PHYSICAL-MECHANICAL ANISOTROPY OF ORDINARY CHONDRITES AND THE SHAPE OF SMALL ROCKY BODIES. E. N. Slyuta, Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, 119991, Kosygin St. 19, Moscow, Russia. slyuta@mail.ru.

**Introduction:** The mechanics of the collisional evolution of small Solar system bodies, the morphology of these bodies, the time of their existence since the moment of their formation, and their disintegration are significantly determined by the physical–mechanical properties of these bodies [1]. The gravitational deformation of small bodies and the observed parameters of transitions between small and planetary bodies of the Solar System are also determined by the mechanical and rheological properties of the material and depend on the body’s composition [2, 3]. Considering the increasing necessity for such data, comprehensive research into the physical-mechanical properties of extraterrestrial material on the basis of the collection of the Russian Academy of Science has been organized. Strong (with coefficient of 1.6) physical-mechanical anisotropy has been revealed, the orientation of which coincides with the main axes of the primary fragment shape of the meteorite [4]. The direct relationship of the revealed anisotropy with three-dimensional mineralogical and petrographic structure [5, 6] allows insight into the fundamental anisotropy of meteorite structure, which could be formed in anisotropic environment of the early Solar System.

**Technique:** As shown by experimental data [7] the compressive strength of samples of less than 15 mm and more than 40 mm in size decreases. For samples less than 10-15 mm in size, it is explained by the influence of defects at the level of individual mineral grains [6], therefore the minimum parity between the size of the sample and the size of mineral grains should be not less than 20-30 [8]. For samples more than 40 mm in size, the compressive strength decreases due to an increase in the number of large defects (fractures) [7]. Thus, samples of stone meteorites from 15 to 40 mm in size are optimum for research of compressive strength which is caused only by mineral structure and texture and does not depend on other factors.

**Discussion:** The documented three-dimensional distribution of compressive strength can be approximated by a prolate ellipsoid with semiaxes of $a_c>b_c\geq c_c$ (Table). Unlike compressive strength the three-dimensional distribution of tensile strength is almost isotropic and can be approximated by a figure close to a sphere. The direct relationship of the revealed anisotropy of physical-chemical properties with three-dimensional mineralogical and petrographic structure permits interpretation of the fundamental anisotropy of meteorite structure. If the distribution of a crystal mineral phase is chaotic, such mineral aggregate as a whole is isotropic and on the contrary if one direction dominates, such mineral aggregate will be characterized by a distinct anisotropy of physical-mechanical properties [5, 6]. To erase the strong primary anisotropy formed during primary condensation and crystallization of material in anisotropic environment, for example, under the pressure of a wind of the young Sun [9, 10], the material should undergo almost full subsequent melting to which the investigated samples were not exposed. The subsequent accretion and collisional evolution could locally disorder and weaken primary anisotropy. For example, as the experimental data show [6], earlier existing anisotropy starts to be erased due to plastic deformation of a material only at shortening not less than 50%, i.e. it would be difficult to erase primary (relic) anisotropy. But it is possible that similar strong anisotropy could be generated also as a result of the subsequent powerful thermal or shock metamorphism of a homogeneous (isotropic) enough primary material. In this case, the shortening caused by homogeneous plastic deformation should exceed 30% [6]. The answer to these questions can be given only as a result of careful petrofabric analysis of strictly directed thin sections and polished sections. Thus, the study of anisotropy of any type of meteorites irrespective of the fragments’ size can be carried out practically without their destruction. It is necessary to keep in mind only a key rule - the thin section orientation whenever possible should correspond to the orientation of the basic semiaxes ($a$, $b$ and $c$) of the primary fragment shape of a meteorite. Certainly, measurement of anisotropy is possible only as a result of mechanical experiment and destruction of
the sample. The minimum required size of a meteorite for such an experiment is approximately $10^4 \times 10^4 \times 10^4 \text{ cm}$.

A second, no less important problem consists of research into the dependence of the meteorite shape and their parental bodies on internal structure of material, i.e. on anisotropy coefficient and orientation. If anisotropy has an influence upon the shape of small (SAUH 001 meteorite) and enough large (Tsarev meteorite) meteorite fragments then it can influence the shape of small rocky bodies of the Solar System. Unlike planetary bodies, the shape of coherent small bodies is a result of long-term collisional evolution, i.e. mainly mechanical processes [2, 11], with the exception of cometary nuclei where there are also degassing and sublimation processes [12]. The distributions of $c/a$ and $b/a$ ratios for small bodies [2] are in agreement with the experimental data [13], which demonstrated that the $c/a$ and $b/a$ ratios of fragments created during collisional disruptions follow well-defined distributions. But the observed mean $a/b/c$ ratios for the experimentally generated fragments $(2/\sqrt{2}:1)$ [13] differ from those for rocky bodies $(1.38:1.23:1)$ [2]. Perhaps the difference is due to the influence of the additional factors adjusting small body shaping [2].

There are simple strength impact craters on small bodies, and there are no complex gravitational craters [14], due to small mass of the bodies and a small gravity. The shape and the sizes of simple craters depend on regolith thickness [15] and on target strength [14, 16]. The more target strength, the less excavation and size of a simple crater. Hence, at the poles of a prolate ellipsoid of anisotropy irrespective of a small body shape the excavation and size of a crater will be less, than in equatorial areas of the anisotropy ellipsoid with other things being equal of impact. As a result of long-term collisional evolution of coherent small rocky bodies it can lead to coincidence of a long axis of the body shape ($a$) with a long axis of the anisotropy ellipsoid ($a_\ell$), i.e. orientation of the main semiaxes of a small body concerning internal structure of a material may be not random. The distribution of anisotropy in a coherent small body, perhaps, may be mosaic and have a different direction in different blocks. But even in this case as a result of a certain dominating direction the integral anisotropy coefficient may be high enough. The more absolute strength of a material, the more difference between the large and small semiaxes of a body shape due to the anisotropy. Hence, if anisotropy influences small bodies’ shape the correlation between the different optical classes of asteroids and the relation of semiaxes $a/c$ of bodies' shape depending on strength of these objects should be observed. For example, the average relation $a/c$ for asteroids of S optical class (presumably ordinary chondrites [17], for example, Ida [18], Gaspra [19], Eros [20] should be more than for asteroids of C class (carbonaceous chondrites [21], for example, Mathilde [21], satellite of Mars Phobos [22]), which are characterized by weaker strength properties [2, 23].

Summary: It is to be noted that investigation of Tsarev meteorite (the sample № 15384,3) by an acoustic-polarizing method [24] has already pointed to physical-mechanical anisotropy of ordinary chondrites [25], in which selective absorption of a signal in various planes of the sample with parallel vectors of polarization of an emitter and the receiver has been observed. Owing to the selective character of destruction of solid bodies (continuity destruction begins in the weakest link and does not depend on strength of other links), variations of strength properties, as well as in rocks [26], are observed even in one sample of a meteorite [7, 25]. But according to the given researches, considerable variations of strength properties in ordinary chondrites and, possibly, in other types of meteorites, are caused as well by strong anisotropy of these properties. Hence, it is necessary to take into account that the strength properties of a meteorite measured only in one of any directions, are not fair for meteorite as a whole and can differ considerably from strength properties in other directions. The anisotropy ellipsoid allows orienting different fragments of a meteorite concerning their disposition in a parental body of the meteorite before its disruption in the upper atmosphere of the Earth. It is obvious that physical-mechanical properties contain the additional important information on conditions of formation of rocky bodies in the Solar System. Besides, the shape parameters and morphology of small rocky bodies of the Solar System, apparently, are not random shot and may depend substantially also on the internal composition and structure of these bodies.