EPSC Abstracts
Vol. 7 EPSC2012-222 2012
European Planetary Science Congress 2012

Disintegration of the solid protocores of the terrestrial planets as a reason of magnetic field generation

Yu.D. Pushkarev (1), S.V. Starchenko (2)
(1) Institute of Precambrian Geology and Geochronology, St.-Petersburg, Russia, e-mail: ydcanon@rambler.ru
(2) Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Troitsk, Moscow region, 142190, Russia

Introduction

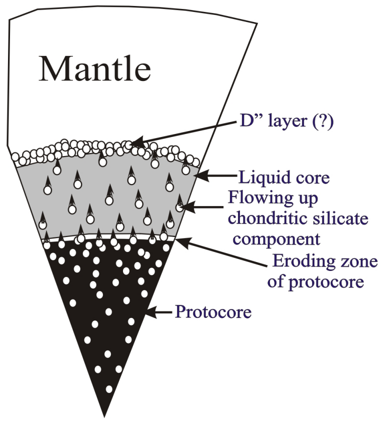
There are evidences of existence of an ancient geomagnetic field [3, 5, etc.] up to the early Archean [10], which intensity is identical to the modern one. This information contradicts the generally accepted ideas according to which the geodynamo, generating the modern magnetic field of the Earth, is produced by the compositional convection caused due to crystallization of a liquid core [1, 7, 9]. The most probable time of excitation of compositional convection is estimated about 1 Ga, but not earlier than 2 Ga [6, 9]. It follows that before this time the geomagnetic intensity should have had the lower value because it was generated only by inefficient thermal convection. Thus, if the compositional convection is required to generate the Archean geomagnetic field, intensity of which is close to the modern one, this convection should have any other nature.

At the sane time identification of the superheated and lightweight material streams in the Earth interiors named as plumes, has put up the problem of the energy source for such overheating. Plume origin at core-mantle boundary suggests that such source is the core, which, apparently, is overheated in comparison with bottom of the low mantle. Magmatic derivatives of the mantle material sometimes contain primary noble gases and in particular the isotope ^{129}Xe (the decay product of the short-lived ^{129}I). It demonstrates that somewhere in the Earth there is a material which became geochemically closed with regard to noble gases before ^{129}I complete decay, i.e. not later than through 150 million years after the beginning of accretion and which subsequently was never mixed with the mantle material. At the same time Hf-W and U-Pb isotope systems show that the formation of a liquid core has taken place during first 100-120 million years after accretion [2].

Conception of the disintegrated protocore

The conception [4, 8] which can explain all above mentioned is offered. This conception suggests that the solid core of the Earth didn't crystallize from the liquid one, but represents the small relict of the protocore on which heterogenic accretion has begun. The protocore consists of a mixture of heavy metal iron-nickel alloy and light chondrite silicate component which contains primary noble gases. Fraction of this silicate component increases from center of the planet (where it is about 5 %) to its periphery, reaching the chondrite value, and continues to increase up to the surface. Soon after the end of accretion or near to its end, the geosphere of the liquid core is formed in an external part of planet. It starts to plunge, expanding due to melting of new portions of iron-nickel alloy. This expansion is happening rather fast during the period of initial formation of the liquid core geosphere due to its intensive overheating. Then the expansion rate is decelerated. The first reason of this is decreasing of the temperature difference between liquid geosphere and solid protocore. It leads to the slower conductive transport of the heat necessary to melt the protocore. Namely the rate of this conductive heat transport determines the time needed for the protocore dissolution in the liquid core geosphere. If we take the known thermal conductivity of the modern liquid core for this time estimation we will obtain a few billion years as it is required for our conception.
During protocore dissolution the silicate chondritic component present in the protocore is liberated. Being almost twice less in density if compared with liquid metal, it floats up to the bottom of mantle (D” layer?) bringing there containing in it primary noble gases and other elements with relict isotopic characteristics. Emerging of silicate material generates the compositional convection which begins soon after the end of accretion and after the fast formation of the liquid core geosphere. Such density

differentiation of the material in the «liquid core - protocore» system is accompanied by generation of gravitational energy transformed into the thermal one. Model calculations [8] show that the power of allocated energy is sufficient for an overheating of the mantle's bottom and formation of plume-streams throughout almost all geological history.



Magnetic field of terrestrial planets and their evolution

There are several factors determining evolution of the "mantle-protocore" system. Their combination defines one or another scenario of the planet development. Using the conception of eroded protocore it is easy to characterize the features of its evolution. In the case of Venus which does not have its own magnetic field, but has a liquid core, it is natural to assume that there is either no convection at all or it is very insignificant. Such conditions can occur after the protocore already has fully reacted with the liquid core, and crystallization hasn't yet begun or has begun quite recently. There is no own modern magnetic field neither on Mars nor on the Moon, but residual magnetization is found and the liquid cores are supposed. Such situation can correspond to the early fading of compositional convection either because of the small protocore or due to the deficit of released energy needed to maintain the temperature demanded for this protocore erosion. The similar situation can also be expected on other quite large moons of giant planets or even on asteroids. Specific features of magnetic field formation and evolution on Jupiter satellites, most likely, are defined by existence of the liquid core arising under the influence of the gravitational disturbance from the central body. Identical in the size Mercury and Ganimed (the satellite of Jupiter), have a hydromagnetic dynamo which generates the magnetic field that is considerably smaller then the Earth's one and very different in terms of structure. It is possible to assume that both tidal forces of the Sun and Jupiter correspondingly and weak compositional convection support the magnetic field generation in the thin layer of a liquid core of these objects.
Below, you will find an example of an included figure. You should use the "Figure_caption" auto-formatting style for the caption.

This work was supported by the Russian RFBR project No 12-05-00523-a

References

[1] Glatzmaier, G.A., Roberts P.H.: An anelastic evolutionary geodynamo simulation driven by compositional and thermal convection, Physica D, Vol.97. p.81-94. 1996.

[2] Kostitsyn Y A, Galimov E.M. Hf-W and U-Pb ages of the Earth core formation: a solution of the paradox, Geochim. et Cosmochim. Acta, Vol.71, p.A516, 2007.

[3] Macouin, M., Valet J.-P., and Besse J.: Longterm evolution of the geomagnetic dipole moment, Phys. Earth Planet. Int., Vol.147, pp.239-246, 2004.

[4] Ringwood A.E.: Origin of the Earth and Moon, New York: Springer, 295 p., 1979.

[5] Shcherbakova V. V., Lubnina N. V., Shcherbakov V.P., et al.: Palaeointensity and palaeodirectional studies of early Riphaean dyke complexes in the Lake Ladoga region, Geophys. J. Int., Vol.175. pp.433-448. 2008,

[6] Starchenko S.V.: Gravitational differentiation in the planetary cores, Russian journal of Earth sciences, Vol.5, No 6, pp.431–438, 2003.

[7] Starchenko, S.V., and Kotelnikova M.S.: Symmetric thermo-mass-transport in rotating spherical shell, Journal of Experimental and Theoretical Physics, V.94, No 3, pp.459-469, 2002.

[8] Starchenko S.V., Pushkarev Y.D.: Variations of geomagnetic paleointensity as a result of the protocore evolution, Proc. of the 8th Intern. Conf. «Problems of Geocosmos», St-Petersburg, pp.358-364. 2010.

[9] Stevenson D.J.: Planetary Magnetic Fields:Achievements and Prospects, Space Sci Rev, Vol.152, No 1-4, pp.651-664, 2009

[10] Tarduno J.A., Cottrell R.D, Watkeys M.K et al. Geodynamo, Solar Wind, and Magnetopause 3.4 to 3.45 Billion Years Ago, Science, Vol.327. pp. 1238-1240, 2010.