EPSC Abstracts
Vol. 8, EPSC2013-337-1, 2013
European Planetary Science Congress 2013

Planetary dynamo and protocore concept

Yu. Pushkarev (1) and S. Starchenko (2)
(1) IPGG RAN, emb. Makarova 2, St.-Petersburg, 199034 Russia, (2) IZMIRAN, Kaluzhskoe Hwy 4, Troitsk, Moscow, 142190 Russia (sstarchenko@mail.ru / Fax: +7-495-8510124)

Already more than a half century it is argued that the geomagnetic field is predominately driven by a composite convection which takes place during solidification of the liquid core [4]. However the same magnetic field can be the result of composite convection which takes place when liquid core decomposes the iron-nickel protocore [5] that contains the solid inclusions of silicate material. These two essentially different models with identical consequence in the form of composite convection and geomagnetic field generated by this convection can differ both by time of the process beginning and by a number of geochemical consequences and thus determine two essentially various options of core-mantle system evolution. It is considered that crystallization of the liquid core could begin not earlier than 2 billion years ago [3]. At the same time traces of magnetic field are found in rocks with age near 3.5 billion years [6] and thus dispose to the model of protocore decomposition which could begin soon after the end of accretion, i.e. soon after 4.5 billion years ago.

The geodynamo could be supported by thermal process if the heat flux from the core is sufficiently grater than adiabatic heat flux that was earlier estimated at about 5 TW [4]. The recent work [3] raises this estimation up to 15 TW making thermal convection impossible for any realistic value of the heat flux from the core in the modern epoch. For more ancient time thermal support to the convection could exist but at very low level. Thus geodynamo is created by convection that is primarily supported by compositional effects [3, 4]. The currently accepted scenario with the inner solid core of the Earth crystallizing from the liquid core provides us with too small value of geomagnetic field during more than 3 billions years after formation of the liquid core. Since this is inconsistent with the available paleomagnetic records we are suggesting another scenario with a solid protocore which occupied almost all the core of just formatted Earth. This protocore is slowly melted under the surface influence of the overheated liquid core (figure 1).

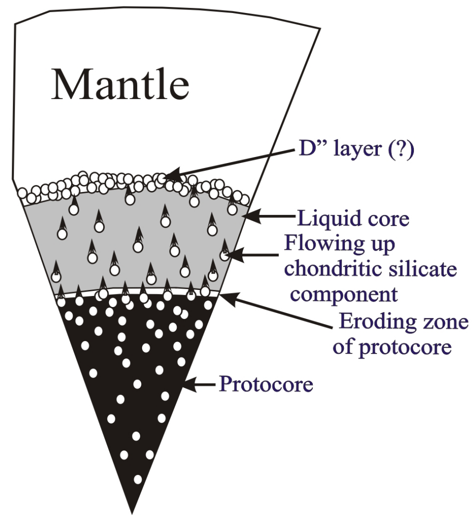

Figure 1: «Core-mantle» system and its evolution on the basis of protocore interaction with the liquid core.

It grows up to its modern size when the solid core is small relic of the protocore. Such protocore concept [5] resolves the problem of the energy source for geodynamo and for plume activity in the mantle. In case of validity of this concept the mantle should be supplemented by silicate material from the protocore with primitive isotope composition of the lead but which can't be the result of the liquid core crystallization. The preliminary results are in our interpretation of compilation from [2] shown in figure 2 below.

Additional argument to the validity of our protocore concept could be the primitive isotope composition of lead in combination with the primary helium enriched by isotope He-3.

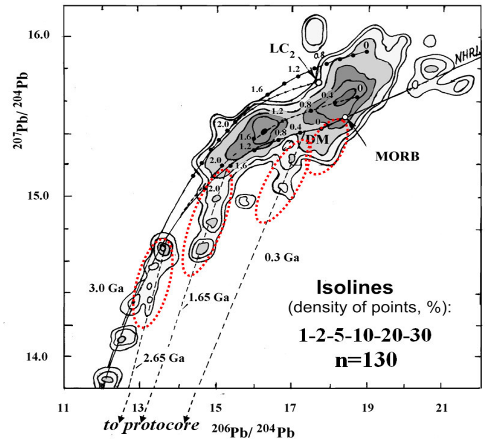

Figure 2: Pb-Pb isotope systematic of the lead ore minerals and feldspars in the Earth magmatic rocks [2]. Dashed lines correspond to the «mantle – protocore» mixes at culmination of endogenic activity 2.65, 1.65 and 0.3 Ga. Dot ellipses reflect an additive of the protocore component up to 3%.

Following the currently accepted crystallization concept Martian dynamo should be stopped only when the central solid core occupies almost all the volume of Martian core. So, nowadays the liquid core should be sufficiently smaller than the solid one. That contradicts to all the available models of the Martian interior. To resolve this paradox we apply our protocore concept to Mars following figure 3.

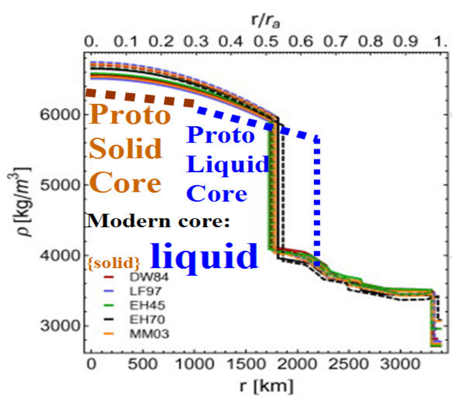

Figure 3: Martian «core-mantle» system evolution.

Paleomagnetic samples from Moon demonstrate very high (a few times larger than on the modern Earth surface) intensity of the magnetic field that was in operation from about 4.2 till 3.6 billion years ago [1]. The currently accepted compositional (under crystallization concept) and thermal dynamo of the Moon are not able to provide enough energy to support so higher magnetic intensity and for so long period. While a Lunar dynamo under our protocore concept could easy provide required energy source for the intensive compositional convection during that long period. Lunar paleomagnetic samples indicate magnetic intensity of order geomagnetic one at about 3.5-3 GA that could be supported by the known crystallization of a liquid core. Sufficiently higher (4.2-3.5 GA) intensity could earlier be supported by protocore erosion under our protocore concept [5].

Acknowledgements

This work was partly supported by the program 22 of the Presidium of Russian Academy of Sciences, the Russian RFBR grants No 12-05-00523-a and 13-05-00893-a.

References

[1] Fuller, M., and Cisowski, S.M.: Lunar paleomagnetism. In: Geomagnetism, Jacobs JA (ed) Academic Press, pp. 307-455, 1987

[2] Kramers, J.D., and Tolstikhin, I.N.: Two terrestrial lead isotope paradoxes, forward transport modeling, core formation and the history of the continental crust, Chemical geology, Vol. 139, pp. 75-110, 1997.

[3] Pozzo, M., Davies, C., Gubbins, D., and Alfè, D.: Thermal and electrical conductivity of iron at Earth's core conditions, Nature, Vol. 485, pp. 355-358, 2012.

[4] Starchenko, S.V., and Jones, C. A.: Typical velocities and magnetic field strengths in planetary interiors, Icarus, Vol. 157, pp. 426-435, 2002.

[5] Starchenko, S.V., and Pushkarev, Y.D.: Magnetohydrodynamic scaling of geodynamo and a planetary protocore concept, Magnetohydrodynamics, Vol. 49, No. 1, pp. 35-42, 2013.

[6] 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.