TO THERMAL HISTORY OF METALLIC ASTEROIDS. E.N. Slyuta, Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, 119991, Kosygin St. 19, Moscow, Russia. slyuta@mail.ru.

Introduction: Physical-mechanical properties of iron meteorites depend on structure, chemical and mineralogical composition, from short-term shock loading and from temperature [1]. The yield strength increases, if size of kamacite and rhabdites crystals decreases, and nickel and carbon contents increases. The more Ni content, the more taenite, microhardness of which is more than one of kamacite, and accordingly more yield strength. Short-term shock loading up to 25 GPa also increases the yield strength. The temperature of small bodies which unlike planetary bodies have no endogenic activity and an internal thermal flux, is defined by insolation level and depends on a body position in Solar system [2]. Body temperature change, for example, in case of radiogenic heat or tidal dissipation, also leads to change of a yield strength. Thus, any cases of rise in temperature will always differ by abnormal gravitational deformation parameters in comparison with usual temperatures in the given zone of Solar system [1,3].

Yield strength of iron meteorites: Yield strength of meteorite Gibeon at decreasing of temperature from 300 to 100 K increases monotonously (Table 1).

Table 1. Yield strength of iron meteorites*

#	Temperature, K	Yield strength, MPa
1	300	134
2	77	227
3	4.2	303
4	300	320
5	300	328
6	140	480
7	133	460
8	103	490

*#1-3 Sikhote Alin [6], #4-8 Gibeon [7].

Linear dependence of yield strength (σ_m) on temperature (T) for meteorite Gibeon is described by the equation (Fig. 1)

$$\boldsymbol{\sigma_m = -0.87T + 584.65}. \qquad (1)$$

Monotonous increasing of yield strength at temperatures from 300 to 4.2 K for a meteorite Sikhote Alin is observed too (Table 1, Fig. 1), which is described by the equation

$$\boldsymbol{\sigma_m = -0.54T + 289.32}. \qquad (2)$$

Hence, the temperature of change of their steady condition [4] is outside of the considered interval of temperatures (4.2-300 K). I.e. within an investigated interval of temperatures T-transition from plastic to a fragile condition in iron meteorites is not observed that usually is not characteristic for technical alloys and steels at which at decreasing of temperature the plasticity can decrease down to 0. For example, for iron-nickel alloy at Ni content about 5% the curve T-bend is observed already about 200 K [5]. The mechanism of plastic deformation in iron meteorites at low temperatures varies only. Deformation at 300 K occurs by sliding, and at 4.2 K and 77 K is accompanied by formation and development of static twins, i.e. mechanical twinning as the basic mechanism of deformation in iron meteorites at low temperatures dominates [6].

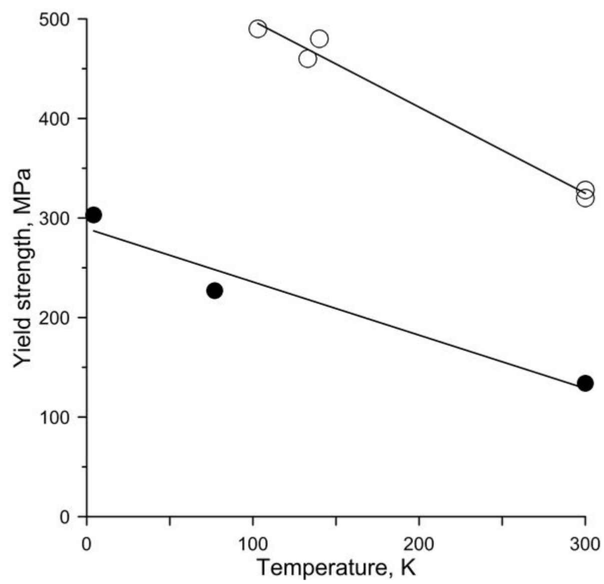

Fig. 1. Yield strength dependence of iron meteorites on temperature: ● - Sikhote-Alin; ○ - Gibeon.

Metallic asteroids: Metallic asteroids belong to M-class [11]. Radar wavelength observations can determine whether an asteroid is metallic and provide information about the porosity and regolith depth. From 19 investigated asteroids of M and X-type only 7 objects (16 Psyche, 129 Antigone, 216 Kleopatra, 347 Pariana, 758 Mancunia, 779 Nina and 785 Zwetana) have high radar albedo, which average value is equal of 0.41±0.13 [12]. 69 Gesperija (Hesperia) has metallic structure and high radar albedo (0.45±0.12) too [13]. On the basis of comparative analysis of spectra of meteorites from library of spectra RELAB it was revealed that spectra of asteroids of 55 Pandora and 872 Holda coincide with spectra of iron meteorites [14]. So, 10 asteroids of M-type have metal structure (Table. 2).

The necessary value of stress deviator responsible for deformation is defined by mass and a nonequilibrium figure of a small body [1,3]. The small body is not deformed, while the stress deviator will not overcome yield strength and transform its nonequilibrium figure to the spherical shape. The modern stress deviator in the identified metal asteroids are presented in Table 2. The density of metal asteroids with unknown mass was taken as 7 g cm^{-3}. The stress deviator in the largest metal asteroid of 16 Psyche reaches of 16.8 MPa (Table 2). If at the early history, for example, as a result of a temperature increasing, the yield strength of a material of an asteroid of 16 Psyche has gone down to 16.8 MPa or lower, the nonequilibrium figure of an asteroid as a result of gravitational plastic deformation would be transformed to the spherical shape. The yield strength of 16.8 МПa (modern stress deviator in asteroid16 Psyche) for composition of meteorite Sikhote Alin according to expression (1) will be reached at temperature 232ºC, and for composition of meteorite Gibeon (expression (2)) - at temperature 380ºC. Accordingly, maximum temperature of asteroid 16 Psyche from the moment of its formation could not exceed ~400ºC. Anyway, the identified metal asteroids from the moment of their formation were not exposed neither partial, nor to especially full melting. It is agreed with another data.

Table 2. Stress deviator in metallic asteroids [1]

Asteroid	Ef. diam., km	Density, kg cm^{-3}	Stress deviator, MPa
16 Psyche	186±30	7.6	16.8
55 Pandora	66.7	-	1.9
69 Hesperia	110	-	5.0
129 Antigone	113±17	-	5.3
216 Kleopatra	67.5±2.9	6.92	7.3
347 Pariana	51±5	-	1.1
758 Mancunia	85±7	-	3.0
779 Nina	77±2	-	2.5
785 Zwetana	49	-	1.0
872 Holda	30	-	0.4

35% of the 27th investigated asteroids of M-type have absorption features at 3 μm diagnostic of water of hydration [12]. The dependence of presence of water of hydration on asteroidal sizes is observed. Presence of hydrated minerals indicate that the thermal history of some M-asteroids was limited by temperatures within from ~0 to ~300ºC [13] because at higher temperatures hydrated water should be evaporate. It means that these asteroids are presented by the primary primitive structure which was not exposed to heating and, especially, to melting and differentiation. Among the identified metal asteroids (Table 2) hydrated water within the method resolution is observed on asteroids 129 Antigone and 55 Pandore.

Summary: Thermal history of asteroid 16 Psyche from the moment of its formation according to parameters of gravitational deformation did not exceed 400ºC. More certain estimation is possible only on the basis of experimental data on change of yield strength of iron meteorites at temperatures higher than 300 K. Anyway, the identified metal asteroids from the moment of their formation were not exposed neither partial, nor to especially full melting. At least, the thermal history of metal asteroids, on which hydrated waters is observed [12], is limited by lower temperatures of about 300ºC [13].

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