnetic transition in fines and rock from the Apollo 12 mission (4). Also, previous magnetic-susceptibility measurements which we made on a wide variety of individual lunar glass spherules from 4.2 to 300 K did not directly reveal any antiferromagnetic (Néel) transitions which might be due to mineral inclusions within the glass matrix (5,6). Indirectly, however, we were able to infer the presence of antiferromagnetic inclusions in the glass from our previous measurements because the experimental magnetic-susceptibility data could best be fitted to an expression that contained the sum of temperature-dependent and temperature-independent paramagnetism and an antiferromagnetic term. The last term was significant in almost all the specimens studied. In the present study of 13 glass specimens, five individual glass spherules had relatively large antiferromagnetic terms and were selected for further examination. Careful susceptibility measurements were then made at closely spaced temperature intervals from 4 to 80 K in an attempt to observe the Néel transitions directly. At least seven different transitions were observed in the five glass specimens. With the exception of a transition that corresponded to ilmenite in one specimen, the observed transitions did not correspond to any transitions in known antiferromagnetic minerals. The large number of unidentifiable Néel temperatures can be explained if the antiferromagnetic mineral inclusions are members of a solid-solution series. Thus, for example, the observed Néel temperature of a given member of the $MgSiO_3$-$CaSiO_3$-$FeSiO_3$ series may be significantly shifted from that of $FeSiO_3$, the antiferromagnetic end member of the mineral series.

It is interesting that the one type of glass in which a large ilmenite transition might be expected is the orange glass from Shorty crater. McKay and Heiken (7) reported finding ilmenite in specimens of orange glass from the same location. The orange glass contains both high iron and titanium, but apparently this particular specimen contains very little ilmenite. Only a very weak transition was found in this sample at 56 K, the Néel temperature of ilmenite.

Although the Néel temperature of terrestrial ilmenite is well known, it was thought advisable to repeat the measurement on lunar ilmenite. In addition to the well-known transitions at 55-56 K, the lunar ilmenite also showed transitions at 11.3 K and at 4.3 K. Contrary to data in the literature, the 11.3 K transition was also found in terrestrial ilmenite. A very weak transition was suggested at 4.3 K, but, if present, it was severely masked by the strong paramagnetic component at this temperature.

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To make sure that the two low-temperature transitions can be ascribed to ilmenite rather than impurities, a study is also being made of high-purity synthetic ilmenite.

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