ON A POSSIBILITY OF SHOCK-INDUCED AND IRRADIATION-INDUCED SELF-REVERSAL OF MAGNETIZATION IN METEORITES AND IMPACTITES.

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Introduction: Self-reversal is a physical phenomenon of magnetization of ferrimagnetic minerals (present in all rocks and meteorites and being determinative of their magnetic properties) in a direction antiparallel to the magnetizing field. Self-reversal has been observed in many types of terrestrial rocks and synthetic samples [1] and was explained theoretically by L. Néel [2-3]: in a single-phase magnetic mineral system self-reversal can take place as a result of change in sign of temperature dependence of spontaneous magnetization $I_s(T)$ of a two-sublattice ferrimagnet ('N-type ferrimagnet' [4]). Partial self-reversal of partial thermoremanent magnetization (pTRM) has been previously reported for lunar samples [5], however complete self-reversal has not yet been discovered in extraterrestrial materials in laboratory conditions. It is known that extraterrestrial materials in space are subjected to impacts and irradiations by solar and galactic cosmic rays (the penetration depth of solar wind is within ~nm, i.e., negligible). It was previously shown that both shocks and particle irradiations (e.g., by protons) [6] may induce non-negligible changes in rock magnetic properties of meteorites and reset their remanent magnetization. The purpose of this work is to check by means of computer modeling whether shock and particle radiation can induce self-reversal of magnetization in terrestrial rocks and meteorites as well as to clarify possible physical mechanisms of such phenomena.

Methods: We used for calculations previously developed numerical model of phenomenon of self-reversal of magnetization (single phase magnetic mineral system) [1], where a rock is modeled as an ensemble of non-interacting single-domain uniaxial (elongated) grains of Neel's N-type. Contrary to [1], in this study we introduced into the existing model a diffusion of ferrimagnetic ions between two sublattices via temperature dependence of fractions of magnetic ions in A-sublattice (λ) and B-sublattice (μ) and made calculations for the ensembles of Neel's Q-type grains (which, contrary to Neel's N-type grains, do not initially possess self-reversing properties [4]).

Results: Depending on the chosen $\lambda(T)$ and $\mu(T)$ laws, thermal diffusion of ferrimagnetic ions between two sublattices may lead to self-reversal of $I_s(T)$, so that $I_s(T)$ of Neel's Q-type ferrimagnet will be transformed and will look similar to the $I_s(T)$ of Neel's N-type ferrimagnet. Further calculations of thermomagnetization (TM) and TRM for different ensembles of non-interacting ferrimagnetic grains in a wide range of magnetic fields revealed self-reversal of TM and TRM in "weak" magnetic fields, i.e., when the magnetic field strength is lower than the corresponding coercive field, i.e., the field needed for remagnetization of rock sample. Thus, this work defined the conditions, under which thermal diffusion of magnetic ions between ferrimagnetic sublattices of initially non-reversing ferrimagnets (e.g., Neel's Q-type grains) results in self-reversal of TM and TRM. Such thermal diffusion can be triggered by any of heating mechanisms: simple heating, shock-induced heating taking place as a result of impact events in space or irradiation-induced heating. Under certain conditions (diffusion speed, number of vacancies in sublattices etc.) post-shock heating can result in shock-induced self-reversal of magnetization, whereas irradiation-induced heating can result in irradiation-induced self-reversal of magnetization. Irradiation processes can also lead to irration-induced self-reversal via another physical mechanism – irradiation-induced recombination of magnetic ions between ferrimagnetic sublattices, which may also lead to the change in sign of magnetization. This mechanism is temperature-independent and does not require any temperature increase.

Overall, the results of numerical modeling confirmed a possibility of shock-induced and irradiation-induced self-reversal of magnetization in ferrimagnets – carriers of magnetic properties in terrestrial rocks and meteorites. Induced self-reversal is likely to be discovered in heavily shocked or/ and irradiated extraterrestrials materials as well as in shock-metamorphosed terrestrials rocks such as impactites; it is more likely to occur in cation-deficient magnetic minerals. The existence of shock-induced and irradiation-induced self-reversal in space may lead to a potential (even if minor) decrease of magnetic anomalies of heavily cratered solar system bodies (such as the Moon and Mars) with time. On the other hand, if one day space missions bring us oriented samples and their natural remanent magnetization happens to be of both normal and reverse magnetic polarities, we will be able to open a discussion on the nature of the samples with reverse polarity (self-reversal vs. field reversals of Mars, the Moon etc.). *Acknowledgements*: The work is supported by Act 211 Government of the Russian Federation, agreement № 02.A03.21.0006 and is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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