FERROMAGNETIC RESONANCE PROPERTIES OF SOME APOLLO 16 AND 17 FINES AND COMPARISON TO THOSE OF TERRESTRIAL ANALOGUES*, R. A. Weeks and D. Prestel+, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

Due to the high abundance of iron particles relative to other ferromagnetic phases in lunar fines, the unambiguous identification of magnetic phases other than iron has been difficult. It has been suggested(1,2,3,4) that some magnetic properties may be due to spinel phases containing ferric ions. Magnetic properties of a sample of 74220 have been attributed to magnetite(5). Hence a comparison of the ferromagnetic resonance (FMR) properties of 74220 with those of other lunar fines and with synthetic materials containing iron particles will be of value in testing these suggestions.

The FMR spectrum of iron particles can be separated into two components, one due to single domain (SD) plus super-paramagnetic (SPM) particles, and the other due to multidomain (MD) particles. The first class of particles (assuming spherical shapes, random orientation, and small particle-particle interactions) have a spectrum with a maximum at $g = h\nu/BH = 2$, and a minimum width $\Delta H \approx 5/3\ (2K/M_S) \approx 1{,}000$ gauss at 300K. The absorption will increase with decreasing temperatures as smaller and smaller particles have their magnetization saturated. The spectral component due to MD particles will have a minimum width $\Delta H \sim 8{,}000$ gauss and an absorption that decreases with decreasing temperature as fewer and fewer particles have their magnetization saturated (D. L. Griscom, private communication). If iron particles are the only source of the FMR spectra of lunar fines, the temperature dependent properties of these spectra are predictable. The temperature dependence of ΔH and of $\Delta H^2 A$ of the primary component, $g = 2$, in the FMR spectrum of synthetic glass containing SD and SPM particles of iron (generously supplied by G. W. Pearce, who determined particle sizes(6)) are shown in Figure 1,b. The solid line drawn through the data for $\Delta H(T)$ is calculated from the relation $\Delta H = 5/3\,[2K_1(T)/M_S(T)]$ for which $K_1(T)$ is obtained from other measurements(7). The straight-line segments drawn through the data for $\Delta H^2 A$ are best fits to the data over the three temperature ranges encompassed by the end points of the segments. These temperature dependencies of ΔH and of $\Delta H^2 A$ are expected for particles of iron whose diameters range down to $\sim$ 40 Å.

Figure 2 shows the temperature dependence of ΔH of the "characteristic" component for three Apollo 16 samples and one Apollo 17 sample. The line width, $\Delta H(T)$, is similar for all four samples. The straight-line segments shown adjacent to the data for 66081-22-1 are best fits to the data over the temperature ranges 450 to 350K (dot-dash), 300 to 150K (solid), and 100 to 1.2K (dash). These show that inflections in $\Delta H(T)$ occur at approximately 350 and 130K and are evident in the data for the other samples. The temperature dependence of $\Delta H^2 A$ for 74220, shown in Fig. 3, has a maximum between 350 and 175K. Similar maximums have been observed for $\Delta H^2 A$ of the "characteristic" component in the spectrum of Apollo 11, 12, 14, 15, and 16 fines samples(3,4).

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A comparison of the data in the three figures shows that: (1) The line width, ΔH, of the "characteristic" component is a function of the Apollo site from which samples were collected and ranges from 417 to 950 gauss[4], while for iron particles ΔH ≥ 1,000 gauss. (2) dΔH(T)/dT is, from 1.2 to 600K, ∿ 2X greater than that predicted and observed for SD and SPM iron particles. (3) Inflections are present in ΔH(T) for the "characteristic" component which are not expected and not observed for SD and SPM iron particles. (4) $\Delta H^2 A$ has a peak in the 100 to 300K range not expected and not observed for the FMR of SD and SPM particles. On the basis of (i) these differences between the FMR properties of the "characteristic" component and those of SD and SPM iron particles, (ii) the identification of a magnetic phase in 74220 with a magnetite Curie temperature, and (iii) similarities in the FMR properties of the "characteristic" component in the spectra of most Apollo fines samples and in the spectra of 74220, we suggest that magnetic phases other than iron are present in most lunar fines. These phases may be titanochromites[1], or titanomagnetites.

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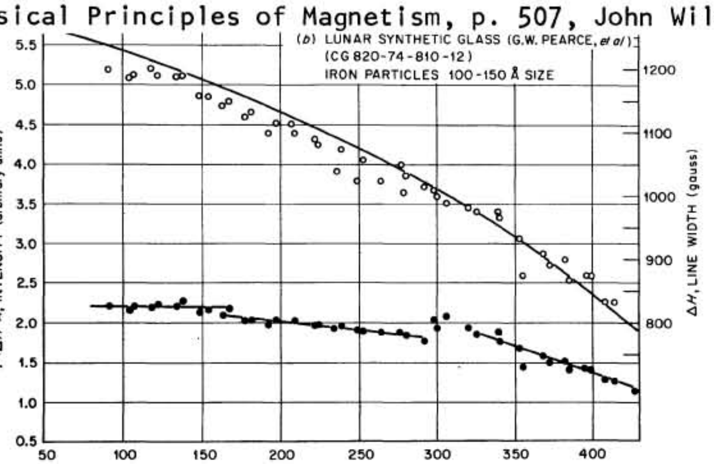

Fig. 1. Line width, ΔH (open circles), and intensity, $\Delta H^2 A$ (filled circles), of a ferromagnetic resonance component (g = 2.0) as a function of temperature.

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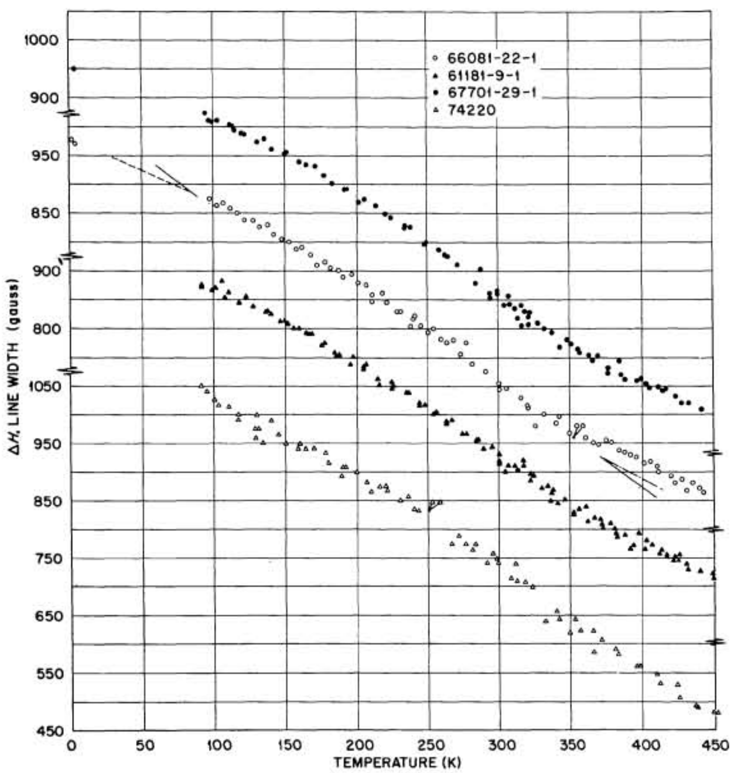
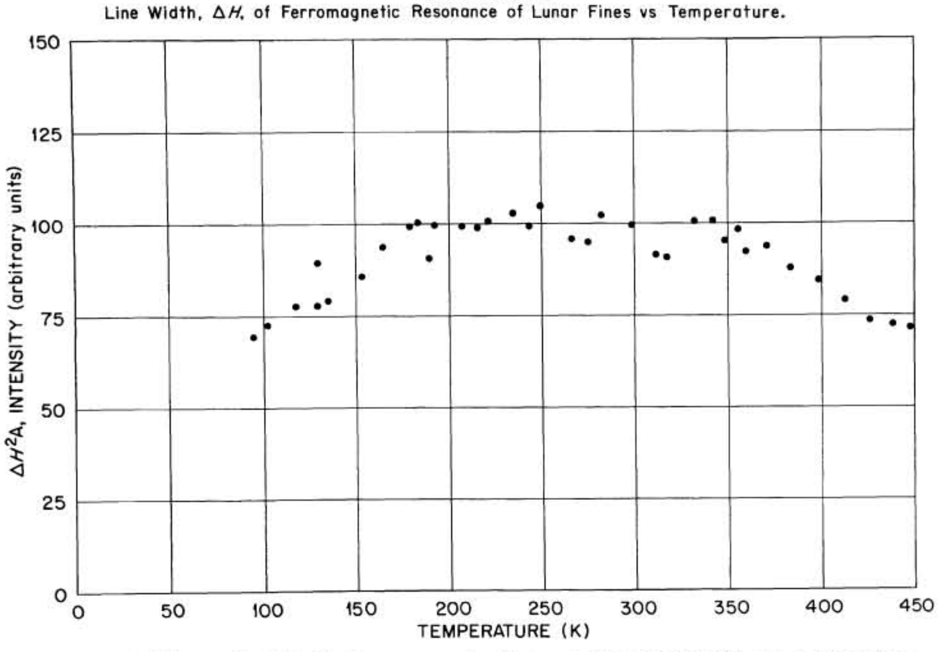


Line Width, ΔH, of Ferromagnetic Resonance of Lunar Fines vs Temperature.



Intensity of "Characteristic" Resonance in Orange Soil (74220) as a Function of Temperature.