SOME FEATURES OF THE YAMATO-74013 DIOGENITE: THE OPAQUE MINERALS AND THE ABUNDANCES OF SOME TRACE ELEMENTS

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***Abstract*:** In a standard mineralogical-petrological microscopic examination of the Yamato-74013 diogenite attention was given to the opaque minerals, chromite and troilite. Iron-deficient sulphides are supposed to be responsible for some features observed on the thermomagnetic curves. Abundances of Sc, Co, Hg and Zn were determined with INAA and AA.

1. The Opaque Minerals

The Yamato-74013 meteorite was recognized as a non-brecciated low-Ca hypersthene achondrite (YABUKI, 1978; YABUKI *et al.*, 1978; TAKEDA *et al.*, 1978). This type of achondrite materialized in the Yamato-692 meteorite was extensively studied by SHIMA and SHIMA (1975) and OKADA (1975). A crystallographic and chemical investigation by TAKEDA *et al.* (1975) was devoted to bronzite and chromite in this meteorite. These authors disclosed its granoblastic texture and found a reheating event resulting in recrystallization of pyroxene to be its main feature.

Within a microscopic examination of a thin section of the Yamato-74013 diogenite our attention has been focused on the opaque minerals—kamacite, chromite and troilite. According to YABUKI (1978) and YABUKI *et al.* (1978) the content of the latter is as small as 3.4%—the orthopyroxene matrix nearly monomineral being predominant. The results as reported below should be regarded as an addition to the above-cited comprehensive study of TAKEDA *et al.* (1978).

Chromite was observed as rounded grains—smaller ones spheroidally shaped and larger less regular. The rounded, lobate shapes of chromite grains seem to argue for a mild recrystallization of the silicate phase leading to the observed chromite-pyroxene contact interference.

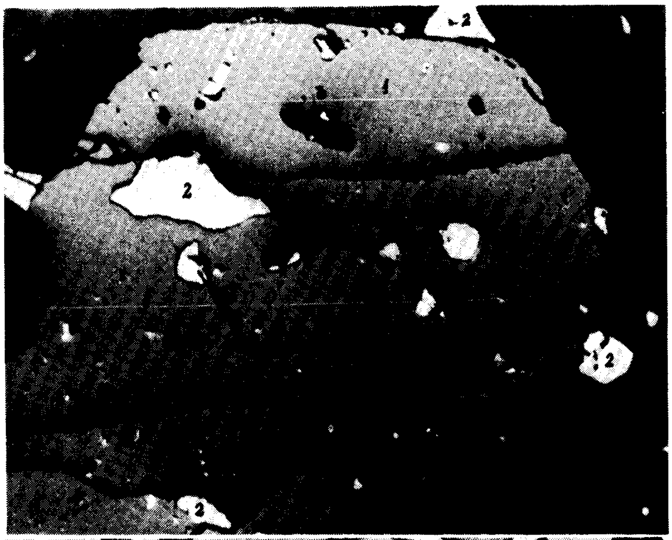

Fig. 1a. Rounded chromite (1) grain embedded in dark pyroxene matrix. Troilite (2) is light-colored, rounded or angular grains. Kamacite (3) is observed as minute inclusion. Magnification 230×.

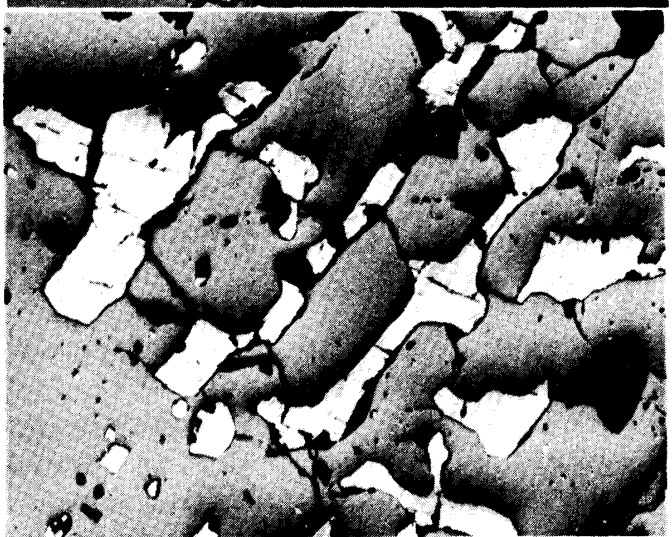

Fig. 1b. Chromite cracks filled with troilite. Magnification 230×.

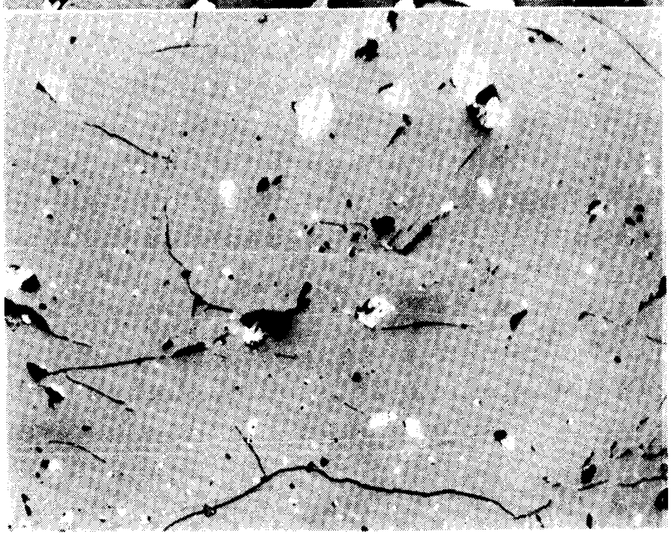

Fig. 1c. Troilite in pyroxene matrix: light colored rounded aggregates are more abundant than smaller angular grains. Magnification 230×.

Troilite grains were found distributed throughout the silicate phase and included as aggregates into chromite grains, being apparently more abundant in chromite than in pyroxene. The angular undistorted very fine troilite grains are likely to be the extensively recrystallized ones occurring in the silicate phase.

The sequence of crystallization can be seen from chromite filling the interstices among pyroxene crystals while troilite the cracks in chromite.

Fine kamacite grains were found mainly in chromite, occasionally in contact with troilite. This feature can be regarded as a proof that this troilite is product of chemical reaction of migrating sulphur with kamacite.

Our observations are referred to microphotographs in reflected light as shown in Figs. 1a–1c. In Fig. 1a grey rounded chromite grain (label 1) is shown against dark pyroxene matrix. Both rounded and angular sections of light-colored troilite (label 2) grains in chromite are seen along with minute inclusions of kamacite (label 3). In Fig. 1b the interstices among darker chromite crystals are shown filled with light-colored troilite. In Fig. 1c the light-colored troilite grains are seen dispersed in the darker silicate phase. The moderately recrystallized sulphide aggregates are more abundant than the undistorted extensively recrystallized single crystals.

2. The Thermomagnetic Analysis

The thermomagnetic curve for the Yamato-74013 meteorite was obtained by NAGATA and SUGIURA (1976), being preceded by the study of the magnetic properties of the Yamato-692 diogenite by NAGATA *et al.* (1975). The feature on the curve at 570°C was explained as the Curie point of magnetite, while that at 792°C as due to iron containing small amounts of Ni and Co. With the latter value for the Curie point and that for saturation magnetization of 0.17 emu/g the plot of the Yamato-74013 diogenite on the θ_c–I_s plane falls on the area covered by basaltic achondrites–in terms of the classification of NAGATA and SUGIURA (1976) and NAGATA (1978).

Taking into account the inhomogeneity of the material four samples (a–d), three lithic fragments (a–c) of mass ranging from 100–200 mg and one powder sample were prepared for measurements. Attention was paid to phase transitions at temperatures below the magnetite transition at 570°C. The magnetization of samples was induced by field of 16 kOe. Heating was carried out under atmospheric pressure leading particularly to facilitated sulphide oxidation. The samples were heated at the rate of 20°C/min. The thermomagnetic curves for two heatings I and II are shown in Figs. 2a–2d. The features as observed on the curves have been tabulated (Table 1).

The obtained data show that the thermomagnetic curves are not identical: they differ both from the powder sample (d) and among themselves. The non-identity below the magnetite transition seems to prove the inhomogeneity of the material.

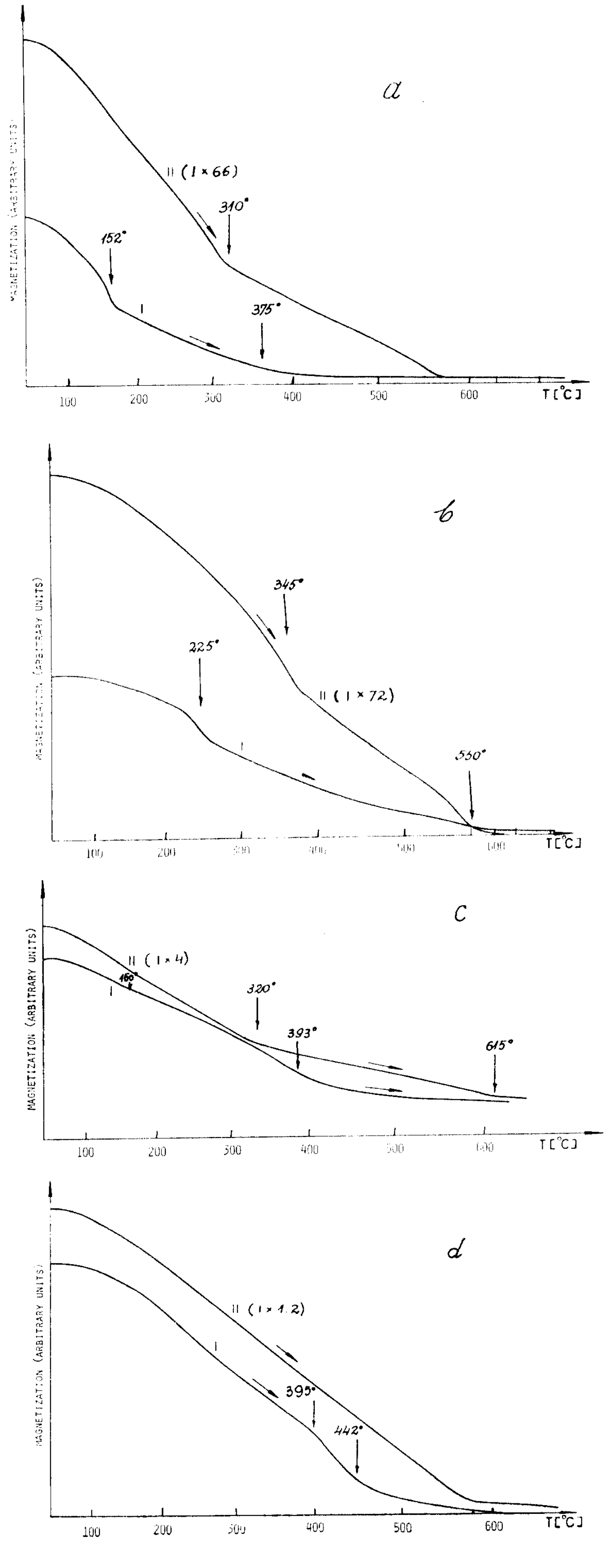

Fig. 2. Thermomagnetic curves for 3 lithic (a–c) fragments and 1 powder (d) samples. Y axis: magnetization in arbitrary units. X axis: temperature in °C. The scaling ratio of ordinates for the second heating are: 66, 72, 4 and 1.2 respectively. The oxidation of sulphides is believed to be responsible for the increase in magnetization. The powder has been oxidized during grinding, prior to first heating.

Table 1. *The thermomagnetic data for the Yamato-74013 diogenite.*

°C	a		b		c		d	
	I	II	I	II	I	II	I	II
—0°								
—100								
	152				150			
—200								
			225					
—300								
		310						
						320		
				345				
	375				395		395	
—400								
							442	
—500								
				550				
	570	575	570				570	
								580
—600								
						615		
—700								

The feature at 150°C on the curves a I and c I can be explained as the α-phase transition of troilite to hexagonal pyrrhotite, clearly pronounced on a I and poorly on c I. The β-phase transition from antiferromagnetic hexagonal to paramagnetic monoclinic pyrrhotite at 320°C has not been found on the a I and c I curves contrary to those for the Yamato-74097 and Yamato-74136 diogenites (FUNAKI, private communication, 1980). The latter diogenites show a characteristic appreciable transient increase in magnetization within the temperature range from 350° to 550°C, preceded by feature at ~330°C, which possibly can be recognized as shifted β-transition of sulphides.

This transition has been recorded on a II (310°C) and c II (320°C) curves. The features at 375°C and 395°C can be explained eventually as due to transition from mixed hexagonal pyrrhotite and pyrite to hexagonal pyrrhotite under varying contribution of Fe in sulphides (see SUGAKI *et al.*, 1977).

3. The Abundances of Some Trace Elements

3.1. Sc, Co and Hg by INAA

Standard method of instrumental neutron activation analysis (INAA) was applied to powdered samples of the diogenite. They were irradiated in the thermal column of the EWA nuclear reactor at Świerk/Warsaw for 70 hours. The irradiated samples and standards, prepared of evaporated to dryness aliquots of reference solution, were counted with a Ge Li co-axial semiconductor detector (32 cm^3) while the obtained γ-spectra analyzed with Plurimat-20 multichannel analyzer. The bulk abundance data as received are shown in Table 2 against the analytical errors of the peak-area calculations.

Table 2. The bulk analysis data for some trace elements of the Yamato-74013 diogenite.

Hg	1.36±0.11 ppm
Co	36.70±4.47 ppm
Sc	10.15±0.74 ppm

3.2. Zn by AA

Zn was determined at 213.9 nm with atomic absorption (AA) facility IL 353, ASA atomizer being applied. The abundance of this element in the diogenite was found of 40.3±2.02 ppm.

4. Discussion

The results from our study argue that the features of the opaque minerals of the Yamato-74013 and similar non-brecciated diogenites are to be approached in terms of the recrystallization which affected the silicate phase according to the finding of TAKEDA *et al.* (1978). Apart from kamacite and chromite the insight into the degree of recrystallization of troilite can possibly facilitate the explanation of the origin and the early story of the diogenites.

With the thermomagnetic analysis of the Yamato-74013 diogenite we arrived at suspected complex phase relations of sulphides in this meteorite. However, the final conclusion encompassing in particular the possible various iron-deficient polymorphic species with various magnetic properties requires both further magnetic study and chemical analysis with the use of an electron microprobe. Valuable implications from such studies for both the story of diogenites and the cosmomineralogy of sulphides are not excluded.

The above-reported bulk analysis data for several trace elements are in agreement with those found typical for diogenites (see MASON, 1971).

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