# *Potential Energy of the magnetic dipole of the Earth*

*Yoshio Omata*

*February 2003*

The Earth has a magnetic field, which is roughly regarded as a dipole field. A magnetic dipole, in theory, has a potential energy when it is surrounded by an ambient magnetic field. The potential energy possessed by a magnetic dipole can be expressed by

$$U = -p \quad B$$

where p represents a magnetic dipole moment and B is a surrounding magnetic field.

If the magnitudes of p and B are constant, the potential energy of a magnetic dipole is maximum when the dipole is antiparallel with an ambient magnetic field. Contrarily, the potential energy of a magnetic dipole is minimum when the dipole is parallel with the ambient magnetic field, as shown in Figure 1.

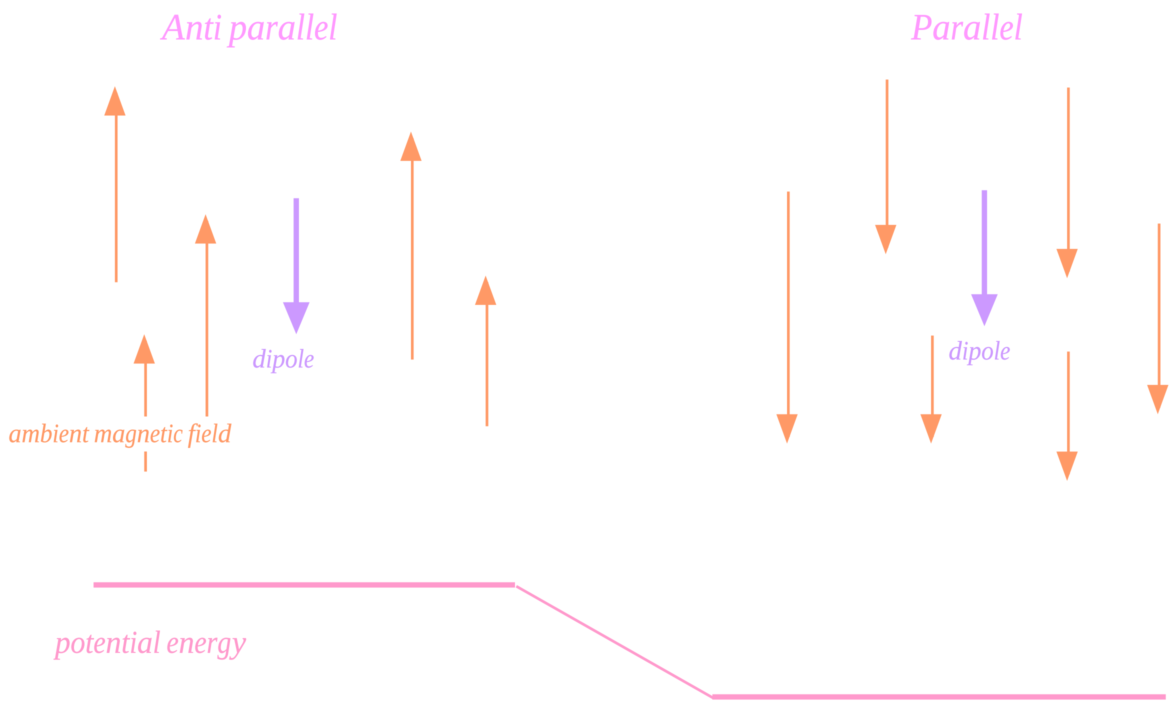


Figure 1. The left panel depicts the situation in which a dipole is antiparallel with an ambient magnetic field. The right panel indicates the opposite situation. The potential energy of the dipole in the left panel is higher than that of the dipole in the right panel.

The needle in a mariner's compass can be regarded as a magnetic dipole and the geo-magnetic field has an effect on the needle. When the compass points north, the magnetic dipole possessed by the needle is parallel with the geo-magnetic field. The mariner's compass settle its needle into the lowest potential energy and points north.

Our planet can be viewed as a magnetic dipole which has potential energy when it is encompassed with a magnetic field. In reality, our planet is surrounded by the magnetic field dubbed the IMF: interplanetary magnetic field. The interplanetary magnetic field is changeable and then can alter the potential energy possessed by the magnetic dipole of the Earth. When the interplanetary magnetic field is northward, the Earth's dipole is antiparallel with the surrounding magnetic field and has maximum potential energy. On the other hand, when the interplanetary magnetic field is southward, the Earth's dipole is parallel with the ambient magnetic field and then has minimum potential energy. Figure 2 is an illustration of the Earths in the northward and southward IMF.

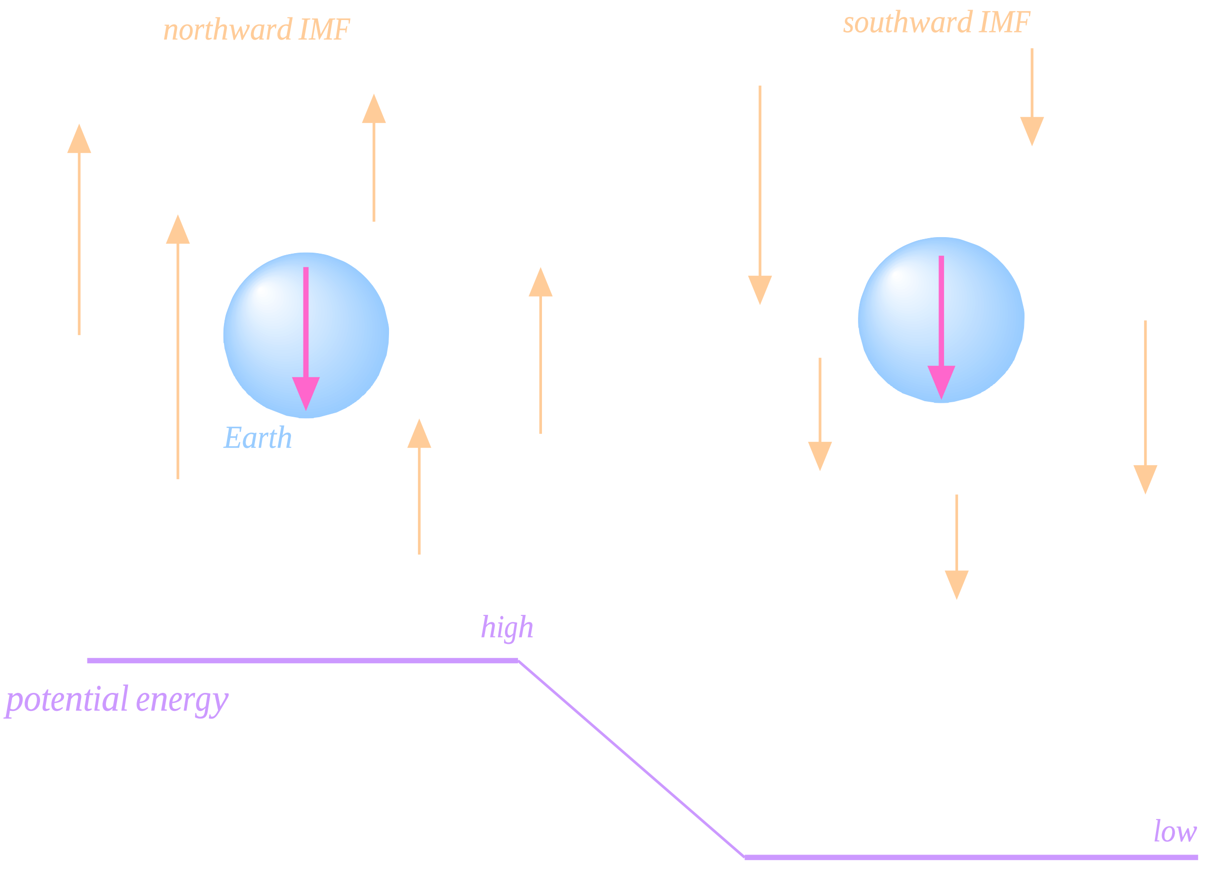


Figure 2. Northward IMF has the direction opposite to the magnetic dipole of the Earth. On the other hand, southward IMF shares the same direction with the Earth's dipole. The potential energy of the Earth's dipole is higher when the interplanetary magnetic field is northward than when the interplanetary magnetic field is southward.

The interplanetary magnetic field whimsically changes its direction. The change of the direction of the interplanetary magnetic field triggers the change of potential energy of the Earth's magnetic dipole. In general, a change of potential energy means release or absorption of energy. When the interplanetary magnetic field changes its direction from northward to southward, the Earth's magnetic dipole decreases its potential energy and then should unleash some energy by some ways. The unleashing process of the energy may be an already-known phenomenon. I think it is the magnetospheric substorm which often occurs when the interplanetary magnetic field change its direction into southward, that is, when the Earth's magnetic dipole decreases its potential energy and then some energy should be released. The fundamental energy source of the magnetospheric substorm may be the unleashed potential energy of the magnetic dipole of the Earth after the southward turning of the interplanetary magnetic field.

One of the phenomena that produced by the potential energy change of a magnetic dipole is the Zeeman effect, which occurs when magnetic dipoles possessed by the electrons in atoms or molecules are immersed in a magnetic field and change their potential energy and then alter the wavelengths of electromagnetic waves that they emit.

Not only electrons but also protons have magnetic dipoles. The magnetic dipoles of protons are applied to medicine as the MRI ( Magnetic Resonance Imaging ), which offers the interior image of the human body to save a life.

The magnetic dipole moment of the Earth is about

$$m_{Earth} = 8 \times 10^{22} A\ \ m^2$$

If the interplanetary magnetic field has the value of 5 nT in northward direction and changes its direction into southward with constant value 5 nT, the magnetic dipole of the Earth decreases its potential energy by

$$\Delta U = m\Delta B_z = (8 \times 10^{22} A\ \ m^2)(10nT)$$
$$= 8 \times 10^{14} J$$

This amount of energy should be released by some ways.