MAGNETIC PROPERTIES AND NATURAL REMANENT MAGNETIZATION OF APOLLO 16 AND 17 LUNAR MATERIALS

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1. Basic magnetic properties

The magnetic properties of three Apollo 16 samples (66016, 61156-11, 61156-12) and four Apollo 17 samples (70017, 74220, 75083 and 77017) have been examined to date. The intrinsic magnetic properties such as saturation magnetization (I_S), Curie point ($\textcircled{H}$), $\gamma - \alpha$ transition temperature of FeNi alloy ($\textcircled{H}^*$) and paramagnetic susceptibility (χ_a) and the structure sensitive magnetic properties such as initial magnetic susceptibility (χ_o), saturation remanent magnetization (I_R), coercive force (H_c) and remanence coercive force (H_{RC}) of these samples are summarized in Table 1. Remarkable magnetic properties of all Apollo 16 lunar samples including 8 other Apollo 16 samples which have already been reported (1) are (a) that the metallic iron contains considerable amount of kamacite and (b) that the paramagnetic susceptibility (χ_a) is unusually small owing to a low content of FeO. In comparison with the Apollo 16 materials, the three Apollo 17 materials contain no kamacite and their paramagnetic susceptibility is of the normal value corresponding to 15 - 20% of FeO, except 77017 which contains only 6.2% of FeO.

A specific sample is the orange soil (74220), in which $J_S(300K) = 0.13$ emu/gm and $\textcircled{H} = 778^oC$. The observed I_S value is in agreement with the result obtained by Brecher and Marosh (2). In the initial heating process in 10^{-5} torr atmosphere, however, a production of metallic iron took place in a temperature range up to about 700°C, and then $I_S(300^oK)$ becomes 0.28 emu/gm. No definite magnetic transition at 580°C such as observed by Olhoeft et al. (3) was detected in this initial heating process. Since no magnetite has been found in chemical and mineralogical studies (e.g. 4, 5, 6) on the orange soils, the original material which has changed to metallic iron could not be magnetite.

2. Natural remanent magnetization (NRM)

The intensity and stability of NRM's of four Apollo 16 samples and four Apollo 17 samples are summarized in Table 2. The stable component (I_o) of NRM is defined here as the stable remanent magnetization with respect to both the intensity and direction for the AF-demagnetization range from 100 to 200 Oe.rms. In the table, only the stable component of NRM's of 60016, 61156-12 and 70215 can be considered to represent the genuine NRM, the remanent magnetization of the other samples being covered by magnetic contaminations. It is noted in the table 2 that the viscous magnetization component of all Apollo 17 samples is extremely small. The stable component of NRM is attributable to the thermoremanent magnetization.

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References

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Table I Basic Magnetic Properties of Apollo 16 and 17 Lunar Samples

Magnetic parameter	66016 -54 (Breccia)	61156 -11 (Breccia)	61156 -12 (Breccia)	70017 -75 (Basalt)	75083 -13 (Fines)	74220 -41 (Fines)	77017* -40	Unit
χ_o(300K)	2.55	7.63	1.43	0.65	-	0.85	0.44	x 10^{-4} emu/gm
χ_a(300K)	0.83	1.72	2.81	3.9	3.4	5.4	1.1	x 10^{-5} emu/gm
I_s (300K)	0.73	1.51	3.80	0.21	0.22	0.13	0.32	emu/gm
I_R (300K)	3.7	3	6	1.0	8.5	-	0.5	x 10^{-3} emu/gm
H_c(300K)	19	7	8	6	31	-	15	Oe.
H_{RC}(300K)	-	450	420	-	900	-	-	Oe.
Ⓗ	768	771	762	779	796	778		°C
Ⓗ*	660	660	685 633	none	none	none		°C
W(Fe)	0.33	0.69	1.29	0.17	0.10	0.13	0.15	Weight %
m_k / m	0.91	0.90	0.96	~0	~0	~0		

W(Fe) : content of metallic iron, m_k / m : ratio of kamacite component to whole metal.

(*) Brecciated or shocked anorthositic rock.

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Table II Magnitude and Stability of Natural Remanent Magnetization of Apollo 16 and 17 Lunar Samples

Parameter	60016 -54	61156 -11	61156 -12	64435 -33	70017 -73	70017 -75	70215 -26	77017 -74	Unit
I_n	30.0	6.0	12.7	3.9	15.5	20.4	6.6	2.8	$\times 10^{-6}$ emu/gm
I_o	1.03	1.13	6.8	0.24	1.9	1.0	1.6	0.29	$\times 10^{-6}$ emu/gm
$\tilde{H}_o$	12	60	42	20	19	12	21	9	Oe. rms
h	27	6	8	-	6.5	6.5	12	5	Oe.
$\tilde{H}_o'$	5	1.5	2	-	2.5	1.5	2	1.3	Oe. rms
$\Delta I_V/I$	1.0	0.9	0.2	-	0.30	0.07	0.07	0.12	

I_n : specific intensity of NRM.

I_o : stable component of NRM.

$\tilde{H}_o$: AF-demagnetization field to reduce NRM to e^{-1} of the initial magnitude.

h : a magnetic field intensity to produce IRM of the same magnitude of I_n.

$\tilde{H}_o'$: AF-demagnetization field to reduce IRM of I_n in intensity to e^{-1} of the initial magnitude.

$\Delta I_V/I$: radio of VRM to stable component of IRM whose intensity is the same as I_n.