New Insights from the Geodynamo
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The earth’s magnetic field is a very important protective shield, saving life on earth from cosmic radiation, as well as from dangerous particles of the solar wind. The main process that produces this fascinating shield is called the Dynamo-theory. The main mechanical process described from this theory is called Geodynamo. Latest researches are showing, that the power amount of the Geodynamo is less than assumed so far. Furthermore these theories have lead to new findings, regarding the age of the inner core and the theory of earth’s magnetic field reversal. For those purposes the Geodynamo describes the processes that are responsible to establish this necessary field. Outgoing from the heat flow, that is starting on the inner core, a convection process, paired with the Coriolis Force and a induced current, is forming the magnetic field. The great challenge with this researches is to find the best combination of computational power intensive theoretical simulations and special experiments in laboratories to strengthen the worked out hypotheses. This leads to the fact, that the inner core is about 3 billion years old and not like older theories, assuming that the core is only one billion years old. Basis of both calculations is the slow emit of heat from the inner core. Moreover these models of the Geodynamo hopefully can be used in the future to describe the process of the magnetic reversal, also called pole shift, which, among other things, is responsible for the loss of 10 percent of the earth’s magnetic field total intensity in the past 180 years.

The earth’s magnetic field is protecting the terrestrials since they are existing. The age of this protective shield is, in addition to this, much higher than life is moving on our planet and reaches back to the formation of earth itself. So how does this fascinating field works and in example, how much energy does it need to run ? Before answering this and many other questions, i want to tell you some facts about it.

The earth’s magnetic field found on the surface can be described to 90 percent as the field of a dipole. The more you are moving into earth’s interior, the quadrupole and multipole parts are increasing. Currently the axis of the geomagnetic dipole field inclines about eleven degrees towards the earth axis. The magnetic field lines are emerging from the southern hemisphere and moving back in on the northern hemisphere. Its magnitude at the Earth’s surface ranges from 25.000 to 70.000 nanoTesla.Fig.1[1] Of course there are magnetic south- and north poles, in addition to the geomagnetic poles ( of the dipole field ), which are in a permanent process of wandering, with changing directions and velocities. The magnetic north pole in example is currently moving with approximately 50 km/h from the northern territories of Canada eastwards towards Siberia.

So what is the driving force behind these facts ? The magnetic field of the earth originates in the liquid outer ferric-core. Due to the heat flow from the solid inner core towards the earth’s mantle, the liquid iron is starting to circulate. In addition to this circulation the Coriolis effect is forcing the moving iron to screwing rolls.[1]

The temperature of the iron down there is indeed way above the Curie-temperature so it can’t produce a magnetic field by itself. But the iron can still act as a electric conductor. This movements of an electric conducting liquid, producing and interacting with a magnetic field is described with the Dynamo theory. A initially very weak magnetic field has produced a induced current. This weak magnetic field is likely being produced by the solar wind, a short time after the earth’s appearance. The solar wind has induced a small electric current in the moving iron, which produced a resultant magnetic field. With this field the Geodynamo gets started and the magnetism causes a electric current, which produces a larger magnetic field, which again has induced a electric current, and so on...
This process is also known as positive feedback. In this way the magnetic field is establishing till it will be limited. This Limitation Effect depends on the viscosity of the moving material as well as the ratios between Coriolis-Force, Lorentz-Force, pressure, uplift and friction. [4] The velocity of this moving material amounts just about 100 kilometres per year.

Now we are knowing that the electric current, establishing the earth’s magnetic field is partly produced by itself. Running researches are offering more and more details about this processes. Numeric Simulations of the earth’s magnetic field are running since the year 1995. Since then, there were made big progresses in simulating the field on the surface as well as the mechanisms and fields in the inner regions of our planet. But the main problem is, that the computational power often is stretched to the limits, when it becomes to simulate the turbulences and the small gyres in the outer core. To keep this simulations practicable, some of these parameters have to be reduced.

Despite this fact, these simulations are describing very well the historical and actual development of the magnetic field. To obtain better results these models are being combined with laboratory experiments, which are simulating the small turbulences as well. A very well known of these is the ‘Karlsruher Experiment’. Therefor liquid sodium flows through a parallel assembly of stainless-steel-tubes, embedded in a big cylinder with a height of approximately one meter. [2] The fact that stainless steel and sodium are both good conductors, is short cutting the whole system, like the homogen Geodynamo. These tubes enclose guide plates which are bringing the fluid into a swirl like movement, like it’s supposed to be in the earth’s core.

This movement is not regarded in the computer simulations. But, the comparison of the power demand from the experiment, with the data from the computer simulations, calculated for the same experimental setup, shows, that these small gyres have no effect on the power demand of the homogen Geodynamo. This means, that we can expect realistic data from the worked out computer models of the Geodynamo. According to this simulation, the calculated power demand of the Geodynamo is between 200.000 to 500.000 Megawatts. [2] For a big System like the earth, that’s nothing much.

The conclusion of this is, that there is no need for a special heat source in the inside of the earth. The Geodynamo runs rather with the slow emit of heat from the inner core, that is stored since the birth of earth. These small loss off power causes a slowly freeze out of the core. That means that the inner core decreases every year by a value of one millimetre by crystallising out the material from the outer core. [3] Thus the iron atoms losing kinetic energy, which will be provided to run the Geodynamo.

These researches also contribute a important part to the discussions about the age of the inner core. Earlier calculations approximated the power demand of the Geodynamo three to ten times higher, so that the inner core would be decreased in the same amount and the age would be accordingly one billion years. But studied rocks with a inside stored magnification show, that the earth’s magnetic field exists at least since 3 billion years. So, before the development of the inner core, there should have been working a totally another mechanism to run the Geodynamo - a not very realistic suggestion. With the new computer models the core is cooling down much slower. Thus the inner core would have a age of 2.5 to 3.5 billion years and this corresponds very well with the analysed rocks.
Further researches of magnetised oceanic crust exhibit as well, that the earth’s magnetic field is happening a magnetic field reversal on an average of every 250.000 years.[5] This reversals are caused by disorders in the Geodynamo. The main part hereby is caused from regions with a reversed magnetic flux compared to the normal flux in this region.[6] This effect causes a weakening of the total intensity of the field, which is according to the loss of the intensity from ten percent since the beginning of records in the year 1830. Because the last reversal is about 780.000 years ago [5], there is suggested that the earth’s magnetic field will change its direction within the next 2000 years. Computer-simulations have already calculated this process, but there is no uniform theory, what is really happening when this magnetic reversals takes place. The results of researching the Geodynamo have brought great conclusions so far, but there is still a lot of work to do, to learn more about the process of the Geodynamo and how this magnetic reversal effects to life on earth.

References