# INTERACTIVE EXHIBITS FOR GEOPHYSICAL EDUCATION: UNCOVERING THE SECRETS OF THE EARTH

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*Abstract:* - The Educational & Outreach Group of the Istituto Nazionale di Geofisica e Vulcanologia (INGV, Rome, Italy) designed a portable museum to bring on the road educational activities focused on the understanding of geomagnetism, plate tectonics, seismology and seismic hazard. Here the main experiments, models and exhibits which have been successfully installed in Genoa for the Science Festival (2003, 2004) and in Rome (2005) with enthusiastic audience participation are shown.

*Key-Words:* - Geophysics, education, geomagnetism, plate tectonics, seismology, portable museum

## 1 Introduction

Since 2003 INGV has started the realization of a portable, modular and expansible museum containing installations and experiments to explain to the most general audience the principles of geophysics. In 2003 we brought in Genoa, for the first festival of Science, the exhibits on plate tectonics and seismology, with a particular attention on the explanation and popularization of seismic risk. The second step, opened for Genoa second festival of Science in 2004, was the realization of a new area of experiments and exhibits on the Earth's magnetic field, giving a full opportunity to learn the Earth from the inner core to the interaction with the Sun. We recently completed and improved this museum for a three-weeks installation in Rome, confirming a wide participation of classrooms and citizens. A virtual tour of this museum is proposed in this paper, starting with the description of the magnetism experiments and following with a section on seismo-tectonics.

## 2 The planet Earth

In the first hall the public can wear a pair of special glasses to watch an intriguing 3-dimensional movie about the solar system; all planets and many satellites are explained in their peculiarities, with a 3-dimensional effect so impressive that the planets seem to run over the audience. The last planet in this movie is the Earth, and, after, the real visit starts.

## 3 The Earth's magnetic field (EMF)

The exhibition on the Earth's magnetic field is mainly divided in the following sections.

### 3.1 The magnetic compass and orientation

In this propaedeutic hall there is a large model with an aerial view of the area of Rome (Ostiense quarter) where the museum is installed; a magnetic compass is also present in this room; the model can be rotated, and the aim is to understand how a map can be magnetically orientated. As soon as the audience has understood where the geographic North is in the model, they have to align the same map according to the magnetic compass direction, obtaining, in this way, a geo-referenced map (Fig.1); this was, historically, the first heuristic knowledge of the Earth's magnetic field.

Fig.1: an aerial view of the quarter of the museum with a compass used to orientate the model.

### 3.2 An overview of the Earth's magnetic field

In the following projection room a video explains the key-role of the EMF in allowing life on the Earth. This film starts with a description of how (probably) the turtles orientate by means of magnetite grains in their brains, going on with the mechanisms behind the EMF generation, its maintenance, its fundamental role in shielding the atmosphere from the solar wind. Some stunning auroras are shown too, as a visible consequence of the interaction between solar wind, EMF and atmosphere.

### 3.3 Elementary magnetism

The main hall is divided into two series of experiments; a first row of tables contains games and instruments to understand the main principles of magnetism. In particular, the first two games have been realized to illustrate the interactions between magnetic poles of the same sign, by means of a magnetic pendulum oscillating in a unpredictable way and with three magnets which, falling, cannot reach the base of the exhibit and bounce approaching the same polarity of another magnet. These games are also a good demonstration of the concept of "field" and distant action (Fig. 2, Fig. 3).

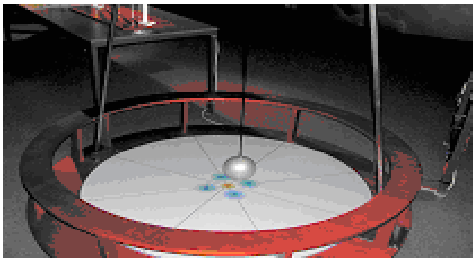

Fig. 2: a pendulum oscillates in a peculiar way when magnetism influences its movement.

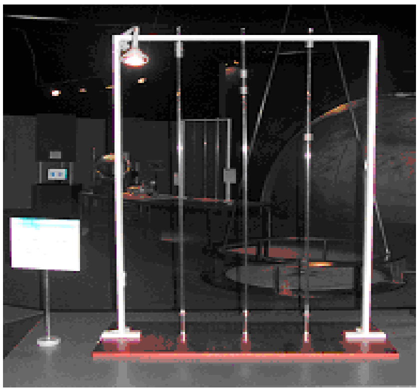

Fig. 3: three magnets fall and, instead of reaching the base, bounce...

After understanding the magnetic interaction between different and same polarities, the audience can visualize the "shape" of a magnetic field, introducing the concept of magnetic field flux lines with the typical experiments of small ferrimagnetic particles oriented and aligned by means of different magnets (Fig. 4).

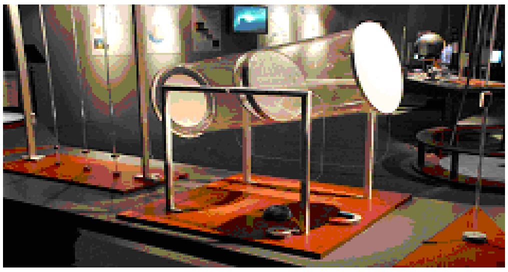

Fig. 4: the cylinder contains iron particles disposing along the magnetic flux lines generated by different magnets

The next experiment, very spectacular, has been made with a particular magnetic oil which shapes up as a magnet approaches, giving a stunning 3-dimensional "ball" view of the magnetic field (Fig. 5).

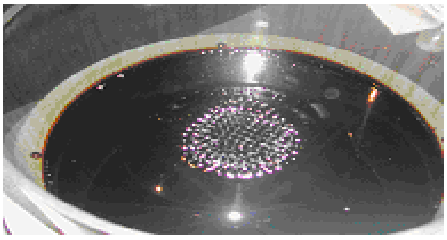

Fig. 5: a particular ferromagnetic oil shapes up as a magnet approaches.

### 3.4 How the EMF is generated; first hypothesis, a magnet inside the Earth

After understanding the basis of magnetism, we are ready to apply these principles to the Earth, illustrating the theories which can explain how the EMF is generated and its behavior.

The first model is an half-Earth with a bar magnet inside (Fig. 6); all the compasses on its surface align to the N-S direction, as it roughly happens in reality. Is this hypothesis correct? The magnet inside the Earth produces flux lines which are resembling the real flux lines (at a first order) of the EMF, but is it a physically correct model? Is there a bar magnet inside the Earth?

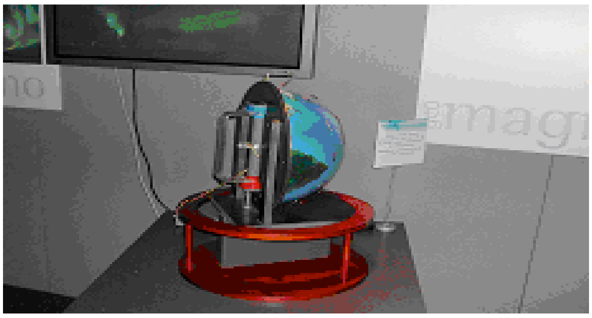

Fig. 6: The Earth with a magnetic bar inside; the magnetic compasses on the crust follow the N-S direction.

## 3.5 The Curie temperature

The demonstration that no magnet can exist inside the Earth is evidenced in the next experiment; an iron wire is attached to a magnet (Fig. 7); as soon as the iron wire reaches about 600°C (by an electrical short-circuit), the magnet detaches from the wire and remains in vertical position influenced only by the gravity field. Inside the Earth, were the temperature reaches thousands of degrees, no magnet can exists, and, thus, there must be another mechanism behind the EMF generation.

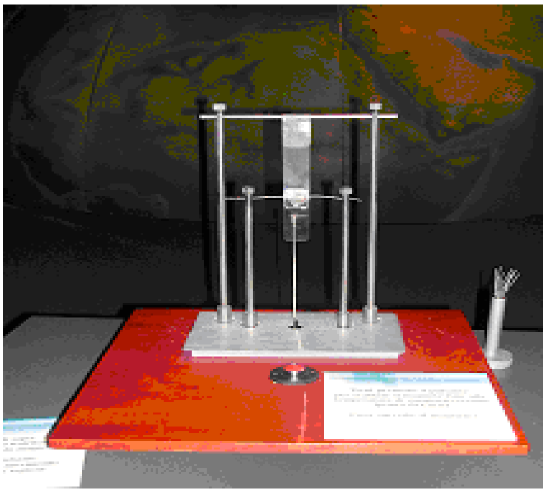

Fig. 7: the Curie temperature; as the temperature of the wire increases, the magnet detaches. No magnet can exist at temperatures larger then about 600°C degrees.

## 3.6 Three magnets falling

The next exhibit consists of three different vertical tubes where a concentric magnet can fall for gravity (Fig. 8); the three tubes are respectively made of aluminum, plastic and copper; the magnet falls with different speeds, going fast when there is a plastic tube, slow for aluminum, and very slow for copper. All these materials are magnetically negligible (not ferromagnetic), and the different effects are due to the ability in conducing electricity; the magnet, moving, induces electrical currents opposite to the directions of the movement; the consequent magnetic field, for the falling magnet, results a sort of "magnetic friction". This effect is obviously as strong as conductive is the medium. This is a first view of the strong connection and interaction between magnetism and electricity.

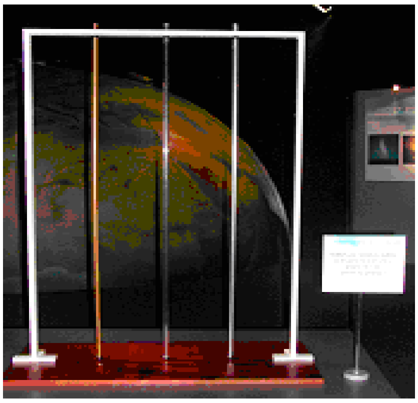

Fig. 8: the three different tubes with a concentric magnet free to fall.

## 3.7 The electromagnet

The next exhibition shows a dynamo, which is used to produce electricity, connected to a coil; a coin is close to this coil, and, as someone rotates the handle of the dynamo, the coil becomes an electromagnet and the coin remains attached to its iron core (Fig. 9). This demonstrates that electricity can produce magnetism and, inside the Earth, electricity can be the source of the EMF.

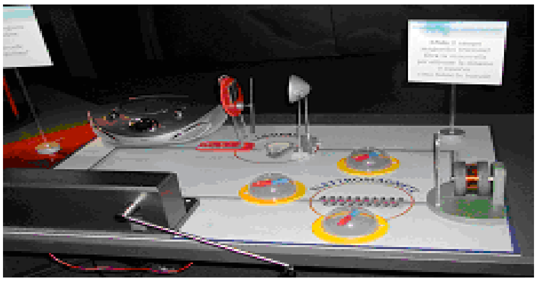

Fig. 9: A dynamo is electrically connected to a coil with a coin near its core; as the dynamo works, the coin is attached to the iron core of the coil.

### 3.8 A magnet falling in a coil

The next experiment completes the precedent one, and shows how a magnet, falling and moving inside a coil, can produce electricity, with a small lamp switching on. A different height of falling correspond to a different light intensity (Fig. 10). We have now a complete view of how a magnetic field can generate a current and how, vice versa, a current can be the source of a magnetic field.

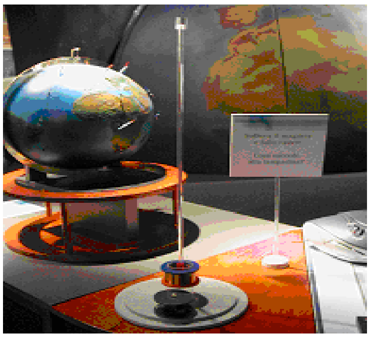

Fig: 10: A magnet falling into a coil induces an electrical current and the small lamp switches on.

### 3.9 A correct model of EMF

The last model is again an half-Earth with compasses all around its surface; instead of having a magnetic bar inside, there is a big coil (Fig. 11), and, switching on the circuit, audience can see the magnetic needles moving and orientating according to the N-S directions. Geomagnetic field inversions are compatible too, simply reversing the direction of electrical current. This is the correct interpretation of the EMF; instead of a big magnetic bar, there is an electrical current produced in the field, and this electrical current is generated in the liquid outer core, where liquid iron, conductive, rich of free electrical charges (comparable to a plasma), moves for convection and Earth's rotation and produces electrical currents responsible of the EMF generation.

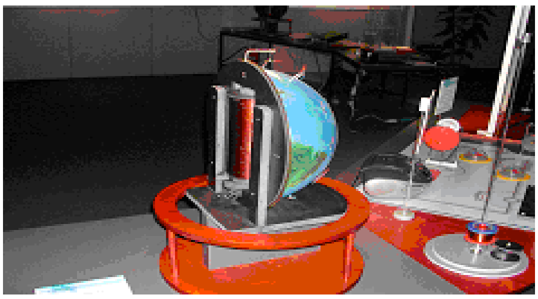

Fig. 11: A coil parallel to the Earth axis; electricity is the real source of the EMF, and it is due to the liquid iron moving in the outer liquid core of the Earth.

### 3.10 Further steps, the interaction between Earth and Sun

A TV set is placed on the next table, and a magnet can be used to "change" the image on the video. This means that a magnetic bar, placed near the screen, produces colored flux lines on the screen. This is a simple way to illustrate how the solar wind can be shielded by the EMF, since, as it happens for the TV set, the electrons "drawing" the images are deflected by the magnet. Videos with auroras are projected near this area, and it is explained why they occur and the relationship between the solar activity, the magnetic storms and these stunning natural phenomena.

### 3.11 The EMF variations

The trip on the magnetic field closes with some computer programs and diagrams to illustrate the short-time (of external origin) magnetic field variations and the long-time (of internal origin) magnetic field variations. Particularly interesting is the magnetic inversion time-scale, one of the crucial open problems in geophysics and one of the most intriguing aspect of modern research.

## 4 Plate tectonics, seismology and seismic hazard

After visiting the part of the museum about magnetism, the audience can enter into a big model of the Earth where they can learn the subdivision of the lithosphere in plates, the inner structure of our planet with the mantle, the convection that moves the plates. This exhibit explains that the Earth is made up of many layers characterized by different temperature, density, viscosity and that the convection is one of the driving force behind the movement of the plates. The origin of magnetism in the outer core is recalled too. This works as an introduction to the second part of the museum, which is devoted to the understanding of Earthquakes and, consequently, of plate tectonics. After a documentary in which are shown the main Earthquakes occurred in Italy in the last centuries, the museum starts with two main halls where the plate tectonics principles are explained.

### 4.1 Africa and Southern America

A moving diorama reconstruct the connection between Africa and Southern America 200 million years ago; rotating a wheel it is possible to proceed in time (a digital counter tells the age) until the actual situation, with the progressive separation of the two continents and the Mid-Atlantic Ridge splitting the Atlantic Ocean, as a common example of a divergent-plate boundary (Fig.12). Similar fossils and geology on both continents were the first evidences of the original contact between these two continents.

Fig. 12: Africa and South America changing their relative positions from 200 million years ago to today and the mid-Atlantic ridge

### 4.2 The tectonic plates; destroy and reconstruct the Earth crust!

The crust of a 3-D Plates puzzle (1m diameter, Fig. 13) is divided in real shaped tectonic plates; with an handle it is possible to "violently" detach these plates (which are magnetically attached) and, then, the visitor is invited to put them again in the correct position, reconstructing, practically, the actual continents configuration.

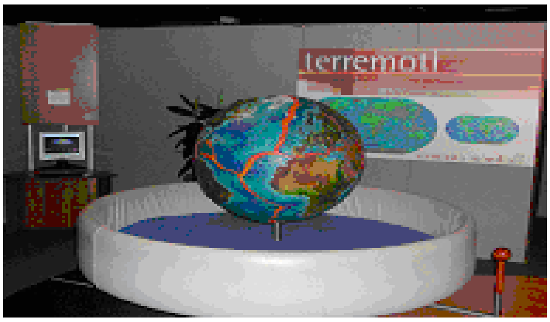

Fig.13: The crust of the Earth as a tectonic puzzle

### 4.3 Why does an earthquake occur? What is a fault?

The next exhibit is a 3-dimensional reconstruction of a fault zone, with a 1 meter long strike-slip fault between two blocks (Fig. 14); the surface has buildings, bridges, trees, and when the left block is pushed, the earthquake occurs, with the buildings fell down according to the strength of the push. In this way it is possible to understand what is a fault, the geometry of a fault and the seismic energy, so that different forces produce different magnitude earthquakes and, consequently, destruction.

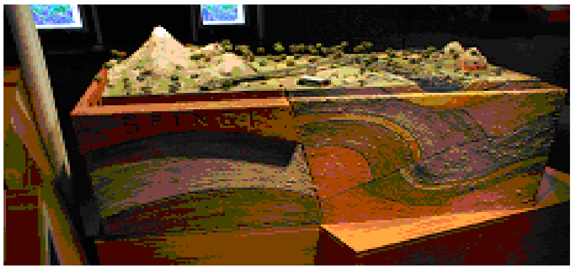

Fig. 14: A strike-slip fault and an earthquake; moving a block, all the buildings are destroyed. After pressing a bottom, the model returns in its original configuration.

### 4.4 Mountains and eruptions

A model (courtesy of Geolab, San Gemini, Italy), shows a system with three typical tectonic situations, explaining, with a recorded voice, why a mountain forms in the case of converging plates, the divergent plates, and a case of seduction with volcanoes (Fig. 15).

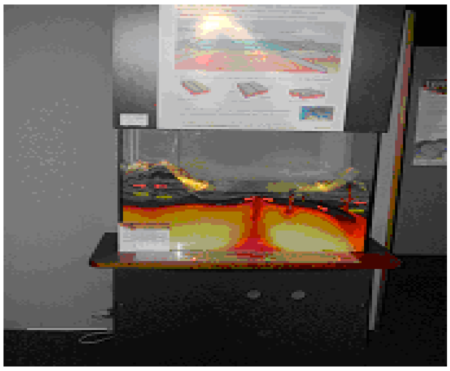

Fig. 15: Mountains, divergent margins and subduction, the key elements on plate tectonics theory

### 4.5 From tectonic plates to Earthquakes

Three monitors show on a map, by means of an educational program developed by Alan Jones [1], the main earthquakes and volcanic eruptions from 1960 to present. It is evident in that way the relationship between earthquakes, volcanic eruptions and plate boundaries, and the impressive amount and the location of seismic events demonstrate that these natural hazards are not random, but they are related to the plate boundaries.

### 4.6 The INGV National Seismic Network Center

The seismic hall of the INGV National Seismic Network has been reconstructed (Fig. 16). It is possible there to watch seismic records in real time, to locate the Earthquakes and to change the automatic localization by means of wave interpretation. Six monitors show real time ground velocity data from several chosen stations in Italian territory and different kind of maps (seismicity, modified Mercalli intensity distribution, tectonic sketch of Italy, seismic risk) illustrate the spatial distribution of past seismicity in Italy, offering good arguments on how we can protect ourselves from seismic risk.

Fig. 16: The seismic hall of INGV, wave interpretation, localization and real time signal analysis.

## Conclusions

This portable geophysics museum has been exposed three times to an always increasing audience; the best effort has been made to produce a complex and complete installation easy to be understood independently of the cultural and scientific level, with correct and elementary experiment that can be curious and intelligible from primary school children to secondary school boys and general public. Electromagnetism principles are usually poorly explained in the classrooms, and magnetism is always a fascinating subject. The explanation of the EMF generation, the magnetic inversions, the Space Weather are topics of particular contemporary interests, and this museum is also a good way for teachers to understand the new fields of research and to learn new practical ways to interact with the students. Concerning Earthquakes and plate tectonics, Italy is a country with high exposure to the seismic risk, and people is really interested in knowing the techniques to measure an earthquake, the difference between Mercalli intensity and Richter magnitudo, and how we are able to collect seismic data in real time from any Italian region. The link between research and practical aspect has been particularly treated in order to explain to the audience how from geophysical theories (plate tectonics etc.) it is possible to understand the seismic risk.

The feedback has been excellent, and we received many request of keeping this museum as a stable installation.

We will try, in the future, to expand this show with further aspects, as volcanism and aeronomy.

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*References:*

[1] Jones A. L., Braile L. W., Braile S. J., A Suite of Educational Computer Programs for Seismology, Seismological Research Letters, 74, 5, 605-617, 2003.