4.3.2.1.PLATE TECTONICS

The need was in trying to make it easier for students, but for many teachers as well the complex and articulated path that in the last century, and particularly in the 70's led the scientific community to the theory of Plate tectonics. The topic of this educational path is obviously how the subsequent discoveries of the last century were able to lead to the final complex model. However the subject is so rich of expected and unexpected interdisciplinary connections, which allows a charming trip along the history of the last century, between wars and changing society, touching all the necessary scientific contents.

It is also an exceptional instrument to promote competences and skills in the students because it involves competence in:

- identify and understand relationships;
- analyze and synthesize
- recognize similarities and differences
- and finally, as requested in the Cultural Axes from the Italian Ministry of Education, (Table 2.1) to observe, describe and analyze phenomena belonging to the natural and artificial reality and recognize in its various forms the concepts of system and complexity.

1ST STEP: the Wegener model (FIG.4 1)

The educational path starts from the Wegener theory, with the traditional approach based on the evidences, geographical, geological, paleontological and paleoclimatic, as commonly presented between Africa and South America, passing through other less known joints of the geological puzzle of the Continents, as the one that linked North Europe and North America, passing through Scandinavian, Scotland and the Appalachian.

DRIVING QUESTION: generally easy to be answered is: what is wrong in Wegener?

ANSWERS:

- the lack of an engine of the movement, necessarily interpreted as a drifting shift,
- the wrong idea, but the only possible in that contest, of a movement concerning only the continents, which required the assumption of a discontinuity between the continental crust and oceanic substrate.

HISTORICAL CONTEXT - The period just before and after the first world war: period

of big social, political and cultural revolutions.

EXPECTED CONNECTIONS - The period was also a characterized by an explosion of

FIG. 4. 1 THE WEGENER MODEL

scientific new theories, among which Wegener Theory is well located, but unfortunately, not enough scientifically supported.

UNEXPECTED CONNECTIONS: Interesting, but not immediately obvious, are the relationship with the Darwin's Evolution theory. Just fifty years before, the same doubts, the same criticisms welcomed Darwin and his revolutionary ideas, that troubled surely more public and scientific opinion because of the deep impact on the centrality of the human being, touching the deep bond between man and his place in religious thought.

While, if Earth with its continents moves, well, who cares about that?

But the same concepts of complex system, of deep times, of braided links are found in both theories.

2ND STEP: Volcanoes and earthquakes (FIG. 4.2)

This step consists in the analysis of volcanoes and earthquakes, I their location on the Earth crust.

The tool is planisphere, with a hundred coloured leds, representing volcanoes and earthquakes. As this educational pathway tries to connect with the history of the last century, the collection of data is placed - a bit "artificially" - in the period between the two world wars, a period of great discoveries, thanks to the

convergence in the United States of "brains", as a result of racial persecution. Then, in our pathway, we leave in a corner the Wegener theory, put aside afterwards in that period from the scientific community, as well, because of the lack of evidence.

The particular location of volcanoes and earthquakes brought the geologists to elaborate the Pacific fire ring model: then a first glimmer started to be opened in the historical fixist, static model of Hutton or, rather the isostatic one, based on a vertical movement of crustal blocks, by Suess and, later, by Argand.

Earthquakes has green, yellow, and red light related to the energy of the events, and they illuminate at different times, progressive, to indicate that they occur at different times. Volcanoes are represented by red fixed light; just some of them are flashing, not because we want to represent active or inactive volcanoes, but simply those that are more meaningful, as afterwards explained.

DRIVING QUESTION: Should the locations of Volcanoes and Earthquakes bother us? Are they speared on the Earth haphazard?

ANSWER: Students' answers are generally correct: they easily notice the relationship between volcanoes and earthquakes, the meaning of the Pacific fire ring; it is possible to collect ideas on the plate tectonics theory, sometimes rather confused because the different lines of volcanoes are not so immediately

FIG. 4. 2 VOLCANOES AND EARTHQUAKES, IN TIME AND IN SPACE

corresponding to the global model, and even the perception of natural risks is not clear.

The effects of the model on the students are strictly related with the level of

education, but also with the competence of the teacher on the complexity of the theory. Even if the model is rough and not exhaustive, generally students understand the meaning of the activity, and they get a general idea of the location, but also of the age. A trick, not scientific but useful to point students sight, is that the led light is flashing in some volcanoes not if they are still active – which is the first logic impression – but just to attract the attention of the observer. And that works quite well, particularly if we have stories to tell on that particular volcano.

HISTORICAL CONTEXT The timeline of the interactive lesson brings us in the period between the two world wars, actually a period of great scientific development, thanks to the concentration of researchers in the USA, as a result of racial persecution. In addition, it was also the period that followed the tragic earthquake in San Francisco (1906) and in Kanto, Japan (1923).

It is important to share the idea that earthquakes and volcanoes are found in every historical epoch, often well documented by geological traces, as well as historical evidence, or socio-economic consequences.

EXPECTED CONNECTIONS: the link between volcanoes and Earthquakes is easy to be observed and recognized. The relationship with Plate tectonics is logical and coherent.

UNEXPECTED CONNECTIONS: an incredible range of histories and stories can be proposed starting from volcanoes. Some examples are proposed in the booklet "*Viaggio al centro della Terra*", but the impact of volcanic eruptions on biological evolution is straightforward and proved. All the meaningful events that characterized the history of the life, from the beginning, the creation of the first atmosphere, the biological extinctions, the big migrations, the disappearance of ancient and recent civilizations, up to the result of some famous battles, i.e Waterloo, the economical slumps, etc, can easy be related to volcanic eruptions.

3RD STEP <u>The vibrating plate (FIG 4.3)</u>

A simple and rough model of a vibrating plate, here made by an old drill and an asymmetric cam is useful to wake up the public and to present considerations on Earthquakes. It is easy to discuss about the quality of the buildings, their locations, their height, the structure and the materials of which they are made. Also reasoning on hypocenter and epicentre, using different kinds of

seismometers, starting from a rough seismograph, made by a writing pen suspended by a spring on a roll of paper, till the App of seismometer contained in a smartphone. The activity can be developed with exercises of researching the epicentre, waves velocity, applying to the model different examples and promoting the use of specialized software. The passage from hands-on models to virtual ones and vice-versa improves the students' skills.

DRIVING QUESTION The tool is quite rough and easy to be reproduced, therefore, depending from the target, many could be the driving questions, like:

1. which are the most secure buildings?
2. is this model truly representative of the natural phenomenon?

FIG 4. 3_THE VIBRATING PLATE FOR REPRODUCTION OF THE EFFECTS OF AN EARTHQUAKE

ANSWER

1. Hypothesis on the most sure and hardwearing building: wooden made cottages, skyscrapers, stone-made buildings, reinforced concrete palaces.

   The result is not obvious, but opens the discussion on the quality of the building.
2. the result is too often that the vibration is too strong, while the problem should be centred pointing out the lack of homogeneity, that normally is typical of a terrain.

EXPECTED CONNECTIONS The immediate consequent idea is the relationship with the

topic of natural risks and hazard, and particularly, in Italy with the most known examples, as

- Naples and its volcano, the Vesuvio area, easily related to the use of the land, the problems of prevention and of escape routes
- L'Aquila and its earthquake, easily related to the problem of location and relocation of buildings and towns.

Frequently and quickly the discussion slips to a social interpretation of how and where, in Italy, buildings are built.

UNEXPECTED CONNECTIONS Even if sometimes, scientific subjects keep their identities are kept in separate disciplines, it is easy to link earthquakes and seismic waves to physics, by investigating the shape and the direction of the movement of primary and secondary waves. Less common is to consider other interesting effects, as resonance on buildings like skyscrapers, as in the Petronas towers in Kuala Lumpur or to switch to acoustic waves, to sound music and to peculiar instruments as the Theremin, easily comparable with earthquakes because of the strong, even incredible effect of invisible waves.

4TH STEP The interior of the Earth (FIG. 4. 4)

The structure of the interior of the Earth, with its typical model similar to an onion, changing physical and chemical features from one layer to the other, is very often not so clearly developed in the school texts. For teachers not so competent in Earth science it is rather difficult to explain the differences between mantle and asthenosphere, crust and lithosphere.

This simple but clear model allows to understand that the materials composing the concentric shells in the interior of the Earth should be considered from two different scientific points of view: 1) a chemical one, analysing the composition of the rock, and 2) a physical one, analysing the structural properties.

The result is a wooden model made of a sphere (since an ellipsoid of rotation as a geoid is too difficult to be realized) that on opening shows the two half of a sphere. One side will show crust, upper and lower mantle, exterior and interior nucleus, than a structure considering the chemical composition of the different shells. The other side will show litosphere, astenosphere, exterior and interior nucleus, considering the physical characteristics of the different shells.

FIG 4.4 THE TWO HALF PARTS OF THE INTERIOR OF THE EARTH

DRIVING QUESTION Why the two half parts are different?

But also: How was it possible to study the interior of the Earth?

Which is the difference between physical and chemical properties?

ANSWER The basic problem is that in some lower levels of education the difference between chemistry and physics is not clear. Then sometime it is necessary to explain first some basic concepts on:

- Physics, and particularly
  - the relationship between pressure, temperature and state of aggregation, necessary to understand why interior nucleus is solid,
  - the flux of heat, by conduction and convection, necessary to understand convective cells and the movements of the astenosphere.
- Chemistry, and particularly
  - the difference between continental crust and oceanic crust, necessary to understand the following activities on isostasy;
  - the different density of materials towards the centre of the Earth

HISTORICAL CONTEST The period after the second world war, rich of new discovery thanks to new instruments.

EXPECTED CONNECTIONS The links between seismic waves and physical property of the shells are generally clear and anyway developed by the books, but they need clear competence to understand the meaning in the practical application.

UNEXPECTED CONNECTIONS The period after the second world war was also characterized by the Cold War, and by a growing activity of nuclear underground explosion, useful to show the power of the owner country, but also to collect data

on the interior of the Earth.

5TH STEP - Faults and folds (FIG 4. 5 and FIG. 4.6)

Many tools, as simple as biscuits or dough bread, more technical as wooden blocks for faults or a glass box with continuous screw to obtain folds in sand, with layers of flour, gypsum, coffee, can easily explain different behaviours of different materials.

FIG. 4.5 FAULTS

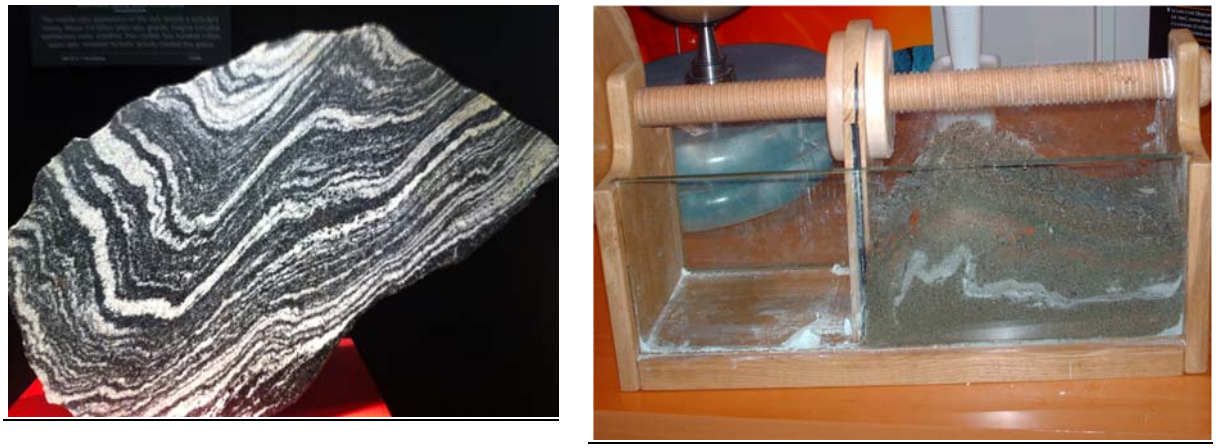

FIG. 4. 6 FOLDS

DRIVING QUESTION How it happens that sometimes a rock breaks, sometimes it bends and deforms?

ANSWER The answer requests competences in physics, geology, petrography but the simple observation of a rock sample, the behavior, rigid or plastic, of a biscuit or of play-doo, of a wooden model or of loose materials, allows students of all ages to understand the concepts of stiffness and ductility.

The use of the model in continuous screw (FIG. 4. 6), which requires even to exert some effort to deform the material contained in it, although it can be flour, chalk or sand, allows to introduce considerations on the amount of pressure

exerted and to verify the production of small-scale folds or regional thrusts. The tool allows to view a wide variety of phenomena, folds, faults, fold-faults, thrust faults, formation of mountain ranges, syngenetic landslides. Again, a simulation software would be more scientifically correct, but, after dozens of experiments in the classroom, we have verified that the *learning object* has remained clearly in the "collective memory" of students at schools, whereas videos, although valid, tend to be easily forgotten.

EXPECTED CONNECTIONS Famous events can easily be explained, as the S.Andrea faults, and less known, as the anomalous direction E-W of the Aosta Valley and of Valtellina, related to important faults (Insubrica line and Aosta-Ranzola fault), with interesting practical effect available to see in the surroundings.

UNEXPECTED CONNECTIONS Some surprising unexpected connections could relate the African rift, easily represented using wooden block, which created environmental conditions more suitable to the natural selection of Australopithecus afarensis, Lucy, to the robust, as evidenced by an increasing number of fossil findings.

6TH STEP- PLATES THEORY (FIG.4.7)

A simple model of the main plates, nicely produced thanks to the work of the technical school for carpenters of Valle d'Aosta, is obviously useful to understand the global dynamic.

DRIVING QUESTION

We can use all the parts of the puzzle to ask questions on: formation of mountains, earthquakes, volcano, oceanic ridge.

The model allows building the puzzle of large plaques, thinking about the different elements that characterize and identify the margin, of whatever nature, convergent, divergent, transcurrent.

Although trivial, the model enables us to recognize the cause of big events, the earthquakes in Haiti and China, ocean trenches and large thrusts.

ANSWER It is quite easy to understand about the convergent and divergent movements even by using simple pieces of a puzzle.

HISTORICAL CONTEST Only at the end of the 70s it was possible to put together all the data collected and analyzed in previous decades: the morphology of the ocean floor, with ridges and ocean trenches, the volcanic chains and the hot spots have allowed to develop the complex theory of plate tectonics.

FIG.4.7 PLATE TECTONICS MODEL

EXPECTED CONNECTIONS The connections are easy to find as each geological phenomenon is related to the movement of the plates. The dynamics of the formation of the Alps and the Apennines chain, though simplified, is easily represented through the use of the small Adriatic plate, deliberately represented despite its size not to scale, in order to understand the events that have affected and still affect local dynamics.

UNEXPECTED CONNECTIONS A lot of possible amazing discoveries are possible. Students at this point are able to relate all phenomena previously presented, often studied as isolated concepts, with the overall dynamic.

The idea of a moving Earth and in continuous transformation is now clear, and how this would affect all biotic and abiotic phenomena that have affected the Earth.

7TH STEP- STRUCTURAL MODEL OF THE AOSTA VALLEY (FIG 4.8)

The final step is generally to give a look around and to understand that our regional contest (Valle d'Aosta) is obviously the result of the dynamism of Earth. In effect, the structural model of the Aosta Valley is particularly "lucky" and useful to understand the convergence of the South of the World in the Pangea, the Paleoafrica. Paleoafrica is here recognizable in the Sesia Lanzo gneiss, which represents the ancient shores of the southern border

of the Tethys sea, where we could imagine dinosaurs of a warm climate walking along the seashore colliding with the North, the Paleo-Europe, again with deposits of shores and lagoons and shallow cold seas.

The two models represent a map of the Aosta Valley and the same area in a section, were made by considering a view from the south, following the line of the Dora river. It is a structural model of the Region, coming from the work of


FIG. 4.8 STRUCTURAL MODELS OF AOSTA VALLEY IN PLANT AND IN SECTION

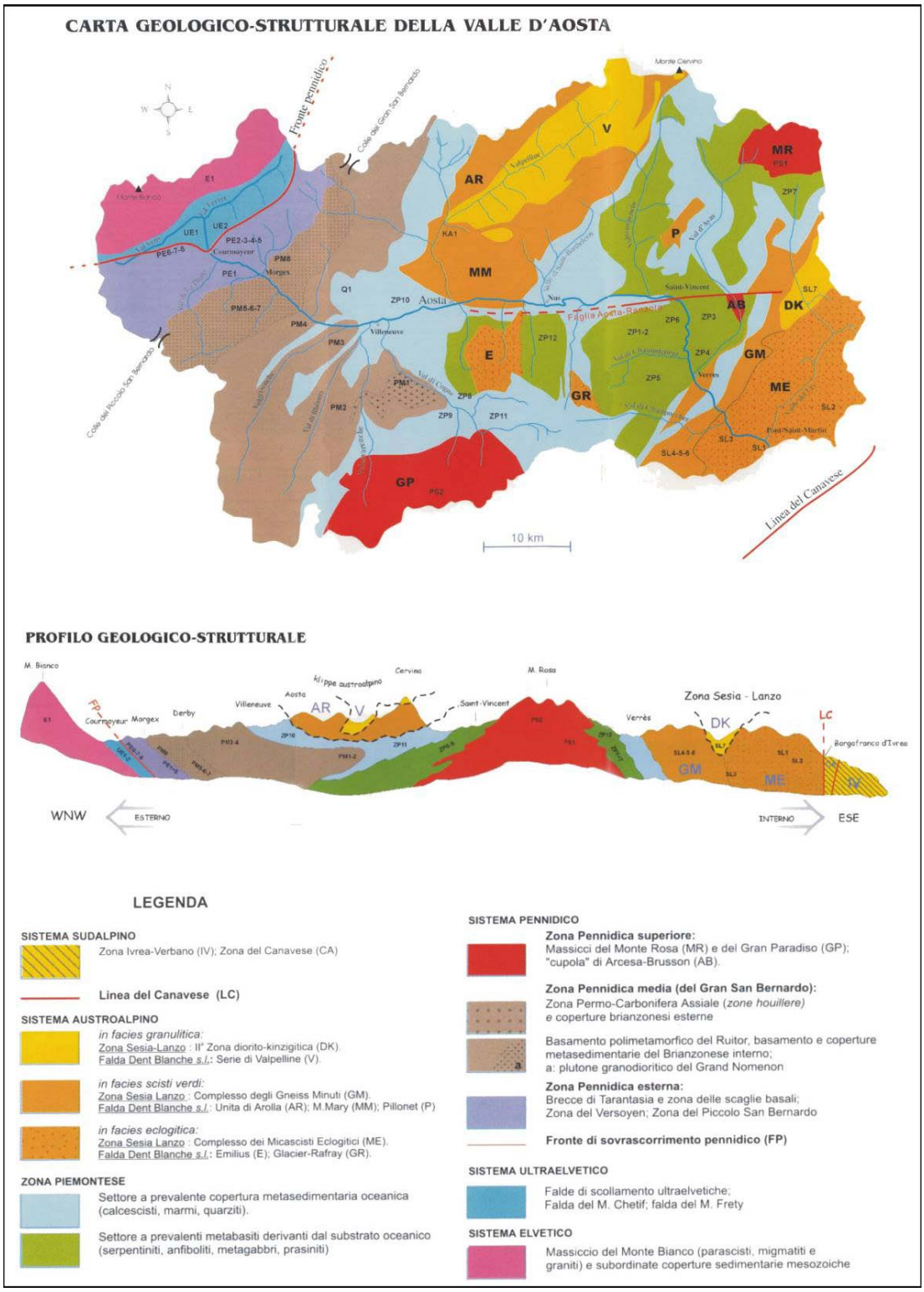


FIG. 4. 9 GEOLOGICAL-STRUCTURAL MAP OF THE AOSTA VALLEY (BONETTO E GIANOTTI 1998)

Bonetto e Gianotti (1998) (FIG. 4.9), where the colours clearly correspond to geological dominions.

DRIVING QUESTION If the yellow pieces represent the Paleo-Africa, the beaches of

warm climate where dinosaurs took a walk, and the grey represents the Paleo-Europe, where dinosaurs of cold climate took a walk, what green and sky-blue pieces of the puzzle represent?

ANSWER We generally obtain that even pupils of primary schools can get the idea that a sea, the ancient Tethys, (the Ligure Piemontese Basin if we are in a secondary level class), should be between the two shores. That "dinosaurs" – just to use the typical representations of animals really living about 150 millions years ago - of cold and warm climates, faced one each other from the two borders of the Tethys.

This model can clearly explain how so many materials, in a simplified representation, but not so far from what really could have happened during the collision and the overthrust, neglecting obviously the dynamics of sinking and rising that are now considered as more correct in the new theories.

EXPECTED CONNECTIONS This "story" is very often able to make easier than a traditional lecture, to understand the complex theory of plate tectonics, as many experiences and observations from the students have shown.

UNEXPECTED CONNECTIONS This model can also explain, if there is time and will, some peculiar aspects as the contact between Ligure-Piemontese basin of the Pennidic Nappe and the Elvetic border, with the horizons of hot climate of the late Cretaceous on the back of the Pyramides calcaires.