GEOTUR

geotur

GUIDE-INTERPRETER OF GEOTURISM

DIDACTIC MATERIALS

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OUR PARTNERS:

NOVOHRAD NÓGRÁD GEOPARK

adesper
AGRUPACIÓN PARA EL DESARROLLO SOSTENIBLE Y LA PROMOCIÓN DEL EMPLEO RURAL

Junta de Andalucía
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INTRODUCTION

The Conservation and management of the geodiversity is an essential element to carry on the path of a green economy, which assists to the construction of a process of socioeconomic sustainable essential development to the human wellbeing. The European policies of conservation and sustainable use of the geodiversity demand to intensify the efforts for its suitable integration and consideration in the sectarian policies, because on this way they will be able to be understood and the links to be reinforced the positive existing links between the conservation of the geological heritage and the economic and social development.

This demand turns out to be specially forced in the tourist sector, one of the most important as for its economic impact to European level, contributing to the gross domestic product (GDP) and to the employment because of 5 % and 5,2 %, respectively, of the active population. The geo-diversity is increaingly one of the factors that motivate the trips, because of the variety of geological landscapes and its well-preserved ecosystems acts like basic attraction of the tourist destinations. These destinations have met reinforced with the creation of the Network of European Geoparks.

It pretends, through an equipment of European work, to recognize and to validate two new units of competition to European level that they give a answer to the demand of creation and impulse of products of geological tourism accredited by its sustainability in relation to the geo-diversity, and that provide to the tourist singular experiences related to the relevancy and exclusivity of the geological heritage.

These two new units of competition would be fitted inside 3 professional families in 4 professional qualifications recognized by the Institute of the Qualifications (INCUAL):

1) Guides for itineraries of fall and a halfmountain;
2) Guide of speleological;
3) Guide of tourists and visitors;
4) Interpretation and environmental education.

In this way, the project expects to develop a series of innovative products based on two units of competition:

1. To interpret the geological heritage and its values to tourists and visitors of European Geo-parks.
2. To give services of accompaniment and assistance to tourists and visitorsand to design itineraries geotouristic across the places of geologicalinterest (LIG).

GEOTUR STAFF

Geotur family

PROFESSIONAL QUALIFICATIONS

1. Guide of itineraries of low and medium mountain.
2. Speleology guide.
3. Guide for tourists and visitors.
4. Interpretation and environmental education.

COMPETENCE UNITS

1. Interpret the geological heritage and its values to geotourists and visitors of European Geoparks.
2. Provide accompaniment and assistance services to geotourists and visitors and design geotouristic itineraries through places of geological interest.

OBJECTIVE

Inform and interpret the geological heritage, the geological and natural interest assets and other touristic resources of the specific area of the Geoparks and places of geological interest to tourists and visitors, in an attractive way, interacting with them and awakening their interest, as well as providing services of accompaniment and assistance, so that they feel cared for at all times, their expectations of information and playful enjoyment are satisfied and the objectives of the entity organizing the service are met.

PROFESSIONAL ENVIRONMENT

Professional field

The guide-interpreter of geotourism, basically, as an independent professional, although he can also participate in touristic services companies as a partner or salaried employee. This professional provides services to tourism companies of nature, ecotourism and active tourism, travel agencies, local promotion agencies or service companies in general, although it can also be hired directly by the people or groups to which he/she reports, interprets, attend and accompany. He/she scope of action, due to the intrinsic nature of the activity, is limited by a territorial area of a regional, provincial or local level, for which each professional has a certain accreditation

Productive sectors

These transversal competences are located in the tourism sector, especially in the subsector of information services, accompaniment and assistance to touristic users in the natural environment.

Occupations and relevant jobs

- Geotourism guide.
- Guide interpreter of the geological heritage.

ASSOCIATED TRAINING

Training modules

- **I. Introduction to geology.**
- **II. European geological heritage.**
- **III. Underground heritage and European tourist caves.**
- **IV. Geoparks and European Geosites.**
- **V. Entrepreneurship in European geotourism.**

COMPETITION UNIT 1

Interpret the geological heritage and its values to tourists and visitors of European Geoparks.

Professional realizations and performance criteria

1. Search and select touristic information about geological heritage and its values, interpreting and processing it, with the aim of adapting it to the different types of receptors and contexts within the European Geoparks.

♣ CR1.1 The primary and secondary sources of information are identified, discriminated, contrasted and selected for use in obtaining current, accurate and truthful information.
♣ CR1.2 The media and the different types of access to information, including the information existing in the equipment for public use, such as visitor centers or thematic museums, are used efficiently in order to determine the available options.
♣ CR1.3 The information of interest about the scope of action or itinerary is selected and contrasted, especially about those related to geology, physical geography, legislation and figures of environmental protection, management of protected areas.
♣ CR1.4 The information identified and interpreted is object to synthesis and preliminary verification, updating it and adapting it to the types of groups or visitors, the natural spaces visited and the routes pre-established by the policy of environmental preservation of the managing body, in case of being protected areas.

2. Integrate information on places of geological interest, so that it can be adapted and transferred, later in an attractive way to geotourists and visitors, satisfying their requirements and expectations.

♣ CR2.1 Information about Geoparks and other resources of the geological heritage, corresponding to the itinerary or visit that is going to be carried out and that has been object to selection and contrast, is analysed in depth and interpreted objectively.

♣ CR2.2 The geological itinerary and activities to be carried out are communicated to the environmental manager and it is verified that the corresponding authorization has been received.
♣ CR2.3 The data and essential aspects, corresponding to the information with has been analyzed and interpreted previously, are memorized andinterrelated.

3. Interpret the geological heritage in the European Geoparks, by satisfying the requirements and expectations of tourists and visitors.

♣ CR3.1 The information is provided in a clear, sequenced, entertaining, contextualized and rigorous manner, avoiding overwhelms, selecting the both language and average level of understanding of the participants and stimulating interaction, curiosity and interest.
♣ CR3.2 The communication techniques and group dynamics are applied to stimulate in the visitors their curiosity, interest and participation, fostering the respect and valuation of the geological heritage and the environment they travel.
♣ CR3.3 The voice as a tool to transmit information is adapted to the specific site where it is located.
♣ CR3.4 Body language as a complementary tool for the voice is mastered and used to reinforce verbal information and motivate geotourists and visitors.
♣ CR3.5 The information is transmitted by adapting it to the demands of the group, tourist or visitor, their diversity or cultural identity, their foreseeable life experiences and geographical origins and the cognitive resources of their age and formation.
♣ CR3.6 The questions asked are answered with clarity and correction, by expanding the information when required.
♣ CR3.7 The places of geological interest and geosites in which the information is interpreted are exhaustively known, so that there is a full capacity for improvisation and reaction to any circumstance.
♣ CR3.8 The times used to transmit the information are adapted to the program, to the temporary limitation planned for the established route, to the characteristics of the visitors, to their availability of time and, where appropriate, to the need to combine times of explanation and leisure times to guarantee that the geotourist is in optimal conditions to receive, assimilate and enjoy the information.

Professional context

Production resources

- Office equipment.
- Office supplies.
- Transport.
- Natural spaces and their facilities.
- Equipment for public use.
- Sound and audiovisual equipment.
- Interpretive materials.

Products and results

・Information corresponding to the scope of action, selected, processed, interpreted, integrated and provided on Geoparks and their geological resources.

Information used or generated

- All types of information and printed documentation, magnetic media, etc.
- General and specific bibliography.
- Plans and maps.
- Touristic legislation.
- Legislation about spaces and natural resources.

COMPETITION UNIT 2

Provide accompaniment and assistance services to tourists and visitors and design geotouristic itineraries throughout places of geological interest.

Professional realizations and performance criteria.

1. Analyze the service of guidance, support and assistance to geotourists that will be the object of benefit, suggesting, when applicable the appropriate changes and managing the necessary means for its realization, so as to ensure compliance with the objectives of the organizing entity and the expectations of the participants are met.

♣ CR1.1 The information about the profile of the group or tourist, georoute or geological itinerary, transportation, accommodations, visits, activities and expected providers, as well as travel documentation, is interpreted.

♣ CR1.2 The information that must be supplied to the group or to the tourist in particular is adapted according to their peculiarities.
♣ CR1.3 The degree of adaptation of the services provided to the requirements of the participants and the cultural characteristics of the environment, is evaluated and if necessary, proposed alternatives that can improve the geo-itinerary or georoute designed by the organizing entity.
♣ CR1.4 The means necessary to provide the service are determined taking into account the economic conditions established, relating to:

- Information on the characteristics of the group or tourist.
- Information about the visits.
- Information that is expected to be used during the trip.
- Predicted means of dissemination.
- Means of transport and other service providers, such as restaurants, museums and others.
- Others

♣ CR1.5 The service providers are contacted, making sure that the conditions, prices and expected terms are met, checking their suitability and relevance according to the determined route, foreseeing the necessary substitutions and collecting information about the contact and reception persons of the group in destination.
♣ CR1.6 The possible conflicting situations are foreseen, by establishing in common agreement with the organizing entity the necessary mechanisms for their solution, so that solid alternatives are assured for each one of the programmed activities and services.

2. Accompany and assist the geotourist or group, ensuring that at all times they feel conveniently attended and entertained when necessary.

♣ CR2.1 The information and documentation provided to the participant describe:

- Program of the route.
- Place and time of meeting.
- Means of identification, both of the tourist or group of tourists and of the companion.
- Information of general interest.
- Tickets and bonuses for excursions, visits, shows and other scheduled events.
- Documents that must be available.
- Means to spread complaints about the organization of the trip or visit.

♣ CR2.2 Its presence in the right places and times is ensured by solving the contingencies promptly and effectively.

♣ CR2.3 The presence of the participants is checked by reviewing and updating the list provided by the organizing entity, emphasizing the importance of punctuality and compliance with schedules.
♣ CR2.4 The allocation of seats, where appropriate, to the participants is established or coordinated, by trying to avoid the separation of people travelling together and ensuring fair distribution.
♣ CR2.5 The arrival and departure procedures are coordinated by checking that the offered services are in accordance with the agreement it trip organizer and by trying to satisfy, as far as possible, the demands of the participants.
♣ CR2.6 The bonds and other documents are handled and filled out exactly, by ensuring that they are if it to the contracted services for a later billing by the organizing entity.
♣ CR2.7 Assistance is provided to the individual tourist or group by trying to feel them accompanied, safe and conveniently cared by responding to all types of unforeseen events.
♣ CR2.8 The animation activities that are appropriate are proposed, energized and conducted by taking into account the profile of the participants, the place and time of the day.
♣ CR2.9 The communication with the participants is fluid by using the most effective means to get a good interaction and understanding in the communication.
♣ CR2.10 The basic rules of protocol, customer service and coexistence are applied to maintain an adequate level of behaviour in the development of the activity.

3. Provide the geotourist or group in route general information of interest about the geodestination or immediate environment, so that their requirements and expectations are met.

♣ CR3.1 The information of general interest is provided in a sequenced, serene manner by selecting the language and average level of understanding of the participants.
♣ CR3.2 The information of general interest is provided by adapting to the individual and, where appropriate, collective requirements, to give a global and synthetic view of the resource object of the visit, trying to establish the suitable framework for the other information services in destination that the participants will receive.
♣ CR3.3 The questions asked by the geotourists are intended to respondwith clarity and correctness by solving their doubts and expanding the general information when required.
♣ CR3.4 The communication with the participants is fluid by using the most effective means to achieve a good interaction and understanding in the communication.

4. Supervise and direct the development of the geological itinerary, georoute, visit or service in which he/she acts as a guide, companion or assistant to ensure compliance with the program or the management guidelines of the Geoparks and other natural areas of geological interest by solving incidents and avoiding difficulties.

♣ CR4.1 They are subject to constant verification by verifying that they fit the intended program:

- The geological or georoute itinerary that is being carried out.
- Transportation services, geotourism guide and other contracted services.
- Visits and other scheduled activities.
- The schedules that affect the opening/closing of the centers of geotourism interest.

♣ CR4.2 The contracted programming is fulfilled, by adopting with flexibility, in case of unforeseen situations, the opportune measures that seek the satisfaction of the participants, and informing as soon as possible the person in charge of the organizing entity.
♣ CR4.3 Decisions and solutions adopted by the organizing entity or the entity managing of the protected space, in the event that unforeseen events arise or significant deviations occur with respect to what is scheduled or expected by the visitors, are put into practice in a effective way as soon as possible, minimizing their effect on their expectations.
♣ CR4.4 The behaviour patterns in Geoparks and protected natural spaces and the reasons for their preservation are explained clearly and simply by seeking the involvement of visitors and raising awareness about their fragility.
♣ CR4.5 The geotourism guide, during the tour of Geoparks and protected natural spaces, behaves in such a way that her/him attitude reinforces the transmission of respect for the geological heritage.
♣ CR4.6 Punctuality, the use of available time, compliance with established rules and adaptability to unforeseen circumstances are controlled at all times, in order to achieve the established objectives.
♣ CR4.7 The georoute or geological itinerary through which the visitors are conducted is followed in order to minimize the impact on the natural environment and ensure its preservation and sustainability, including geodiversity.
♣ CR4.8 The group security is tried to be maintained at all times when necessary.
♣ CR4.9 The interpersonal incidents that may arise along the route, itinerary or visit are solved efficiently and professionally by adopting a mediating and conciliatory attitude between the parties, where appropriate
♣ CR4.10 The communication with the participants is fluid by using the most effective means to achieve a good interaction and understanding in the communication.

5. Design geological and geological itineraries, visits or tourist products of geological interest, for companies, agencies or other operators or their own clients, so that they are attractive and susceptible to commercialization.

♣ CR5.1 The design of geological itineraries is done through:

- The concretion of the territorial and temporal scope of the itinerary.
- Identification and consultation of touristic information sources.
- The synthesis and organization of the collected information.
- The programming of services and activities.
- The justification of the viability of the itinerary.

♣ CR5.2 The components of the geotourist offer and the framework for action are identified and considered, especially as regards:

- The geological, natural, cultural, historical resources and tourist resources in general.
- The geological and natural resources, their characteristics, the environmental policy of the Geoparks and the natural spaces of geological interest and their environment and the fragility of the environment.
- The potential impacts of visitors on the environment and the capacity for ecological and psychosocial reception.
- The new demands of the geotourists.
- The basic infrastructure, such as accesses, supplies, transportation, signage, interpretation rooms, and others.
- The tourist infrastructure in the surroundings, such as accommodation, catering services, recreational offer and others.

♣ CR5.3 The collected information is analyzed to evaluate the possibilities of designing new itineraries, geororutes, visits or geotouristic products, according to the tourist offer, demand of the organizing entity, market trends or management policy of the Geoparks and natural areas of geological interest, by estimating their commercial, technical, financial and environmental viability, where appropriate.

♣ CR5.4 The new geological itineraries, georutas, visits or geotouristic products are designed based on an in-depth analysis of the area or natural space, by adapting them to the environment visited and maximizing the use of their geological resources.

♣ CR5.5 The design of geo-itineraries, georoutes or geotouristic products within the framework of Geoparks and other natural spaces of geological interest is adapted to the informative and playful objectives of the visit, by maximizing the interpretative use of the geological and natural resources that ensures and contributes to its sustainability in a best way and it is carried out by considering its effectiveness for the disclosure of the values of
said spaces and of their environmental protection policies.

♣ CR5.6 It contributes with the design of the new geological itineraries, georoutes or geotouristic products in Geoparks and natural spaces of geological interest to their preservation and to the generation of economic resources for them and for the organizing entity.

♣ CR5.7 The quality parameters established by the organizing entity, or the manager of the natural space, are assumed as minimum in the design of new geological itineraries, georoutes, visits or geotouristic products.

6. Participate in the improvement of the quality of the process of providing the geotourism guide service, support or assistance to geotourists and visitors in which it takes part by evaluating the provision of own and external services, to raise the established standards and the level of satisfaction of the participants.

♣ CR6.1 The work is carried out by meeting or exceeding quality standards, in accordance with the established procedures and achieving the satisfaction of the participants' expectations.
♣CR6.2 The direct information about the geotourists and their expectations, as well as about the potentially adverse conditions to the quality, is providedto the organizing entity of the service or manager of the Geopark or natural area of geological interest, making suggestions for improvement with regarding to future programs.
♣ CR6.3 The information obtained from surveys, quality questionnaires and others, to assess the degree of satisfaction of the participants and the level of compliance with the planned objectives, is collected and saved for further processing.
♣ CR6.4 The degree of adequacy of the provision of the services to the established conditions or communicated to the visitors and agreed with the client is object to evaluation.
♣ CR6.5 The information generated during the provision of the service is organized in order to:

- Provide the contracting entity with a report on the results of the service.
- Enrich your knowledge and georesources to improve your services in future provisions.

♣ CR6.6 The complaints or claims of the participants are treated with kindness, efficiency and maximum discretion by following the established procedure, complying with current regulations and taking the appropriate measures to facilitate their resolution.
♣CR6.7 The communication with the participants is fluid by using the most effective means to achieve good interaction and understanding.

Professional context

Production Resources

- Transport.
- Facilities of the geotouristic service providers.
- Office equipment.
- Sound and audiovisual equipment.

- Recreational material.
- First aid kit.
- Individual protection equipment.
- Communication system.
- Signalling and beaconing material.

Products and results

- Guidance, assistance and accompaniment service analyzed.
- Information and other documents derived from the management of the geo-itinerary searched, understood or formalized. The means necessary for the realization of the managed service.
- Development of the itinerary, georoute, visit or supervised service.
- Collection, reception, accompaniment, assistance and guide for individual and group of tourists.
- Evaluation report on the provided service.
- Georoute itineraries, visits or tourist products of geological or natural interest, designed.
- Participation in the quality improvement process carried out.

Information used or generated

- Information and printed documentation, on magnetic support and web pages, of a general nature, on destinations, products, resources and geotouristic services.
- Plans and maps.
- Specific travel information and documentation, such as type of group or tourist subject of accompaniment, georoute or geoitinerary program, visits, transportation to be used, means of identification, documents to extend complaints or claims for loss, information for activities of animation, accommodations, scheduled activities, planned providers or other interesting ones.
- Information about contact people and reception of the group in destination.
- Information on the promotion of the company or entity that organizes the geotourism service.
- Required requirements and regulations applicable to national and international geotourists, professionals in the geotourism guide activity, assistance and accompaniment of visitors, tourists and groups, and other related professionals.
- Information about service providers, prices and rates.
- Internal regulations of the organizing entity.
- Specific information adapted and synthesized for the geotourist or group.
- Reports of evaluation of the provided service.
- Legislation on formulas of assets protection of geological interest or natural areas.
- Deontological code of the profession.

DIDACTIC UNIT I: INTRODUCTION TO GEOLOGY

MODULE 1: Basic concepts and definitions.

1.1. Basic Geologic Processes: Planet Earth; Earth materials (minerals, magmatic, metamorphic and sedimentary rocks); rock cycle.

1.2. Earth structure, internal heat, Plate tectonics, Plate movements & continental drift, Magmatism, volcanism & earthquakes, Modification of rocks by folding and fracturing; Orogens and Cratons.

1.3. Geologic Time (Deep Time): Time scale; life evolution and fossil evidences; Earth through time (the lost worlds); how to measure the age of rocks; how to reconstruct past environments;

1.4. Geologic techniques; laboratory and field equipment and safety, recording paleontological information, recording features of different types of rocks, geological maps and diagrams.

MODULE 2: Origin and geological evolution of Europe.

2.1. Overview of the Geological and Tectonic Structure of Europe.

2.2. Europe through time.

MODULE 3: Europe geomorphology.

3.1. Introducing landforms and landscapes.

3.2. Shaping the Earth surface - processes and forms.

3.3. Ice Age in Europe and related landforms.

MODULE 4: Other European geological elements.

CASE STUDIES:

MODULE 1: Basic concepts and definitions

Geology was born as the science that studies Earth, its formation, composition and evolution as a system. The science developed during the last three centuries and its name is coming from ancient Greek words Gē (Earth) and λογία (study of). When we talk about the study of extra-terrestrial bodies the science the science is called planetary geology or astrogeology or exogeology. Earth is a unique planet in the Solar System, part of the Milky Way Galaxy which is one of the billiards of the galaxies of the known universe.

- *1.1. Basic Geologic Processes: Planet Earth; Earth materials (minerals, magmatic, metamorphic and sedimentary rocks); rock cycle.*

Planet Earth

What is making our planet unique? If we look around us and identify the major physical components and geological processes and compare our planet with the other planets in the Solar System there are some key elements we can identify:

- It`s a rocky planet made of rocks and metals like Mercury, Venus and Mars, all of them the closest planets to the Sun and much smaller and rotating more slowly than the gas planets like Jupiter, Saturn, Uranus and Neptune (figure 1.1).
- Has water in a liquid form for a very long time enabling life evolution, climate balance, watering and erosion processes under the control of external and internal energy;
- The existence of a system of plate tectonics moving continuously controlled by the internal heat transfer and enabling the carbon-silicate cycle regulating temperature;

- Right distance from the Sun and the moon’s stabilizing effect on our planetary rotation, which prevents the poles from shifting unexpectedly and preserving life from extinction;
- It`s the only known planet fostering life, including us.

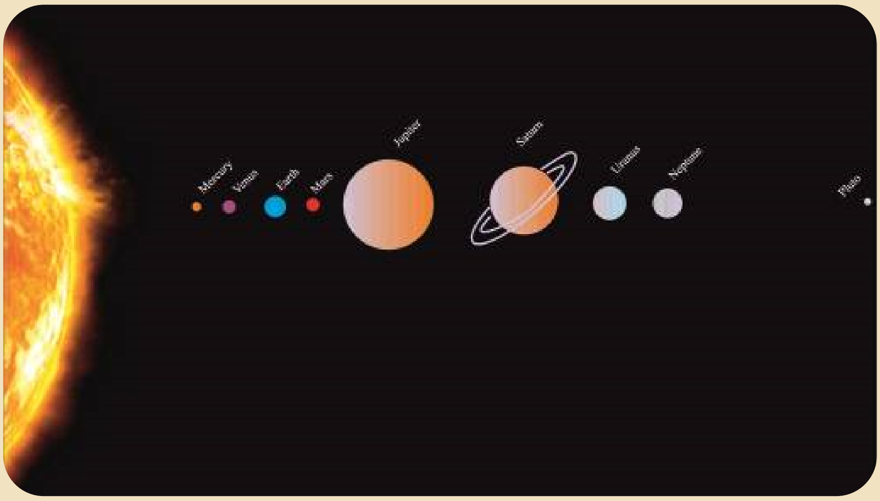

Fig. 1.1. The Solar System

The Earth is a very active planet, subject of continuous changes controlled by the so called geological processes. Earthquakes, volcanic eruptions, mountain building and erosion, sediment transport and deposition, rock formation and destruction, plate motion, continental drift, live evolution are ones of the most important. The driving forces behind all these are the internal heat and the Sun heat combined withelectromagnetism, gravitation, physical and chemical interactions at atomic level and cosmic influences. Taking into consideration all these we arrive to one logic principle in geology the principle of ACTUALISM allowing us to understand the geologic past and Earth evolution. In other words, if we understand how Earth is working today we have a solid reference base to understand the geologic past. The same forces acting today have been acting during the 4.54 billion years of Earth evolution, with variation in intensity and impact. The Earth is working as a whole and unique system but in our understanding,we can classify geological processes as internal and external based on the main sources of energy acting inside and outside.

Internal geological processes are mainly driven by the heat stored in the Earth`s interior as residual heat from the moment of Earth formation and as radioactive heat generated by radioactive decay. The main internal geological process is the movement of the lithospheric plates generating earthquakes, volcanic eruptions the movement of the continents, the opening of new seas and the closing of old ones, and the formation of mountain ranges where rocks are folded and overthrusted (figure 1.2).

External geological processes are powered mainly by solar incoming radiation and subsequently by other cosmic influences and affect the Earth's surface shaping the relief and influencing life evolution. They include all the changes that generate, alter or wear down the rocks and deposit materials resulting from erosion and from biological activities (figure 1.3.). Although processes such as volcanic eruptions and earthquakes affect the Earth's surface, they clearly originate in the Earth's interior.

Fig. 1.2 - Folded structure in sedimentary rocks, Psiloritis Mountains, UGGp (Greece)

Fig. 1.3 – Weathering and erosion in Roussillon ochre quarry, Luberon UGGp (France)

Earth materials

In all Earth processes there are two fundamental components acting together: energy and matter. Different types and forms of energy were already presented. Matter is defined as anything that occupies space and has mass. All matter in the natural world from minerals, rocks, atmosphere, living organisms, and our bodies is composed of one or more of the 92 fundamental chemical elements from the 118 chemical elements ordered in the Periodic table. The other ones are instable in nature and cannot interact to form stable materials. An element is a pure substance that is distinguished from all other matter by the fact that it cannot be created or broken down by ordinary chemical means. These elements were forged in cosmic process and recycled in new stars and planets including Earth. We can say we are stars dust. The most abundant elements on Earth`s crust are: oxygen, silicon, aluminium, iron, calcium, sodium, magnesium, potassium and titanium. The other 83 are representing less than 1 percent.

Minerals

Minerals are solid chemical compounds occurring naturally in pure form. Minerals are made of one or more chemical elements and are represented by a specific chemical formula. For example the rock salt is made of a mineral called halite a form of sodium chloride with a chemical formula Na Cl. Quartz, the second most abundant in Earth`s crust, is a hard, crystalline mineral composed of silicon and oxygen atoms with the formula SIO2. The minerals have ordered atomic arrangements forming a crystalline structure which in combination with the chemical compound generates specific macroscopic physical properties for each mineral type such as crystal form, hardness, luster and diaphaneity, color and streak, specific gravity, etc. We can use these properties to identify specific minerals. For example, Mohs hardness scale is a chart that measures how resistant a mineral is to being scratched when exposed to general wear and tear. The scale has values from one (Talc – a mineral) to ten (Diamond). A higher number on the scale, indicates a harder the mineral.

Minerals form in very different geologic conditions like oxidation, crystallization from magma or volcanic gases, precipitation from fluids. Based on the chemical composition and crystalline structure few thousands minerals have been identified, new minerals being added every year and some declassified. The dominant elements in Earth crust are silicon and oxygen they forming silicate elements the most important class of minerals in terms of abundance and rock composition. The main component is the tetrahedron of SiO. The non-silicate minerals are economical important especially as ore deposits.

Rocks

Rocks are all around us, forming the solid Earth `s crust. Any rock is formed by one or several minerals, or by fragments of other rocks organized together in what we call rock `s mineralogy and structure. There are thousands of rock types, each of them formed in specific geological conditions. The most practical way to classify the rocks is by their genesis (figure 1.4). Based on the way rocks are formed geologists identified three main groups: igneous rocks, metamorphic rocks and sedimentary rocks.

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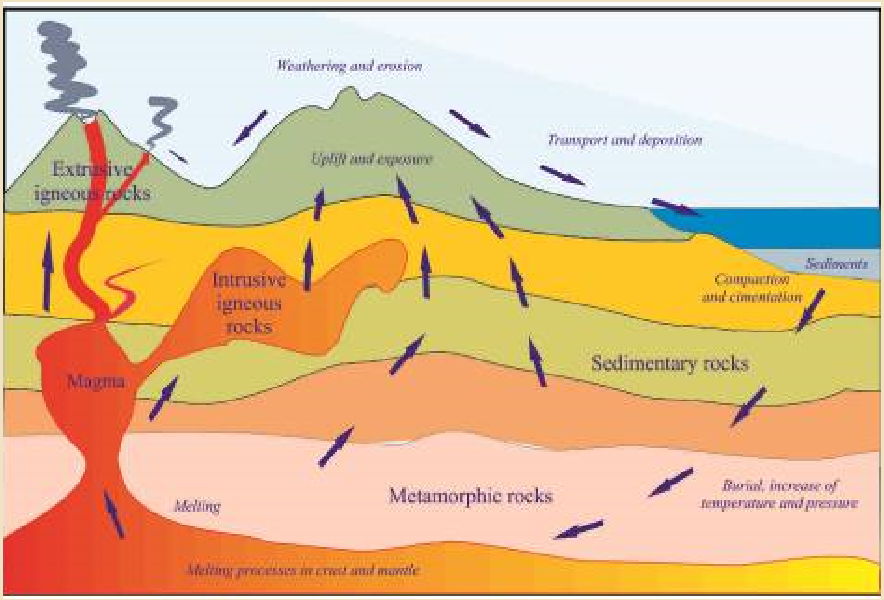

Fig 1.4 - Different types of rocks: magmatic, metamorphic and sedimentary. The rock cycle (Redrawn from http://www.geologyin.com/2016/

Igneous rocks (from Latin ignis – fire) are formed by crystallization (solidification) from molten magma deep inside the crust or from lava that erupt at the surface. On the basis of the size of their crystals two categories could be identified. Intrusive igneous rocks such as gabbro, diorite, and granite are formed deep inside the crust by slowly crystallizing magma allowing formation of large interlocking crystals of specific minerals. Extrusive igneous rocks such as basalt, andesite, and rhyolite form from rapidly cooled magmas (lavas) that erupt at the surface. Common minerals in igneous rocks are quartz, feldspar, mica, pyroxene, olivine, and amphibole. The amount of different minerals are controlled by the magma type and the place of formation.

Sedimentary rocks are formed on Earth's surface as layers from clastic, chemical and biochemical sediments under the control of weathering, erosion, organisms' activity and gravitational sedimentation. Continuous accumulation of additional layers of sediments led to burial, compaction and cementation converting sediments into sedimentary rocks. The process is called lithification when loose particles such us sand grains, silt, shells of organism, precipitated minerals are packed together, in specific structures, to form a solid rock. Sedimentary rocks are characterized by bedding, parallel layers of sediments due to the settling of particles to the bottom of the sea, lake, river or land surface. Common minerals of sedimentary rocks are quartz, clay minerals, feldspar, calcite, gypsum, and halite. Common sedimentary rocks are: conglomerates, sandstone, loess, mudstone, limestone, salt, gypsum, chert, coal.

Metamorphic rocks (from Greek words meta (change) and morphe (change). The rocks are formed when pressure and temperature deep in the Earth`s crust are high enough to change the type of minerals and the way they are organized, without melting. The metamorphism processes start at temperatures greater than 150 to 200 °C and pressures of 1500 atmosphere causing profound physical and/or chemical change. The original rock affected by metamorphism is called protolith and could be any type of magmatic, sedimentary or metamorphic rock. The process is controlled by tectonic processes like plate tectonics collision, intrusion of magma that heats the rocks, and by burial of sediments due to massive accumulation down to earth crust were temperatures and pressure are continuous increasing due to Earth thermal gradient and lithospheric pressure. In the field we can identify two types of metamorphic rocks: foliated and non-foliated. The foliated metamorphic rocks show layering or parallel alignment of mineral grains due to greater action of pressure than temperature. Examples are: slate when rock breaks along parallel planes, phyllite with shiny appearance, and schist with large crystals aligned in sub parallel planes, gneiss with alternating light and dark coarse mineral bands. Non-foliated metamorphic rocks are formed when temperature is higher and pressure quite low. Examples are: quartzite (metamorphosed sandstone) and marble (metamorphosed limestone).

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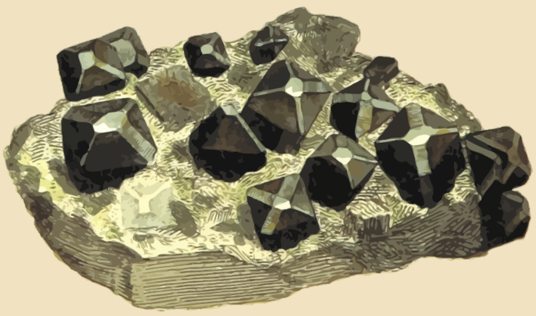
Rock cycle

The Earth is a very active planet and internal and external processes are producing continuous transformations. Due to internal thermodynamic molted materials evolve into magmatic and volcanic rocks. Magmatic and metamorphic rocks are continuously formed inside the crust and pushed to surface by plate movement and exhumation. Weathering and erosion are affecting all types of exposed rocks generating sediments and sedimentary rocks. Interactions between atmosphere, hydrosphere, lithosphere and biosphere are controlled by Sun`s energy. When rocks are pushed deep under the Earth's surface, they are transformed into metamorphic rocks or may melt into magma, producing magmatic rocks. As we can see through geologic time there is a continuous transition among the three types of rocks called the rock cycle, a key concept in geosciences (see figure 1.4).



- *1.2. Earth structure, internal heat, Plate tectonics, Plate movements & continental drift, Magmatism, volcanism & earthquakes, Modification of rocks by folding and fracturing; Orogens and Cratons.*

Earth structure

Earth is a rocky planet made of different chemical compounds organized in concentric spherical layers: a gaseous atmosphere, a liquid hydrosphere, a silicate solid lithosphere (made of crust and part of the upper mantle), a viscous asthenosphere, the rest of the mantle made of silicates, a liquid outer core and a solid inner core made mainly of iron. This model is based on different types of observations. Direct observations allow us to study the atmosphere, hydrosphere and several kilometres of the crust. Also, direct observations could be done on meteorites and other cosmic bodies. Indirect observations are based on analysis of seismic wave's propagation, electromagnetic field, heat flow, gravimetric field. Measuring the velocity of P (primary) and S (secondary) seismic waves generated by earthquakes or explosions geologists have come up with a model as can be seen in figure 1.5.

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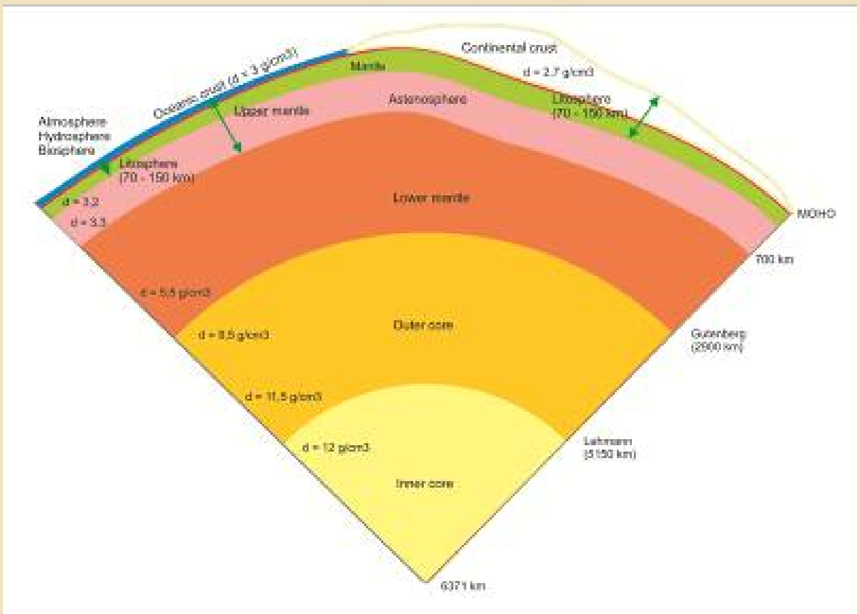

Fig. 1.5 - The Earth structure based on chemical composition and mechanical properties. Earth s internal layers are separated by discontinuities

The structure of Earth can be defined based on mechanical properties of different layers or by chemical composition (types of chemical elements, minerals and rocks). Based on composition the Earth can be divided into **CRUST, MANTLE, OUTER CORE and INNER CORE**. Based on mechanical properties the Earth is divided in **LITOSPHERE, ASTENOSPHERE, MESOSPHERE, OUTER CORE,** and **INNER CORE.** The Earth`s CRUST can be divided into continental crust and oceanic crust. Continental crustis 30 – 70 km thick, is made of less dense granite type rocks (2.5 – 2.7 g/cm3). The oldest rocks are about 4 000 billion of years old. Oceanic crust is 5 – 10 km thick, it is made of denser rocks (2.7 – 3 g/cm3), such as basalt, diabase, gabbro and the oldest rocks are about 200 million years. The differences in age, composition and thickness indicate that the two types are generated in two completely different ways and have different geologic evolution (figure 1.6).

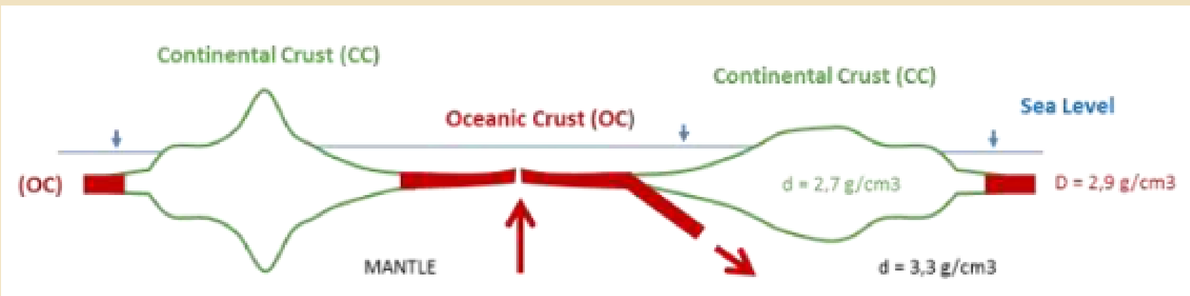

Fig. 1.6 - Types of crust and relationship with continents and oceans

The **MANTLE** is about 2900 km thick, made of silicate rocks and has different properties on the upper part compared to the lower part. It is made of silicate minerals in different physical states due to increasing pressure and temperature (peridotite, ringwoodite, perovskite) Density is ranging from 3.3 g/cm3 in the upper part to about 5.5 g/cm3 in the lower part. It is predominantly solid but in geologic time behaves like a viscous fluid. The difference in composition between crust and mantle is marked by Mohorovicic (MOHO) discontinuity.

The **OUTER CORE** is made of iron and nickel, is about 2.260 km thick and has a liquid state as was deduced from the drop in velocity of the P seismic waves and the lack of S seismic waves. The density ranges from 9 to 11.5 g/cm3 and temperature from 4000ºC to 5000ºC. The limit between mantle and outer core is marked by Gutenberg discontinuity. Convections of liquids in outer core and dynamo effect between outer core and inner core is generating the Earth electromagnetic field, a field acting like a shield against cosmic radiation protecting atmosphere, water and life. Without the outer core, life on Earth would be very different.

The **INNER CORE** is solid and is believed to be composed of iron and nickel, its density is about 12 g/cm3, its temperature is estimated at 5500 ºC and its the pressure of 360 GP (giga Pascals) or about 3.6 million of atmospheres. The limit between outer core and inner core is marked by the Lehmann discontinuity.

The **LITHOSPHERE** is the most external rigid part of the Earth and is made from crust and the upper part of the upper mantle. The two types of crust make the lithosphere to be continental and oceanic lithosphere. The lithosphere thickness varies between 50 – 150 kilometres, depending on the type of crust. The lithosphere is not continuous, being divided in 7 major lithospheric plates which are made by smaller ones.

The **ASTENOSPHERE** is part of the upper mantle, bellow lithosphere and is in viscous state (plastic rheological characteristics) playing a key role in plate movements. The limit between lithosphere and asthenosphere is an isotherm (point of equal temperature) at the 1300 °C where few percent of the material starts to melt and give the viscous state of the whole asthenosphere. Due to its plastic behaviour the asthenosphere plays a key role in plate tectonics assuring isostatic equilibrium and allowing plates to move. The lower part is considered at 660 (700) kilometres, based on the seismic waves.

Internal heat

The existence of volcanoes, hot springs, high temperatures in deep mine of boreholes indicate the Earth`s interior becomes hotter and hotter with the depth. This correlation between depth and temperature is called natural thermal gradient and has mean value of 1 ºC per 33 meters or 30 ºC for every kilometre. The main sources of internal heat are the residual heat from the moment of formation when the entire Earth was completed molten and started to cool down from outside, as well as disintegration of radioactive elements like uranium, thorium, and potassium.

These two main sources are quite equal and the heat flows from inside to outside, from the hot interior, with temperature up to 5500 ºC to the surface where the temperature is 14 ºC on average. The Earth cools in two main ways: by conduction (more slowly) and by convection. The flow of heat from Earth's interior to thesurface is estimated to 47 TW, which is very small percent of Earth`s total energy budget at the surface dominated by 173.000 TW of incoming radiation. Taking into consideration the energy budget we can consider that internal dynamic of plate tectonics, volcanoes, earthquakes are driven by internal heat and external processes like weathering, climate, wind and water erosion are driven by incoming Sun energy. Gravity plays an important role both for internal and external processes.

Plate movements & continental drift.

The lithosphere is divided in 7 major lithospheric plates which are made by smaller ones. The lithospheric plates, or tectonic plates are moving continuously over the plastic asthenosphere driven by heat transfer of the convection currents, gravity and other subsequent forces. Continents are part of some of the moving plates (plates with continental crust) and travel passively (figure 1.7).

Fig. 1.7 - Major plate tectonics and type of boundaries. (https://opengeology.org/textbook/wp-content/uploads/2016/07/Tectonic_plates_boundaries_detailed-en.svg_.png

Each plate is moving as a distinctive rigid block at a rate of few centimeters per year over the asthenosphere which is also in motion. Most of the large scale geologic features occur at plate boundaries, where plates interact. There are three types of boundaries: divergent, convergent es (parallel movement) (figure 1.8).

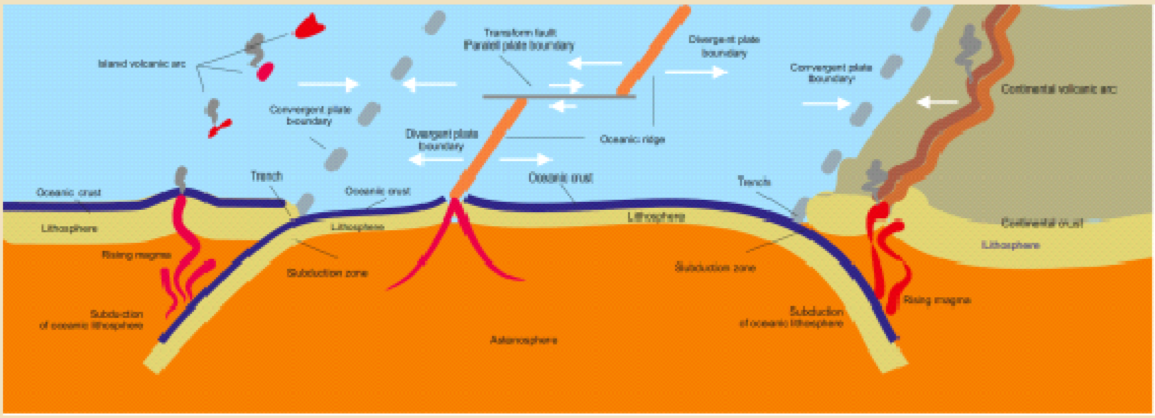

Fig. 1.8 - Lithospheric plates boundaries

- **Divergent boundaries –** plates move in opposite direction allowing magma to come from the mantle and to form new lithosphere of oceanic crust. These margins are only between oceanic lithosphere and are marked by rifts (crack like valleys) and a mid-ocean ridges. As plate move apart the rising magma solidifies forming by accretion new oceanic crust made of basaltic rocks. The sea-floor spreads and the ocean basin enlarges. This is the mechanism for creation of new oceanic crust.
- **Convergent boundaries** - totally different geologic processes are involved when two plates collide heads on along convergent boundaries. If both plates have oceanic lithosphere, one of them (the heaviest one /the older one) will sink beneath the other one in a process called subduction (figure 11). The sinking area produce a deep elongated depression on the ocean floor of about 10 km below sea level, called trench. If one of the plates has oceanic lithosphere and the other one continental lithosphere, only the oceanic lithosphere sinks, the edge of the continental overriding plate is crumpled and uplifted to form an orogen (a mountain chain) parallel to the divergent margin. The subduction process generate enormous forces partly released in strong earthquakes. During subduction part of the descending plate moltens forming magma. Due to its lower density magma floats upward and most part crystalizes generating large magmatic rock bodies and a small part reaches the surface and generates volcanic eruptions on the overriding plate. When oceanic lithosphere is completely consumed and two continental plates collide heads-on none of them is subducted due to their equal buoyancy on the asthenosphere. The process is called continent – continent collision and generates enormous forces able to squeeze and deform the rocks and sediments between the two plates and create a mountain chain (orogen) and to merge the two plates in a single one. The subduction is the mechanism by which oceanic lithosphere is destroyed and continental lithosphere (crust) is generated. This explains the big difference in age of the two types of crust, oceanic and continental. Oceanic crust is continuously generated in divergent areas and consumed in convergent ones. The continental crust is generated, folded and overlapped in big piles, uplifted but preserved for a much longer time.

- **Parallel boundaries–** ome plates just slip past each other horizontally along what is called a transform fault. The process is not smooth and earthquakes and deformation of rocks occur.

Continental drift

If we compare the coastline of South America with that of Africa both fit quite well. Indeed the two were part of a supercontinent called Pangaea 250 million years ago. Plate movement mechanisms can explain what happened with the continents and evidence for plate movements are now extensive and complementary. These evidences are based on paleontological, tectonic, and lithological and paleomagnetic studies. Extending the research to all continents geologists found evidences for continuous movement of the continental blocks at least from Proterozoic time, when tectonic plates originated. Continental blocks are colliding, splitting, moving from south to north, from east to west and from time to time grouping together in so called supercontinents.

Magmatism, volcanism and earthquakes

Magmatism, volcanism and earthquakes are strongly related to lithospheric plate movements. Magmatism is the process of production, evolution and crystallization of magma. Two types of plate boundary are associated with magma formation: divergent boundaries and convergent boundaries. In the mid-oceanic ridges heat from the convection currents creates condition for melting and basaltic magma is flowing intermittently from the rift. The magma in the subduction zone is generated by the input of sediments and water deep in the mantle which reduce the melting point generating large intrusive bodies into the crust and volcanic eruptions at the surface.

There are volcanoes and intrusive bodies not connected to the divergent neither the convergent margins. We call them hot-spots volcanoes and represent the upper part of a plume (pillars), Magma forms deep inside the Earth and rises up due to its lower density comparing to surrounding rocks. Most part of the magma body crystallizes in the crust and a very small amount will reach the surface as lava and produce volcanic eruptions (figure 1.9).

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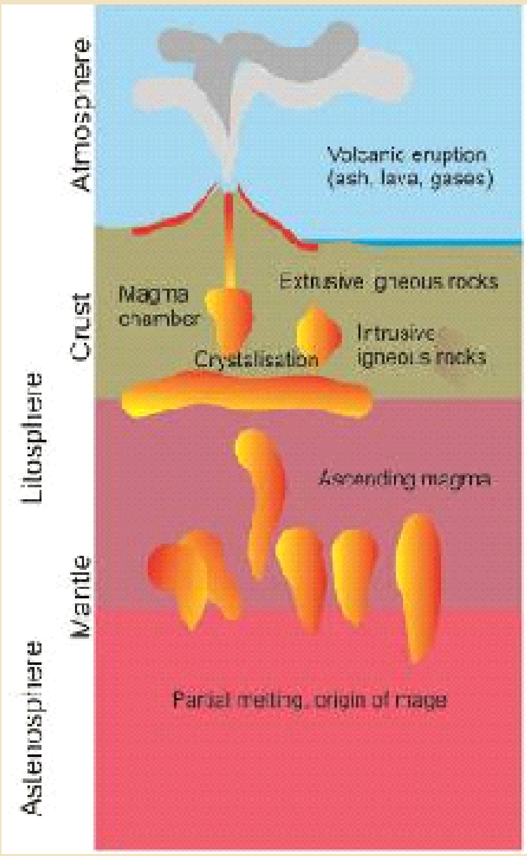

Fig. 1.9. Magma formation and evolution

Earthquakes are natural phenomena connected mainly to the plate tectonic movements. arthquakes are rapid movements of the Earth`s surface due to a rapid release of a huge quantity of energy accumulated during plate movements, volcanic eruptions, landslides or cosmic impact. Energy could come also from human sources (explosions) or could be induced during seismic measurements. According to the energy released or the impact or damages, there are different scales to measure earthquakes. The bigger the number on the scale (Richter or Mercalli) the bigger the impact. Earthquakes are produced continuously and like volcanoes are natural hazards being a permanent risk for human communities.

Modification of rocks by folding and fracturing

We know sedimentary rocks were originally deposited in horizontal layers. Plate movements generate enormous tectonic compression, extension and shearing forces able to transform and deform rocks and create folds and faults (figure 1.10). Folds constitute the twists and bends in rocks. Faults are planes of detachment resulting when rocks on either side of the displacement slip past one another. The process of deformation affects also magmatic and metamorphic rocks generating their typical deformation or transformation.

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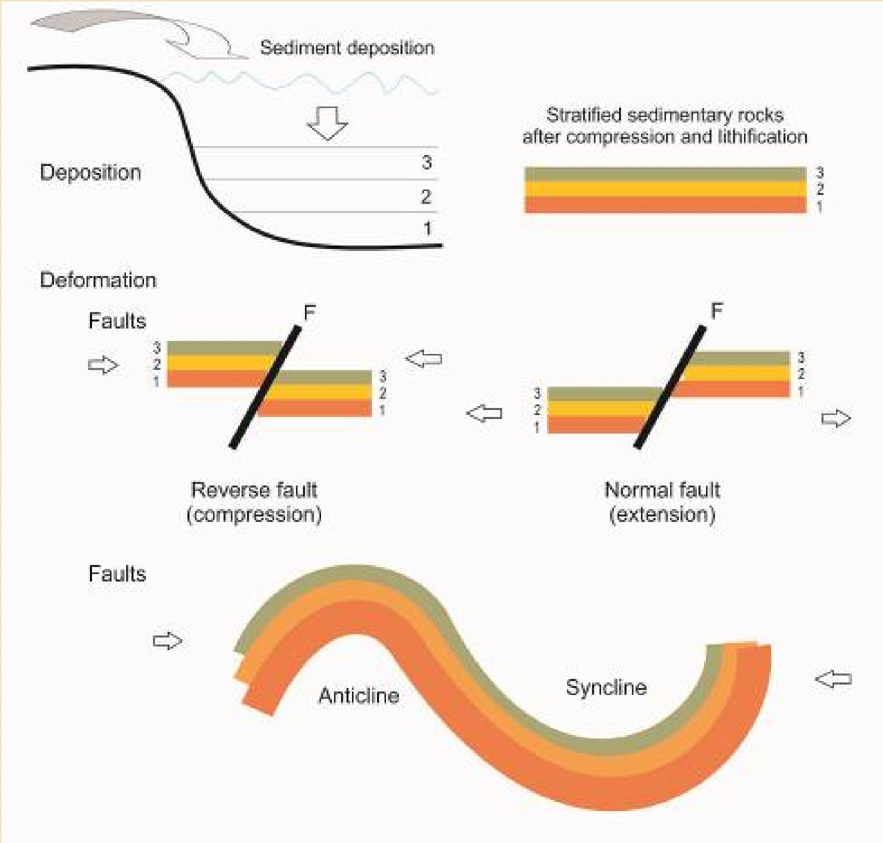

Fig. 1.10 – Deformation of sedimentary rocks by faults and folds

Orogens and Cratons

When we speak about present continents we have to consider their long geologic evolution and specific structure. Every continent, including Europe, as part of Eurasian plate, has two major structural components: orogens (orogenic belts) and cratons. See module 2 for more details.

Cratons are areas of old continental crust (Precambrian), with no major tectonic activity during Phanerozoic. Cratons represent the first continental blocks, remaining roots of old mountains. They are composed of old crystalline basement rock, which may be covered by younger sedimentary rock. We call shields area where crystalline basement could be seen and platforms, areas where the basement is overlaid by almost horizontal Phanerozoic sedimentary rock and sediments. The European craton is made of the Baltic Shield and The East European Platform.

Orogens represent active areas with Phanerozoic deformed continental crust. An orogen has small fragments of Precambrian crust incorporated called terrane. An orogen is a major elongated and geologic structure forming orogenic belts or mountain ranges, from the morphological point of view. Orogens were formed by accretion or by collision and comprise all the compressed and deformed rocks bodies during the process. Accretionary orogens are formed during the subduction of an oceanic plate beneath a continental one (Andin type). Collisional orogens were produced by collision between two continental blocks (Alpine type). In both cases all types of rocks are strongly deformed and affected by volcanism, metamorphism and uplift of the whole area with thousands of meters. There are three main orogenic cycles Caledonian, Hercynian (Variscan) and Alpine (see module 2).

- *1.3. Geologic Time (Deep Time): Time scale; life evolution and fossil evidences; Earth through time (the lost worlds); how to measure the age of rocks; how to reconstruct past environments;*

Geologic Time or Deep Time is one of the key concepts of geosciences. In order to understand different geologic processes like: mountain formation (orogenesis), plate tectonic movements and opening or closing of ocean basins, formation and breaking of supercontinents, evolution of life and terrestrial habitats, large scale climate changes, sea level rise and down we need to understand and think in geologic time. All the processes mentioned before take million or tens or hundreds of millions of years to take place. Based on geological studies and scientific techniques we consider the Earth was formed 4.54 / 4.6 billions of years ago. Since then, it suffered continuous transformations. What we see today around us is the result of these transformations. Transformations will continue and Earth will look totally different in future.

The Geologic Time Scale (GTS)

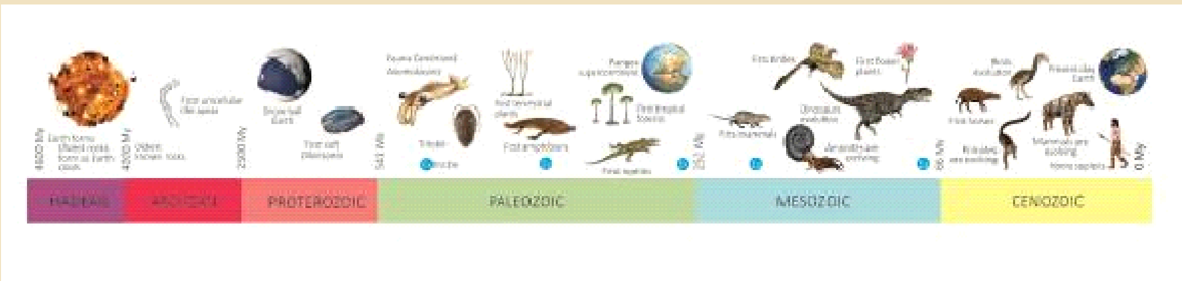

Fig. 1.11 - Simplified Geologic Time Scale and the emergence of life

One important objective of geology is to place different past events in their proper order and to answer to questions like: when a mountain was formed? When dinosaurs disappeared? Did the first humans live in the same time with dinosaurs? The answer to all these questions is written in rocks and their fossil content. Geologists as time detectives are trying to reconstruct the context and chronology of facts. Large scale observations, studies on rocks and their fossil content, experiments and other types of measurements allowed geologists to split the Earth Time in smaller intervals called, in order, from large ones to smaller: eons, eras, periods, epochs and ages. The Geological Time Scale is a system that relates rocks and fossils to time, each interval being characterized by specific fossils, rocks and events. A simplified GTS is presented in figure 1.11 and the official International Chronostratigraphic Chart, updated every year by International Commission on Stratigraphy (https://stratigraphy.org/chart), could be found in Annex I.

How to measure the age of rocks

We can consider relative age and chronometric age of rocks. The first one places rocks relatively in terms of older, younger or coeval. The chronometric dating uses radioactive decay as a method to measure the \`absolute\` age of a rock and expresses it in thousands, millions, or billions of years. Relative dating uses the fossil content and the principle of superposition, lateral continuity, correlation, intersection or inclusion.

Life evolution and fossil evidences

Fossils can be shells, bones, teeth, and impressions of plants or animals, or other kingdoms, traces. Fossils are the remains of ancient organisms. Some are similar with modern organisms but others are very different and even have no modern correspondents. Fossils have different sizes, from meters to microns, they can have a very simple architecture (one cell) or can be very complex (multicellular organisms). At first, 3.5 – 4 billion ago when life began all living things were simple, single-celled organisms. Billion years later multicellular organisms evolved and since then Earth\`s biodiversity increased and new types of organisms appeared and disappeared. The similarities of all known present day species suggest that they have a common ancestor from which they evolved. The diversity of life we can see today is the result of evolution. Is it estimated that all living things we know represent less than one percent of all species that ever lived. In figures 18 and 19 characteristic organisms for different past time intervals are presented. In Precambrian Eon life record started with simple single cells organisms (3,7 billion years ago), first algae able to produce photosynthesis and release oxygen (3,5 billion years ago), first multicellular organisms (600 million years ago). Phanerozoic Eon begins with a sudden development of large diversity of organisms (Cambrian explosion), trilobites, fishes, cephalopods, first tetrapod and plants are characteristic of Paleozoic Era. The end of Paleozoic Era is marked by a great mass extinction when almost 95 % of all species disappeared. Mesozoic Era is characterized by the presence of dinosaurs, ammonites, first mammals, first birds, first flowers and subsequent development of insects. The limit between the Mesozoic and Cenozoic Era is marked also by a great mass extinction when 75% percent of all species became extinct including dinosaurs and ammonites. Cenozoic era is characterized by the continuous development of mammals, plants, insects and the apparition of human species. As we can see in figure 1.11 each time interval is characterized by specific groups of organisms.

Earth through time (the lost worlds)

The past worlds are completely different from the world we know today and very different of future worlds, with different biodiversity and ecosystems. Reconstructing the lost worlds is a detective work. We need to collect evidences of the past mainly from fossils and rocks. Fossils give us information about how animals and plants lived in the past. Fossils are only traces of the once living organisms and we can easily recognize and identify some fossils if they are ancestors of today's plants and animals. But many fossils represent animals that no longer exist and we have to make educated guesses about extinct groups like dinosaurs, ammonites and trilobites.

Extinct organisms reconstructions are based on the comparison with similar groups, studies of anatomical remains, lithological, sedimentological and chemical analysis, as well as scientist and artists skills. Most palaeo-interpretations are a mixture of scientific and artistic views. A good example is the interpretation of a dinosaur species , Balaur bondoc, from Hateg Country UGGp, where the skull is missing. The lack of teeth information makes imposible to determine whether Balaur was a carnivore or herbivore. In this case, the final interpretation depends on the paleo-artists criterium. An opposite example is the dinosaur Borealopelta, a case of exceptional conservation, found in bituminous sands in Canada. The best preserved dinosaur, ever, does not leave much space for interpretation, since even the original colour has remained (figures 1.12 and 1.13).

Fig. 1.12 - Artistic view (Mihai Dumbrava)

Fig. 1.13 - Artistic view (Brian Cooley si Mary Ann Wilson)

- *1.4. Geologic techniques; laboratory and field equipment and safety, recording paleontological information, recording features of different types of rocks, geological maps and diagrams.*

Field application aims to apply in the real world theoretical data and to observe and collect data from rocks fossils, to measure different parameters and collection of samples for laboratory studies.

A basic toolkit for observations and field techniques comprises: a geological hammer for collection of samples or to create fresh surfaces to better see and describe the minerals or rock characteristics; hand lens is an essential piece of equipment for the detailed observation of all rock types and fossil material; a compass - clinometer is used to measure: (1) the orientation of geological planes and lineation with respect to north; and (2) the angle of dip of geological features with respect to the horizontal plans; comparison charts to provide semi - quantitative description of grain size and rock classification diagrams; a geological map of the area to provide information about the types of the rock, their geometrical position, age, other characteristics; cross sections and stratigraphic charts are very useful; a notebook, GPS, chlorhydric acid to test the presence of calcium calcite (limestones)

For guiding tours or educational field applications apart of the above mentioned tools a toolkit with molds of local fossils, or typical fossils, rock samples, diagrams, a stratigraphic chart are very helpful. Field work or visits involve physical exertation and involves being outside in different weather conditions. For these reasons it is important to select comfortable clothing, appropriate boots, and to be prepared for a range of conditions.

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MODULE 2: Origin and geological evolution of Europe

2.1. Overview of the Geological and Tectonic Structure of Europe.

After almost two hundred years of field studies, laboratory analysis and multidisciplinary research, we are now able to offer a quite accurate picture of the basic fabric and evolution of different continents.

The European continent is part of the Eurasian Plate and extends from the ancient Precambrian Fennosarmatian (Baltica) Shield in the north-east to the complex Mediterranean region in the south and from European submarine continental margin in the west to the Ural Mountains in the east. The geological history of Europe began about 3,500 million years ago and contain records of its continental growth from north-east towards the southwest, from Achaean and Late Proterozoic nuclei (Fennosarmatian or East European Shield and Laurentian Shield) with gradual accretions of different crustal blocks (microcontinents) in western, central and southern margins of the Europe, from Palaeozoic to Recent (Neubauer, 2003; Plant et al., 2005). In fact, the Precambrian basement (mainly of Late Proterozoic age) in western, central and southern Europe is subordinated and the rest of the crust is formed by progressive accretion of younger orogenic belts: Cadomian (ca. 670 – 520 My), Caledonian (ca. 500 – 400 My), Variscan (380-300 My), Cimmerian (ca. 210-180 My) and Alpine (120-0 My).

The heterogeneous crust of western, central and southern Europe was affected by rifting and the opening of the Tethyan and Atlantic oceans, generating sedimentary basins postdating each of these orogens. Such sedimentary basins were formed for example in North and South Germany, Paris Basin, Aquitan and North Sea basins, Panonian and Dacian Basin. Apart the north-western part of Europe (northwestern Scotland and the Hebride) that represents small remnants of Laurentia (North American) continent, the European continent is built of two major areas:

- The East European Craton (or Fennosarmatia or Baltica Shield) in north-eastern and Eastern Europe composed of Archean/Lower Proterozoic basement and a Upper Proterozoic to Tertiary sedimentary cover, and
- Western, central and southern Europe represented by a complex mosaic of crustal elements, assembled during different Precambrian orogenic cycles followed by the Caledonian, Hercynian and Alpine orogenic cycles. Therefore the western, central and southern Europe reveals a complex pre-Late Carboniferous basement covered by Permian to Neogene sedimentary cover.

The connection between these two areas is produced along a broad zone of NW-SE-striking faults named Trans-European Suture Zone (TESZ) that extends for almost 2000 km from the North Sea to the Dobrogea region of the Black Sea. Generally TESZ is covered by Mesozoic and Cenozoic sediments and was identified using geophysical observations mainly. However, in Dobrogea Region (south-eastern Romania) this system of major faults can be observed at the surface. The European continent is built therefore by a number of major tectonic units that represent in fact the gradual continental growth from north-east towards the southwest since Late Archaean times until Recent. According to Neubauer (2003) and Plant et al. (2005) the major tectonic units of Europe include (figure 1.14):

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Fig. 1.14 - The major tectonic units of Europe (https://www.britannica.com/place/Europe/Geologic-history)

- ***East European craton (made of Baltic shield and East European platform*** **)** represents the old continental nucleus, mainly formed during Archaean and Early Proterozoic times. The basement of this unit is exposed in the Baltic and Ukrainic (or Podolic) shields and the rest the craton is covered by Late Proterozoic to Quaternary sedimentary cover from the North until the Caspian Sea.

- ***Remnants of Laurentia craton (or North American Craton)*** with Arhaic to Early Proterozoic age, exposed today in north-western Scotland and the Hebrides.

- ***The Caledonian belt (or Caledonides)*** (ca. 450 – 400 My) developed on northeast-southwest direction marking the collision of the late Proterozoic continents of Fennosarmatia, Laurentia and Avalonia (a fragment of Gondwana, North Africa) by the closure of the Iapetus, Tornquist and Rheic Oceans. The Caledonian belt contains mainly Early Paleozoic island arc, ophiolites (oceanic crusts) and passive continental margin sequences which collided during the Late Silurian (Caledonian) orogeny. The metamorphic rocks of the Caledonian belt are located in Irish-Scottish-Scandinavian Caledonides, and then strike southeastwards into north Germany and Poland, following the margin of the Precambrian East European Platform. The remnants of the Rheic Ocean are located in the mid-European Caledonides, in the Saxothuringian and Moldanubian terranes.

- ***The Variscan-Scithian belts (or Variscides)*** were formed during the Hercynian orogenic cycle, which took place between the Devonian and Early Permian (ca. 380-300 My). The Variscan belt extends from the Iberian Peninsula through Western and Central Europe to the TESZ (Trans-European Suture Zone) at the south-western margin of Fennosarmatia. The Schithian belt (or) represents the extension of the Variscides along the southern margin of Fennsarmatia and is mostly included in Alpine orogenic belt. - Remnants of Cimmerian orogen are preserved in North Dobrogea (in south-eastern Europe near to the Black Sea) and extend via the southern Crimea peninsula to the Caucasus, Turkey, Iran, Afghanistan, Tibet, Shan–Thai, and Malay Peninsula. Cimmeria was an ancient archipelagos of microcontinents (terranes: Iran, Central Afghanistan, Karakorum, Qiangtang) that rifted from Gondwana in Early Permian and migrated northward across the Tethys Ocean to subequatorial paleolatitudes by the Middle Permian–Early Triassic times when was accreted to Eurasia forming the Cimmerian orogen (Sengör,1979; Bera and Angiolini, 2014).

- ***The Alpine belt*** (ca.120-0 My) comprises mountain ranges extended from the Betic Cordillera on the Iberian Peninsula, Sicily, Apennines, Alps, Dinarides, Carpathians, Balkans and Hellenides and can be traced further towards the east Asia as part of the Alpine-Himalayan orogenic system. This complex orogenic system was formed through accretion of Gondwana-derived continental microplates to the older stable Europe during the Cretaceous to Cenozoic interval, but the alpine orogeny is still an ongoing process.

– ***The Mediterranean Region*** represents a complex system of continental microplates (e.g. Adriatic or Apulian microplate, the Corso-Sardinic and Balearic blocks, separated by Oligocene-Neogene back arc basins in the western Mediterranean and by

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Neotethyan, Mesozoic oceanic crust forming the Eastern Mediterranean Sea that presently is subducting beneath the Hellenic arc.

- Numerous Late Paleozoic to Cenozoic **extensional and rift basins** of variable ages developed on the Variscan basement of Europe.

- **The Moesian platform:** the position of Moesia is somewhat uncertain. It could have belonged to the Baltica or to Peri-Gondwana. The Moesia plate could have been accreted to Baltica during the early Paleozoic (Golonka et al., 2006).

- **The Black Sea** is located at the interface between the Alpine and Cimmerian orogenic belts. The western Black Sea is underlain by oceanic crust of supposed Late Cretaceous to Paleogene age. In contrast, the eastern Black Sea comprises orogenic crust which has been shortened by Cenozoic tectonic processes.

- **Late Mesozoic and Cenozoic anorogenic intraplate volcanism** is widespread in north western and western Europe. Volcanism and shallow plutons of Late Cretaceous and Early Tertiary age formed in response to initial stages of the opening of North Atlantic sectors of the Atlantic Ocean. Hot-spot related volcanism is widespread in Ireland, Scotland, the French Central Massif, the Rhenic Shield and the north western Bohemian Massif.

- A passive continental margin and slope faces towards the Atlantic Ocean and Barents Sea. The passive continental margin was formed at different times during rifting and subsequent break-up between Middle-Late Cretaceous along Iberian sectors of the Atlantic margin, and during Late Cretaceous to Paleogene in northern sectors of the Atlantic margin.

2.2. Europe through time.

Precambrian Europe

The Precambrian history of the oldest parts (rocks) of Europe is related to the history of two supercontinents: Rodinia and Pannotia. The first late Neoproterozoic supercontinent Rodinia ("the mother of all continents") formed during the Grenville Event (ca. 1100 My) and broke apart about 750 My ago, then remained intact for approximately 300 My, making it a long-lived supercontinent (Scotese, 2009). The second late Neoproterozoic supercontinent, Pannotia or Greater Gondwanaland ("all southern lands") was assembled 650–500 My ago during the Pan-African Event and had begun to break apart ca. 560 My ago with the opening of the Iapetus Ocean, therefore it was a short-lived supercontinent. Pannotia broke apart into the four principal Palaeozoic continents: Laurentia (North America), Baltica (northern Europe), Siberia and Gondwana (Scotese, 2009). Reconstruction and evolution of different continental blocks and supercontinents can be found in Christopher Scotese, Paleomap Project (http://scotese.com/).

The Precambrian rocks of the European continent are represented by:

- Fragments from **Laurentia craton** (or North American Craton) exposed in northwestern Scotland and the Hebrides, represented by Archaic to Early Proterozoic magmatic and metamorphic rocks;
- **East European Craton (or Fennosarmatia or Baltica Shield)** which comprises four main NW to SE trending orogenic belts (cf. Plant at al., 2005):
- **The Kola-Karelian Orogen:** Archaean terranes amalgamated by collision between 2.0-1.9 Gy;
- **The Svecofennian Orogen:** rocks younger than <2.2 Gy (Giga-year: 1000My), which accreted and underwent collisions between 2.0-1.8 Gy, and later were reworked by crustal melting between 1.8-1.54 Gy;
- **The Gothian Orogen:** rocks accreted between 1.77-1.5 Gy;
- **The Sveco-Norwegian Orogen:** rocks dated at 1.05-0.9 Gy that reworked most of the Gothian Orogen.
- **The Cadomian orogeny** between 650-550 My (late Precambrian) was the last in the sequence of events that formed the crystalline basement rocks of Europe. Continental crustal blocks generated during the Cadomian orogeny are recognized today within the Caledonian and Hercynian basement complexes (e.g. Irish Sea Horst, the London Platform, the Armorican and Bohemian cratons, the East Silesian block, the Malopolska Massif of SE Poland) and Alpine-Carpathian basement complexes. At the end of the Proterozoic, Europe drifted towards high southern latitudes (where the Gondwana continent was assembling) and remained in these latitudes during Cambrian times (Plant et al., 2005). The Cadomian orogeny caused the deformation and magmatic events of various terranes from Iberia through Armorica (northwest France), Erzgebirge (Saxoturingian zone in Germany), Bohemian Massif, Brunovistulicum and Malopolska massif (Czechia and southern Poland), and the Carpathians to the Transcaucasus area (Golonka et al., 2006). For more detailes and reconstruction the following site is recommended:

  http://earthwise.bgs.ac.uk/index.php/Geotectonic_setting_of_Wales.

Paleozoic Europe

Baltica (Northern Europe) originated as a result of disintegration of supercontinent Pannotia, which occurred during Early Cambrian. Baltica included part of Poland and adjacent areas located northeast of Transeuropean Suture Zone (e.g. parts of Scania, Warsaw, and margin of Eastern Carpathians to the Black Sea) (Golonka, 2015).

During Late Cambrian - earliest Devonian time interval occurred the Caledonian orogenic cycle reflecting the collision of the late Proterozoic continents of Baltica, Laurentia and Avalonia and marking the complex closures of the Iapetus Ocean. The metamorphic Irish-Scottish-Scandinavian Caledonides form a NE-SW trending belt across NW Europe (Plant et al, 2005).

The maximum dispersion of continents (in Paleozoic) was produced in early Ordovician. Between Gondwana, Baltica, Avalonia and Laurentia, a large longitudinal oceanic unit, known as the Rheic Ocean was formed. Avalonia was a continent probably drifted from Gondwana and moved towards Baltica during the early Ordovician (Golonka, 2015). The continent of Avalonia consisted of parts of New England, southern New Brunswick, parts of Nova Scotia, the Avalon Peninsula of eastern Newfoundland, south-eastern Ireland, northern France, England, Wales, the Ardennes of Belgium, parts of northern Germany, north-western and possibly southern Poland and some accreted terranes in the basement of Eastern Carpathians and their foredeep (Golonka et al., 2006). Later, by the end of Ordovician or in the Early Silurian, Avalonia was probably sutured to Baltica. Silurian was the time of Caledonian orogeny, the closure of Early Paleozoic oceans, the collision of Baltica with Avalonia and Laurentia and origin of the supercontinent Laurussia (Golonka, 2015).

The Variscan orogeny is the major Middle to Late Palaeozoic tectono-metamorphic event in central Europe, and the Bohemian Massif is the largest exposure of rocks deformed during this orogeny (figure 1.15). The Variscan orogeny represents the final collision of Gondwana with the northern continent, Laurasia, and marks the European version of the evolution of the supercontinent of Pangaea at the end of the Palaeozoic (McCann 2008). The term Variscan refers to the European part of the Hercynian orogen or fold belt, and specifically relates to the time of Carboniferous (late Visean–Westphalian) consolidation. Variscan extension in western and central Europe in early Devonian times led to the development of the Rhenohercynian Basin, filled with thick Devonian and Carboniferous sediments (Plant et al, 2005).

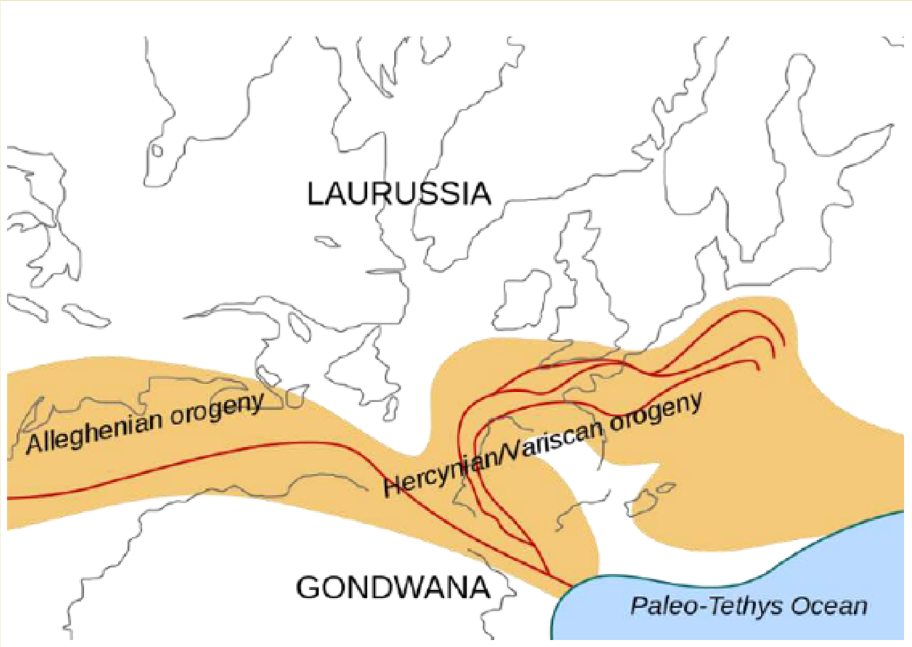


Fig. 1.15 - Location of the Hercynian/Variscan/Alleghanian mountain chains in the middle of the Carboniferous period. Present day coastlines are shown for reference. Red lines are sutures, capitalized names are the different continents that joined during these orogenies. Literature used to make this map: Matte, P.; 2001: The Variscan collage and orogeny (480±290 Ma) and the tectonic definition of the Armorica microplate: a review, Terra Nova 13, 122-128. Ziegler, P.A.; 1990: Geological Atlas of Western and Central Europe, Shell Internationale Petroleum Maatschappij BV (2nd ed.), ISBN 90-6644-125-9. https://en.wikipedia.org/wiki/Variscan_orogeny

The Variscan orogenic belt extends in western Europe for more than 3,000 km from Portugal, Ireland, and England in the west through Spain, France (Brittany, Massif Central, Vosges, and Corsica), and Germany (Black Forest, Harz) to the Czech Republic in the Bohemian Massif. This belt contains rocks and structures indicating their formation as result of seafloor spreading, subduction of oceanic crust and plate collision. The thickening of the crust led to melting of the lower crust and the formation of large numbers of late Carboniferous granites, especially in the Massif Central. The thickening of the crust determined the extensional collapse of the central part of the belt in the Massif Central and Bohemian Massif and led to the formation of coal-bearing basins (in Silesia, Poland) and the Massif Central during the Carboniferous and Permian. The largest Variscan unit in central Europe is the Bohemian Massif, representing the most prominent outcrop of pre-Permian rocks. It was formed by the amalgamation of the Armorican terranes and their final collision with Avalonia (Schulmann & Gayer 2000).

Mesozoic and Cenozoic Europe

At the beginning of the Mesozoic, during the Triassic period, almost all the continents were concentrated into a single supercontinent centred more or less on the equator and spanning from pole to pole, called Pangaea ("all the land"). About 250 My ago a new ocean began forming in the southern end of the Paleo-Tethys Ocean. From the east, along the equator, the Neo-Tethys Ocean penetrated Pangaea, causing the Paleo-Tethys Ocean to be closed. Later in the mid-Triassic a similar sea penetrated along the equator from the west. The remaining world-ocean was named Panthalassa ("all the sea").

During the Permo-Triassic times there was no crustal separation in Europe. However, the presence of basinal structures (at the end of Permian and Triassic) provided an indications of the extent of future Jurassic, Cretaceous and early Cenozoic break-up of Pangaea in the Arctic, North and Central Atlantic and Mediterranean regions and, thus initiated a new and different reorganisation of plate boundaries. Some of the important Permian basins continued to evolve into the Triassic. The Triassic rocks consist of continental to brackish marine red beds, shallow marine carbonates, sulphates and halites. During Triassic times, a rise in sea level was reflected by the Triassic sediments overstepping Permian basin margins. During Late Triassic times, a clastic-evaporite regime of the Northwest European Basin was synchronous with the repeated advance of deltaic systems from the Fennoscandian High and the EEC across the northern North Sea, Denmark and the Southern Baltic sea areas (Plant et al., 2005).

The breakup of the supercontinent of Pangaea began along the central Atlantic axis during the Jurassic period. In Europe, Late Triassic - Early Jurassic times commenced with a major transgression of the Tethys Sea and the establishment of a broad, open-marine shelf sea that occupied much of southern Germany, the Paris Basin, the Celtic Sea-Western Approaches region, the Irish Sea, the southern andcentra North Sea, Denmark and northern Germany. The opening of new oceanic basins in the Mediterranean area during the Middle and Late Jurassic produced the separation of Gondwana from Laurasia after almost 100 Ma. The middle and late Jurassic evolution of western, central and part of Eastern Europe was dominated by crustal extension across the north Atlantic rift system and adjacent areas accompanied by development of a complicate rift systems, changing of regional stress pattern and important changes to the palaeogeography.

During the Cretaceous to Tertiary, the post-Variscan stage was followed by extensional and compressional tectonics, related to plate motions between Europe and Africa, which resulted in the Alpine orogeny (Plant et al., 2005).

The Alpine orogeny is an orogenic phase in the Late Mesozoic and the Cenozoic that has formed the Alpine-Himalayan mountain ranges. These mountains include (from west to east) the Atlas, the Rif, the Betic Cordillera, the Cantabrian Mountains, the Pyrenees, the Alps, the Apennine Mountains, the Dinaric Alps, the Pindus (Hellenides), the Carpathians, the Balkanides - Balkan Mountains and Rila-Rhodope massifs, the Pontic Mountains the Taurus, the Armenian Highlands, the Caucasus, the Alborz, the Zagros, the Hindu Kush, the Pamir, the Karakoram, and the Himalayas.

The Alpine orogeny is caused by the continents Africa and India and the small Cimmerian plate colliding (from the south) with Eurasia in the north. Convergent movements between these tectonic plates had already begun in the early Cretaceous, but the major phases of mountain building began in the Palaeocene to Eocene and Miocene.

MODULE 3: Europe geomorphology

3.1. Introducing landforms and landscapes.

The Earth`s surface is very diverse and is made up of a vast number of elements shaped by internal and external natural processes. During the last millennia human activities started to influence more and more the surface natural environment. The results of all these activities have generated what we call landforms and landscapes.

A **landscape** is related to human activities and the way these activities transformed the natural forms (figure 1.16). Generally speaking a landscape is the totality of features of an area, features we can see and we can analyse taking into consideration the origin, evolution, significance, cultural and scientific values and could be considered as a component of local identity and generating a sense of place. A landscape includes physical elements such as mountains, hills, river valleys, lakes, ponds, sea shore and living elements of the land cover including indigenous plants, trees, animals, human elements and land use buildings, infrastructure. Additionally we can consider transitory elements like lightening, wheather conditions, ephemeral installations, land art, vents, etc.

A **landform** is characterized by the natural features of a landscape mentioned above and characterized by their natural origin: tectonic and structural elements, erosion, rocks, and geologic phenomena like volcanoes, gravitational slides, and depositional environments (figure 1.17).

Fig. 1.16 - Landscape in Hateg Country UGGp. Volcanic and sedimentary rocks landforms transformed by human activities

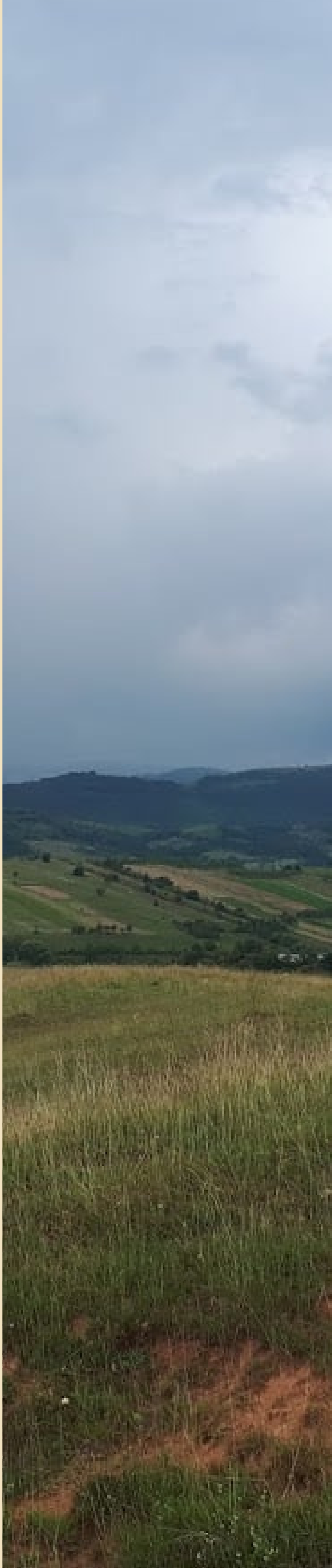


Fig. 1.17 - Landform in Hateg UGGp. Outcrop of sedimentary rocks along Sibisel Valley and Retezat Mountains in background

3.2. Shaping the Earth surface - processes and forms.

The Earth s surface is at the intersection of lithosphere, biosphere, hydrosphere and atmosphere, being continuously influenced by internal and external factors. The Earth s surface is changing continuously under the influence of two sets of processes: internal and external. External ones are leading mainly to denudation involving the processes that cause the wearing away of building material by water, ice, wind, gravitation and biological activities, leading to a reduction in elevation. Rock construction due to organic activities could be considered too an external process with positive impact of construction, with great impact in some moments of Earth`s evolution (e.g. algal or reef constructions). Internal processes include the uplift of mountains, volcanoes, isostatic rebound, subsidence and formation of sedimentary basins, crustal growth in mid ocean ridges, continental rifts and tectonic basins. The Erarth`s surface and its relief and landscape are controlled by climatic, tectonic, hydrogeological and biological processes, including human activities.

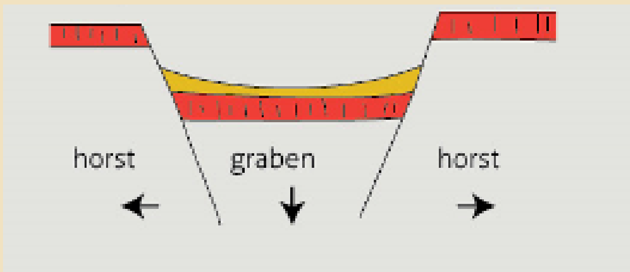
3.2.1. Geologic structures and landforms (plate tectonics, volcanoes, faults and folds, impact forms) in Europe.

Landforms are surface shapes we can measure and mapp. Surface landforms we call mountains or hills or valleys could have different geological contexts (see figures 1.18 to 1.21). For example what we call a positive landform, a mountain with an elevation of more than 1000 meters could be formed by different geological processes: plate collision and accretion (figure 1.18), large normal faults generating grabens and horsts (figure 1.18); successive volcanic eruptions (figure 1.20); long time erosion (figure 1.21). Landforms could be regarded at different scales. Large scale landforms include mountains, plains, glaciers, ocean middle ridges, volcanoes, rivers and deltas.

Small landforms include hills, ravens, lakes, valleys, impact craters. Large scale landforms are generated by plate tectonics movements and local ones by erosion or / and biochemical constructions.

Examples of large scale landforms generate by plate mechanism are (figure 1.22): continents (related mainly to continental crust), oceans (overlapping areas with oceanic crust), mountains (related to collisional zones), volcanic arks and trenches (related to subduction), mid oceanic ridges (related to divergent zones), shield volcanoes (related to hot-spots) and rift valleys (related to initiation of plate boundary in extensional zones), pull apart basin (related to continental crustal extension).

Fig. 1.18. - Mountain landform generated by plate collision and subduction



Fig, 1.19. - Mountain landform generated by extension and generation of normal faults

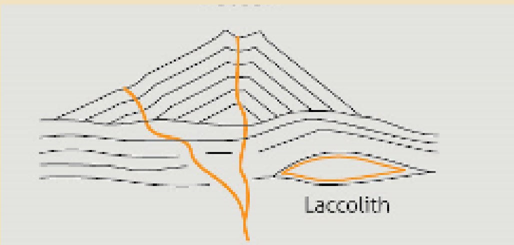


Fig. 1.20. - Mountains builded by volcanic erruption

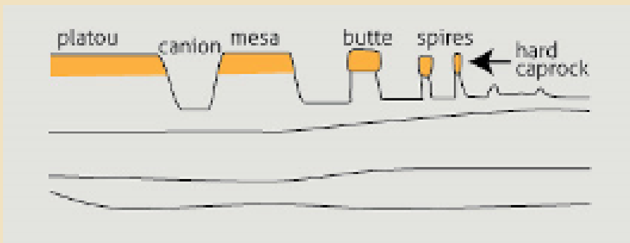


Fig. 1.21. - Mountain landform type generated by regional long term denudation

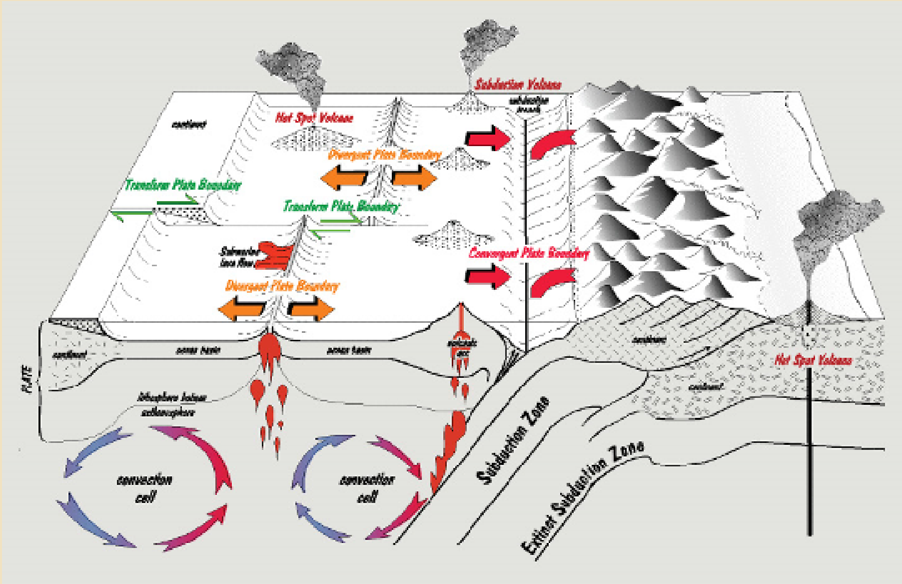


Fig. 1.22 - Relation between plate tectonics and landforms. (Redrawn from http://www.glogster.com/buddygor/plate-tectonics-project/)

Landforms related to volcanoes are correlated with the eruption of lava. Examples of landforms are: volcano, crater, lava plateau, caldera, volcanic crater lakes, maars, pyroclastic landforms, dyke, neck, volcanic islands, mud volcanoes (figure 1.23 to 1.27).

Fig. 1.23 - Volcanic lake (Azores UGGp)

Fig. 1.24 - Maar (Vulkaneifel UGGp)

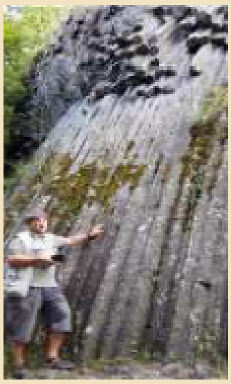


Fig 1.25 – Joint columnar basalts (Novohrad-Nograd UGGp)

Fig. 1.26 - Mud volcanoes landforms (Buzau Land Aspiring Geopark)

Fig. 1.27 - Volcanic neck (Uroi, Romania)

Landforms related to faults and folds. Folds and faults are structural elements generated by the plastic or brittle deformation of rocks. In figures 1.28 to 1.31 there are examples of folds, and faults. Other landforms are: horst, graben, rift, and cuesta.

Fig. 1.28 - Folded rocks in Fforest Fawr UGGp. (Anticline)

Fig. 1.29 - Folded rocks in Haute Provence UGGP (Syncline)

FiFig 1.30 - Monocline – Basque Coast UGGp

Fig. 1.31 - Folds generated by ice cap (Danemark)

3.2.2. Weathering: physical, chemical and biological processes.

All the rocks outcropping at the Earths surface are subject to weathering, a process that is breaking down the components due to the action of physical, chemical and biological organism, including humans, without movement of the resulting components. Erosion process involves movement of exposed rocks or rock components by external agents like: gravity, water, ice, wind, snow, waves. Resulting particles are transported in other location forming sediments (figures 1.32 and 1.33).

Fig. 1.32 - Physical and biological (human) weathering (Cappadocia, Turkey)

Fig. 1.33 - Chemical weathering (dissolution in a salt massive) Buzau Land Aspiring Geopark, Romania

3.2.3. Denudation and deposition: hill-slopes, fluvial landscape, glacial landscape, eolian landscape, coastal landscape, karst landscape.

Denudation and deposition are controlled by gravitational forces and by the agent of transportation. Denudation is the process that cause the wearing away of the Earth`s crust components by different agents: water, gravity, ice, wind. Denudation contributes to exhumation of deep magmatic and metamorphic rock bodies. The process is controlled by general uplift of one area, paleoenvironments conditions, and intensity of denudation agents. Deposition is controlled by gravity and all sedimentary particles will try to accumulate in the lowest potential energy position. Based on this very simple and fundamental observation, Nicolas Steno enounced few inductive principles with great impact on field observations and geological analysis of one area (see module 4). The principles are: the principle of superposition; Principle of initial horizontality; Principle of strata continuity; Principle of cross-cutting relationship. These principles are used to identify any type of deformation after deposition and related forces and for relative dating of rocks bodies.

Hillslopes are the flanks of a valley where rock and soils are transported down, usually to a river channel (figure 1.34).

Fluvial landscape is generated by the evolution of a river system. The evolution is a balance between tectonic uplift, erosion, climate, accumulation of sediments and human activities. Deposition is controlled by the quantity of sediments transported by the river and its tributaries, the erosion rate and river speed, and the slopes and discharge (figure 1.35).

Glacial landscape is generated by the action of ice (figures 1.36 and 1.37). There are two main forms of ice action: ice caps (polar ice caps) and glaciers (in mountain areas). Advance and discharge of ice cap generate specific landforms and discharge of large blocks of rocks (erratic boulder). Glacier action generates U shape valleys and large quantities of unsorted rock fragments (moraines).

Costal landscape is located in the transition zone between continental and oceanic domains influenced by human activities (figure 1.38). The landform is controlled by the action of wind and wave erosion and is influenced by the rock type, climate and sea level changes.

Aeolian landscape is generated by the wind action which causes erosion and deposition of large quantities of sand and dust, in arid areas (figure 1.39). Ancient aeolian deposits are recognized due to specific internal structures (cross stratification), sand grains morphology and specific colour.

Karst landforms are generated by the dissolution of existing rocks. The process is influenced by climatic conditions, tectonics and lithology. The most frequent are formed in limestone, dolomite, gypsum and salt, rocks with a higher rate of dissolution under the present climate conditions. Typical karst landforms are karst valleys, caves, sinkholes, poljes, doline, karst towers.

Fig 1.34 - Hillslopes (Aspromonte Aspiring Geopark, Italy)

Fig. 1.35 - Fluvian landscape (Haute Provence UGGp, France)

Fig 1.36 - Glacial landform (Alps, Austria)

Fig 1.37 - Ice cap erosion and erratic boulders **(GeaNorvegica UGGp, Norway)**

Fig 1.38 - Coastal landscape (Azores UGGp, Portugal)

Fig 1.39 - Aeolian landscape (Morocco)

3.3. Ice Age in Europe and related landforms.

In geologic time Earth has faced large intervals of warm and cold temperatures called greenhouse periods and ice age periods. During cold intervals large icecaps and mountain glaciers are developed. In warm intervals the ice quantity is relative small and supposes that in some intervals even the ice caps are totally molten. The last cold climatic interval started 2.58 million years ago and is known as the Quaternary Glaciation or Quaternary Ice Age. During this ice age the temperature of Earth`s surface reduced and ice caps and mountain glaciers extended.

During the Ice Age there are more severe and more temperate intervals we call glacial and interglacial periods. These periods have different names for Northern Europe and Alpine area. The last glacial period is encompassing the interval 115,000 – 11,700 years ago. The end of the last cold interval is maked by the beginning of Holocene, a geologic epoch characterized by the continuous melting of glaciers and ice caps and rapid development of human civilization.

The glacial landscape were dominated by ice caps of several kilometers thick and glaciers covering the highest mountain peaks, Global temperature was several degrees lower than today and the sea level was more than 100 meters lower than it is today.

Typical glacial landforms (ice caps and mountain glaciers) are: Cirque – an ellipsoidal shape valley formed by glacial erosion; Drumlin – elongated hill created by erosion of a glacier against the substrate rocks; Esker – long and stratified wall / ridge of sand and gravel due to glacier action; Glacial terraces – terraces flanking sides of river valleys; Erratic blocks – big blocks of rocks transported by ice for kilometers; Moraine – unconsolidated and unsorted glacial debris; Trim line – the line on the sides of a valley marking the highest extent of a glacier; Glacier valley – U shape valley shaped by a glacier; Glacier lakes – lakes formed behind a natural dam formed by glacier moraines.

MODULE 4: Other European geological elements

4.1. Geology and culture in Europe.

Geology as science is part of the human culture. All great geological discoveries could be considered as milestones in evolution of our modern society leaving traces in economy, biology, geography, social life, astronomy, history, philosophy, literature and art. The key moments and persons are part of a common cultural intangible heritage and could be regarded also as sources of inspiration and understanding how science is working. Their discoveries and their stories are valuable assets in development of geotourism and educational products and activities. Few of the first European scientists playing a key role in development of geology and paleontology are presented below:

Nicolas Steno was the first to describe in 1666 few principles to define different time and space relationships of geological bodies: law of superposition, principle of original horizontality, and principle of lateral continuity. This principles are still used and represent a very good tool in field observations and interpretation.

James Hutton in late Eighteenth century is considered the father of geology and was the first to come with logical arguments about rock formation and evolution. Based on actual observation, Hutton demonstrated how processes of sedimentation and erosion could help us to understand the evolution of Earth. One classical point, now a famous geological heritage site, is Siccar Point where relationships of different tilted rocks layers indicate a long geologic time (see https://www.eoas.ubc.ca/courses/eosc326/resources/Stratigraphy/Siccar.htm). Is the reason Hutton is called The Man who Found Time (Repcheck, 2003).

William Smith in the beginning of nineteen century was the first to discover the connection between rocks and fossils and to state that sedimentary layer could be identified by their fossil content. He produced the first map of Britain, a map that changed the world (Whinchester, 2001).

Charles Lyell continued the work of Hutton and in his seminal book Principles of Geology in three volumes published between 1830 – 1833 he explained the continuous changes of the Eart`s surface by natural causes. The processes that are occurring today are the same processes that occurred in the past. This concept is known as uniformitarianism and can be summarized: "the present is the key to the past."

Georges Cuvier is the founding father of paleontology. He was able, using comparative anatomy and paleontology to reconstruct animal starting from one or few bones. He suggested that species extinction is due to periodic catastrophic events and became the most influential supporter of catastrophism theory.

William Buckland was the first to describe a fossil dinosaur, which he named Megalosaurus, in the beginning of nineteen century.
Mary Anning was known and famous around the world for the important paleontological findings In the Lyme Regis area (Dorset coast) during the first part of the nineteen century. She found a large number of ammonites, belemnites and the first skeleton of Plesiosaurus and for the first time in UK remains of the flying reptile pterosaur.

Charles Darwin was also a geologist and is best known for his contributions to the science of evolution. Was one of the most preeminent scientific figure of the nineteenth century and histheory of evolution by natural selection published in On the Origin of Species, in 1859 is still valid.

Alfred Wegener a German meteorologist and geophysicist was the first to present in 1912 his idea on Continental Drift hypothesis. Based on similarities for rock types and fossils he found on both sides of the Atlantic Ocean he assumed that Africa and America were united in the geological past. In his book Die Entstehung der Kontinente und Ozeane published in 2015 he stated that almost all continental masses were at one moment united in a supercontinent (Pangea – the whole land).

In the late 60` the Plate tectonic model was finally accepted after important discoveries in geophysics, sedimentology, paleontology. Builded on the concept of lithospheric plate movements over the asthenosphere, seafloor spreading, continental drift the model is explaining most part of the Earth geological processes. It was a breakthrough and lot of old models needed to be reinterpreted.

4.2. Stone made objects - intangible heritage of European Geoparks.

A fascinating way to express local geodiversity and its role in shaping local identity is to uncover and tell the stories of objects made from raw materials - from rocks and minerals. Producing most of the objects surrounding us - either valuable or functional items – requires the use of rocks and minerals. A stone made object reveals three stories involving the relationships between the use of geological resources and man-made objects.

The geological story, concerns the natural processes leading to the formation of specific rock types and minerals. Millions or hundreds of millions of years separate the origin of the raw materials and the moment when people used them to create objects.

The anthropological story reveals how local communities used geological resources to create decorative and/or functional objects which express their sense of place and unique identity. Stone made objects from different geoparks could express the geological diversity of Europeand different local techniques in using Earth materials. Each geopark could identify local Stone made objects and their related stories. These could be used as an important tool in interpretation and promotion of local geology and cultureof Europe and could be integrated into geotourism activities. Few examples are presented in the table below.

Table Stone made objects and related geologic, anthropologic and socio-economic stories:

Age / Geopark	Description	Object / Photo
CZ / Neogene Hateg Country UGGp	Local ceramic traditional based on local clay extraction then transformed into objects of a required shape and heating them to high temperatures in a kiln. One century ago in Baru Mare village, the type locality, 22 potter's wheel were registered in the area. The clay formed in an aquatic environment is Middle Miocene in age.	Baru Mare potery
MZ / Jurassic NZ / Paleogene Haute Provence UGGp	Curved tiles are well known in Haute Provence area. During the 18the and 19th centuries more than 110 of local producers were counted with important contribution to local economy. It is often said that the characteristic curved shape of the tile romaine was formed by a man wrapping the clay over his bare thigh. This may or may not be true, but it does describe perfectly the shape. Still used, the tills are now produced in industrial factories. The clay is coming from local sedimentary deposits of different ages but the most important ones are 180 million years old and 25 million years old both accumulated in the former Tethys Sea.	Curved tiles

CZ / Neogene **Haute Provence UGGp**	Moustiers faience became famous all over the world thanks to its fine glazed earthenware produced in the 17th and 18th centuries. Recognisable by its distinctive floral designs, the craft is perpetuated today by a number of local workshops. The object is made on a potter's wheel then fired at more than 1000°C. After that is dipped in a bath of enamel, covering the pot with a fragile white powder. The delicate artwork is painted on the powdery enamel with a brush then fired a second time to fuse the glaze and coloured oxides. The local clay used by producers has accumulated as sedimentary rocks more than 10 million years ago in local lakes. The whole sedimentary body generated during the geological evolution of the area is called the Valensole Complex.	Moustiers faience
PZ / Permian **Muskau Arch UGGp**	Product of a fine glass factory. Quartz has been melted thanks to potassic flux, to make the glass harder and suitable for engraving. It was used on the best aristocratic tables during the XIX century, thanks to its high artistic value and hardness.	
	The pure hyaline quartz from the Borzago Valley ancient quarry, geosite of the Adamello Brenta UNESCO Global Geopark, is a fine mineral, devoid of scorias, suitable for crystal glass production. The quartz vein derives from the Permian magma rising and subsequently cooling within the crust about 270-80 million years ago.	 Crystal glass
PZ / Carboniferous Fforest Fawr UGGp (UK)	Silica firebricks, produced by the now derelict Penwyllt Brickworks were essential for iron and steel production in the late 19th and early 20th centuries. The bricks, which survive temperatures up to 1700°, lined the furnaces at iron and steel manufacturing sites in South Wales and throughout Britain. They were also exported worldwide. The firebricks were made from course sand and gravel, probably derived from deeply weathered approximately 323 – 315 year old Carboniferous Twrch Sandstone. Sand and gravel mixed with lime and water were shaped in cast iron moulds, extruded, dried and, once set, the bricks were stacked in kilns and fired for up to three weeks.	Silica firebricks

CZ / Neogene **Haute Provence UGGp**	Moustiers faience became famous all over the world thanks to its fine glazed earthenware produced in the 17th and 18th centuries. Recognisable by its distinctive floral designs, the craft is perpetuated today by a number of local workshops. The object is made on a potter's wheel then fired at more than 1000°C. After that is dipped in a bath of enamel, covering the pot with a fragile white powder. The delicate artwork is painted on the powdery enamel with a brush then fired a second time to fuse the glaze and coloured oxides. The local clay used by producers has accumulated as sedimentary rocks more than 10 million years ago in local lakes. The whole sedimentary body generated during the geological evolution of the area is called the Valensole Complex.	Moustiers faience
PZ / Permian **Muskau Arch UGGp**	Product of a fine glass factory. Quartz has been melted thanks to potassic flux, to make the glass harder and suitable for engraving. It was used on the best aristocratic tables during the XIX century, thanks to its high artistic value and hardness.	
CZ / Neogene Sitia UGGp (GR)	The cooked their food over an open fire in both indoor and outdoor spaces (ca. 1900–1450 BC). People used tripod cooking pots to prepare watery soups or thicker stews to simmer over a hearth fire. In excavations in east Crete, archaeologists have found the remains of lentils, wild hare, goat bones, small fish bones limpets in these pots. The material came from a peculiar rock with interbeded layers of reddish conglomerate, sandstone and clay. They were formed approximately 10-8.5 million years ago. Over a long period of time, the locals have exploited these rocks and have used them for creating crafts and other useful material.	 Minoan pottery
MZ / Jurassic Swabian Albs Geopark UGGp (DE)	Stone Age people of the Swabian Alb, Neanderthals and modern humans, used chert to make tools. They even invented a technique to improve the features of the material by heating it. Also the famous 40, 000 years old Ice Age Art of the Swabian Alb, little figurines made of mammoth ivory, were carved with tools out of chert. Jurassic chert is the flint of the Swabian Alb, usually found in the form of bright nodules. As these concretions consist of insoluble siliceous material, they appear when the surrounding soluble limestone has been removed. Its characteristics are its hardness and	 Jurahornstein/ Jurassic Chert

	extremely sharp broken edges.	
MZ/ Cretaceous Massif des Bauges UGGp (FR)	During the XIXth century, the Massif des Bauges specialized in nail manufacturing. This industry was linked to the presence of small iron deposits in some parts of the karst landscape. The abundance of wood in a thick forest area and the presence of mountain streams helped the industry to compete with the later importation of richer deposit from the neighbouring area of the Hurtières Massif. Iron deposits are located on some of the main reliefs of Urgonian limestones, in the form of nodules or fracture fillings. These deposits, associated with siderolithic events, were trapped by an early paleokarst, prior to the Alpine Orogeny. The high iron content allowed the very early industrial production, with rudimentary low-furnaces.	 Nails and scoria
Pz / Ordovician Bohemian Paradise (CZ)	Since Medieval times, phyllites of ŽeleznýBrod crystalline complex were of great economic importance in northwestern part of Bohemian Paradise UNESCO Global Geopark as documented by huge already abandoned quarries. Material quarried there was used for high quality roofing. Technical tests proved their unique hardness, endurance and durability under fluctuating temperatures. Phyllites of Železný Brod crystalline complex are metamorphic, thin-bedded and usually greyish-green or purplish rocks. They originated during the Ordovician Period as deep-sea clay shales and were metamorphosed during the Variscan Orogeny at the end of Devonian. Rarely, Ordovician ichnofossils and also body fossils can be found in these rocks	

4.3. Vocabulary of geology.

A

'A'ā lava - type of lava flow that cool down forming fragmented, rough, sometimes spiny, or blocky surface.

Absolute ages – specific ages of rock units; define the actual numerical age of a particular geologic event. For example, large dinosaurs died out 66 million years ago.

Accretionary lapilli - Rounded tephra balls are called accretionary lapilli if they consist of volcanic ash particles. They are are formed in an eruption column or cloud by moisture or electrostatic forces, with the volcanic ash nucleating on some object and then accreting to it in layers before the accretionary lapillus falls from the cloud.

Active volcano - is the volcano that has erupted since the last ice age (i.e., in the past ~10,000 years).

Andesite - is an extrusive igneous, volcanic rock, of intermediate composition, with aphanitic to porphyritic texture Andesite is the intermediate type of rock between basalt and granite, with a silicon dioxide (SiO_2) content ranging from 57 to 63%. Andesites are typical for lava domes and stratovolcanoes.

Anticline – a deformation of rock bodies generating a fold that is convex upward.

Aquifer - any geological formation containing or conducting ground water, especially one that supplies the water for wells, springs.

Asthenosphere - the highly viscous, mechanically weak and ductilely deforming region of the upper mantle of the Earth. It lies below the lithosphere, at depths between approximately 80 and 200 km below the surface.

Avalanche (snow, rock, or air & snow) - is a rapid flow of snow down a sloping surface. Slides of rocks or debris, behaving in a similar way to snow, are also referred to as avalanches.

Axial plane of the fold – is the plane that devices the fold as symmetrically as possible.

B

Basalt - The most common type of extrusive volcanic rock, with aphanitic texture with a relatively low (45–55%) silica content and typically erupted at shield volcanoes (but there are many basaltic cinder cones, tuff rings, etc.).

Batholith - a large mass of intrusive igneous rock that forms from cooled magma deep in the Earth's crust and can be exposed due to uplift and erosion.

Body waves - travel through the interior of the Earth along paths controlled by the material properties in terms of density and modulus (stiffness). The density and modulus, in turn, vary according to temperature, composition, and material phase. Two types of particle motion result in two types of body waves: Primary and Secondary waves.

C

Caldera - a large cauldron- like depression that forms following the evacuation of a magma chamber/reservoir. When large volumes of magma are erupted over a short time period, structural support for the crust above the magma chamber is lost. The ground surface then collapses downward into the partially emptied magma chamber, leaving a massive depression at the surface (from one to dozens of kilometres in diameter).

Caldera – A very large vent or crater opening caused by the collapse of a volcano's top.

Cambrian - the first geological period of the Paleozoic Era, of the Phanerozoic Eon. Prior to the Cambrian, the majority of living organisms on he wholewere small,unicellular and simple. Complex, multicelular organisms gradually became more common. Cambrian explosion - a dramatic burst of evolutionary changes in life on Earth.

Carboniferous - a geologic period that spans 60 million years from the end of the Devonian (359 million years ago), to the beginning of the Permian. The name means "coal-bearing". The Carboniferous is often treated in North America as two geological periods, the earlier Mississippian and the later Pennsylvanian. Terrestrial life was well established by the Carboniferous.

Cenozoic - an era, which began 66 million years ago and is characterized by the ascendancy of mammals. Is the current and most recent of the three Phanerozoic geological eras.

Cinder/scoria cone - a steep conical hill of loose pyroclastic fragments, such as either volcanic clinkers, cinders, volcanic ash, or scoria that has been built around a volcanic vent. It is the simplest and most common type of volcano.

Columnar joint - A structure that forms in rocks (most commonly in basalt) that consists of columns (mostly commonly hexagonal in shape), formed when the rock contracted, most often during cooling.

Collision - is an event in which two or more bodies exert forces on each other for a relatively short time. Although the most common colloquial use of the word "collision" refers to incidents in which two or more objects collide with great force, the scientific use of the word "collision" implies nothing about the magnitude of the force.

Continent - is one of several very large landmasses on Earth. Generally identified by convention rather than any strict criteria, up to seven regions are commonly regarded as continents. Ordered from largest in size to smallest, they are: Asia, Africa, North America, South America, Antarctica, Europe, and Australia. Islands are frequently grouped with a neighbouring continent to divide all the world's land into geopolitical regions (for example Oceania). Geologically the continents largely correspond to areas of continental crust that are found on the continental plates. However some areas of continental crust are regions covered with water not usually included in the list of continents – submerged continents.

Continental collision - is a phenomenon of the plate tectonics of Earth that occurs at convergent plate boundaries. Continental collision is a variation on the fundamental process of subduction, whereby the subduction zone is destroyed, mountains produced, and two continents sutured together. Continental collision is known only to occur on Earth and it is not instantaneous event. It may take several tens of millions of years before the faulting and folding caused by collisions stops.

Compressional tectonics - tectonic movements that squeeze plates or parts of plates together. Opposite of extensional tectonics.

Crater – Opening or vent on top of a volcano.

Createaceous - a geologic period that spans from the end of the Jurassic (145 million years ago) to the beginning of the Paleogene (66 million years ago). It was a period with a relatively warm climate, resulting in high eustatic sea levels that created numerous shallow inland seas. The Cretaceous ended with a large mass extinction, in which many groups, including non-avian dinosaurs, pterosaurs and large marine reptiles died out.

Cross-bedding – a sedimentary structure, (near-) horizontal units that are internally composed of inclined layers. Cross bedding forms during deposition on the inclined surfaces of bedforms such as ripples and dunes, and indicates that the depositional environment contained a flowing médium (typically water or wind).

Crust - the outermost layer that covers our planet like a shell, and also the only one that sustains life! Underneath the continents, the crust is almost three times as thick as it is under the oceans.

Continental crust – is the outer Earth layer. It is made of igneous, sedimentary, and metamorphic rocks. This layer is sometimes called sial beause its bulk composition is more felsic compared to the oceanic crust which is called sima. The average density of continental crust is about 2.7 g/cm3, less dense than the ultramafic material that makes up the mantle, which has a density of around 3.3 g/cm3. Continental crust is also less dense than oceanic crust which is 2,9 g/cm3. It has a greater floatability than the oceanic crust, forming the continents and continental shelves. The continental crust is made of a mosaic of rocks of different ages, the oldest ones being about 4 billion years. At 25 to 70 km, continental crust is considerably thicker than oceanic crust which is only 5 – 15 km About 40% of Earth's surface is currently occupied by continental crust. It makes up about 70% of the volume of Earth's crust.

Continental Drift - Theory proposed by Alfred Wegener (1915) to support the notion that the continents had changed position through geological time. Alfred Wegener was unable to propose a mechanism to explain how drift occurred and the idea was ignored for almost half a century.

Continental shelf – area of shallow seabed, close to continents shores.

Convection – one of the three main types of heat transfer, the other two being conduction and radiation. Convection can only happen in fluids. This includes liquids and gases and is because the molecules have to be free to move. Head energy can transfer by convection when there is a significant difference in temperature between two parts of a fluid. When this temperature difference exists, hot fluids rise and cold fluids sink, and then currents, or movements, are created in the fluid.

Convection currents – currents in the fluid, that occure because of the temperature difference when hot fluids rise and cold fluids sink.

Convergent plate boundary - also known as a destructive plate boundary, is a region of active deformation where two or more tectonic plates or fragments of the lithosphere near the end of their life cycle. As a result of pressure, friction, and plate material melting in the mantle, earthquakes and volcanoes are common near destructive boundaries, where subduction zones or an area of continental collision (depending on the nature of the plates involved) occurs. This is in contrast to a constructive plate boundary.

Core – the part of Earth in the middle of our planet. It has a solid inner core and a liquid outer core. Seismic measurements show that the core is divided into two parts, a "solid" inner core with a radius of ≈1,220 km and a liquid outer core extending beyond it to a radius of ≈3,400 km.

D

Dacite - an igneous, volcanic rock. It is intermediate in composition between andesite and rhyolite.

Devonian - a geologic period, spanning from the end of the Silurian (419 million years ago), to the beginning of the Carboniferous. It is named after Devon - England, where rocks from this period were first studied. The oldest known trees of the world's first forests appeared. The first tetrapods — landliving vertebrates — appeared during the Devonian.

Diatreme - A long vertical pipe or plug formed when gas-filled magma forced its way up through overlying strata.

Dip of a fault plane – angle of inclination measured from the horizontal, given by the number (0°-90°).

Divergent plate boundary –also known as a constructive boundary or an extensional boundary is a linear feature that exists between two tectonic plates that are moving away from each other. Divergent boundaries within continents initially produce rifts which eventually become rift valleys. Most active divergent plate boundaries occurbetween oceanic plates and exist as mid-oceanic ridges. Divergent boundaries also form volcanic islands which occur when the plates move apart to produce gaps which molten lava rises to fill.

Dormant volcano - the volcano that hasn't erupted in the past 10,000 years, but is expected to erupt again.

Dyke – subvertical sheet-like intrusion of magma in a fracture in a pre-existing rock body (magmatic dyke).

E

Earthquake - a sudden, violent shaking of the ground, often causing a great destruction. It is a result of movements within the Earth's crust or volcanic action.

Effusive eruption/Effusive volcanism - a type of volcanic eruption in which lava steadily flows out of a volcano onto the ground. A volcanic eruption is effusive when low-viscosity magma, usually basaltic in composition, is released from the Earth's crust. In an effusive eruption, gas escapes the magma as it erupts and forms lava that flows downhill continuously. This type of lava flow can build shield volcanoes.

Effusive eruption/rocks - a type of volcanic eruption in which lava steadily flows out of a volcano onto the ground. A volcanic eruption is effusive when low-viscosity magma, usually basaltic in composition, is released from the Earth's crust.

Eons - the largest intervals of geologic time and are hundreds of millions of years in duration. For example: the Phanerozoic Eon is the most recent eon and began more than 500 million years ago.

Epicenter - the part of the Earth's surface directly above the focus (hypocentre) of an earthquake.

Epochs - Finer subdivisions of time are possible and the periods of the Cenozoic are frequently subdivided into epochs. Subdivision of periods into epochs can be done only for the most recent portion of the geologic time scale. This is because older rocks have been buried deeply, intensely deformed and severely modified by long-term earth processes. As a result, the history contained within these rocks cannot be as clearly interpreted.

Eras - Eons are divided into smaller time intervals known as eras. Example: the Phanerozoic is divided into three eras: Cenozoic, Mesozoic and Paleozoic. Very significant events in Earth's history are used to determine the boundaries of the eras (for example: catastrophic extinction).

Erosion - A natural process that wears away rock and earth. The removal and/or breakdown of rocks by physical, chemical or biogenic processes. Erosion can take place from weathering, from wind, from glacial action, from corrosion, from grinding action, and from movement of earth and rocks from one place to another.

Explosive eruption / Explosive volcanism - is a volcanic term to describe a violent, explosive type of eruption. Sometimes a lava plug will block the conduit to the summit, and when this occurs, eruptions are more violent. Explosive eruptions can send rocks, dust, gas and pyroclastic material up to 20 km into the atmosphere at rate of up to 100,000 tonnes per second, travelling at several hundred meters per second. Example: Mount St. Helens eruption (1980).

Extinct volcano - the volcano that nobody expects to ever erupt again.

Eruption column - a cloud of hot volcanic ash suspended in volcanic gas emitted during an explosive volcanic eruption. The ash forms a column that may rise many kilometres into the air above the vent of the volcano. In the most explosive eruptions, the eruption column may rise over 40 km, penetrating the stratosphere.

Extensional tectonics - concerned with the structures formed, and the tectonic processes associated with the stretching of the crust or lithosphere. Opposite of compressional tectonics.

Extinctions – the end of a group of organisms (taxon), usually a species. Mass extinctions refers to the end of large number of taxa in a very short time. This are events due to catastrophic change in the environment. There are five mass extinctions recorded: End Ordovician, Late Devonian, End Permian, End Triassic and End Cretaceous. The last one is also known as the K/T boundary (Cretaceous / Tertiary) when among other groups the dinosaurs disappeared.

F

Fault - in geology, a planar or gently curved fracture in the rocks of the Earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite sides of the fracture - a broken section of the Earth's crust along which movement occurs. Faults range in length from a few centimetres to many hundreds of kilometres, and displacement likewise may range from less than a centimetre to several hundred kilometres along the fracture surface (the fault plane). Faults may be vertical, horizontal, or inclined at any angle. Although the angle of inclination of a specific fault plane tends to be relatively uniform, it may differ considerably along its length from place to place.

Fault plane – the fracture surface.

Fault scarp – is a small step or offset on the ground surface where one side of a fault has moved vertically with respect to the other. It is the topographic expression of faulting attributed to the displacement of the land surface by movement along faults. They are exhibited either by differential movement and subsequent erosion along an old inactive geologic fault (a sort of old rupture), or by a movement on a recent active fault.

Felsic – adjective refers to igneous rocks that are relatively rich in elements that form feldspar and quartz. It is contrasted with mafic rocks. Felsic refers to those rocks rich in silicate minerals, magma, and rocks which are enriched in the lighter elements such as silicon, oxygen, aluminium, sodium, and potassium. The most common felsic rock is granite. Common felsic minerals include quartz, muscovite, orthoclase, and the sodium-rich plagioclase feldspars. In terms of chemistry, felsic minerals and rocks are at the other end of the elemental spectrum from the mafic minerals and rocks.

Focus – or hypocenter, is the location where the earthquake begins, the origin of the earthquake. The ground ruptures at this spot, then seismic waves radiate outward in all directions.

Fracture - in engineering, rupture of a material too weak to sustain the forces on it. A fracture of the workpiece during forming can result from flaws in the metal; these often consist of nonmetallic inclusions such as oxides or sulfides trapped in the metal during refining. Laps are another type of flaw, in which part of a metal piece is inadvertently folded over on itself but the two sides of the fold are not completely welded together. Structural and machine parts subject to vibrations and other cyclic loadingmust be designed to avoid fatigue fracture.

Focal depth – or hypocentral depth is the distance between epicentre and hypocenter (focus).

Fold - in geology, waves in the stratified rocks of the Earth's crust. Stratified rocks were originally formed from sediments that were deposited in flat, horizontal sheets, but in a number of places the strata are no longer horizontal but have been warped. An area on the Earth´s crust that has been bent due to enormous internal pressure from gas or magma deep inside the Earth. It can be an upward, downward, or lateral movement of the crust. Some mountains are formed due to folding. Some folds take 1.000 years ore more to form. Some folds form quickly. Some folds are small; others are enormous.

Foliated metamorphic rocks are formed within the Earth's interior underextremely high pressures that are unequal, occurring when the pressure is greater in one direction than in the others (directed pressure). This causes the minerals in the original rock to reorient themselves with the long and flat minerals aligning perpendicular to the greatest pressure direction. This reduces the overall pressure on the rock and gives it a stripped look**.**

Fumarole - an opening in a planet's crust, often in areas surrounding volcanoes, which emits steam and gases such as carbon dioxide, sulfur dioxide, hydrogen chloride, and hydrogen sulfide. The steam forms when superheated water vaporizes as its pressure drops when it emerges from the ground.

Footwall – when rocks slip past each other in faulting, the block below is called footwall; or with another words, on the other side of the hanging wall, shaped a little bit like a foot.

G

Geologic time scale (GTS) - a system of chronological dating that relates geological strata to time, and is used by geologists, paleontologists, and other Earth scientists to describe the timing and relationships of events that have occurred during Earth's history.

Geohazard (Geologic hazard) - one of several types of adverse geologic conditions capable of causing damage or loss of property and even life.

Geomorphology - the branch of geology that is concerned with the structure, origin, and development of the topographical features of the earth's surface.

Geomagnetic storm - also known as Solar or magnetic storm is the disturbance in the Earth's upper atmosphere due to large eruptions from the Sun's corona.

Geyserite cones – precipitated from silica- and calcium carbonate-rich minerals and thermal water in hot springs around maar craters.

Geyser - a hot spring that intermittently sends up fountainlike jets of water and steam into the air – the water/steam column can be over 50 m high (example: Iceland).

Glacier – a very high persistent piles of ice due to large quantities of snow accumulation formed in mountain areas and in pole regions (ice sheet). .Pressure from heavy, newly fallen snow that has been compacted creates even higher piles of ice. The ice that is piled high above the bottommost layer of ice is under a lot of pressure. This immense pressure causes the bottom layer of ice to flow or move. When a glacier flows or moves it carries rocks with it. When the pressure is released through the movement of the glacier, thewater created from friction of movement refreezes. The refreezing of the glacier is similar to what happens to ice when you go ice-skating. The ice directly under the blade of an ice skate is under a lot of pressure. The ice under the blade melts for an instant and acts as a lubricant for the blade. When the blade moves, the ice refreezes.

Gneiss - very high temperatures and pressures; coarse grained texture of alternating light and dark mineral bands.

Granite - the most well-known and one of the most common intrusive igneous (plutonic) rock type. It is formed when an intrusion of viscous magma with high silica content (68-75 wt %) remains under the surface of the earth, where it cools and crystallizes slowly inside the crust.

Graben - a block that has dropped relatively downward between two normal faults dipping toward each other.

Groundwater - All the water contained in the void space within rocks. Most groundwater derives from surface sources; is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called anaquifer when it can yield a usable quantity of water

H

Hanging wall - or headwall, the upper or overlying block along the fault plane, when rocks slip past each other in faulting; or with another words – the side that slides downwards has a shape that makes it look like it is reaching, or hanging, out over the side, so we call it the hanging wall.

Holocene - is the geological epoch that began after the Pleistocene at approximately 11,700 years (0,01 million years) before present. It encompasses the growth and impacts of the human species worldwide, including all its written history, development of major civilizations, and overall significant transition toward urban living in the present.

Horst - a block that has been relatively uplifted between two normal faults that dip away from each other.

Hypocenter - the point (focus) of origin of an earthquake.

Hydrogeology - (hydro- meaning water, and -geology meaning the study of the Earth) is the area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crust.

Hydrosphere - a generic term for all the water in, above, and on the Earth.

Hot Spot - An area of abnormally intense active volcanism thought to be underlain by a mantle plume. Many hot spots, for example Hawaii are located in the middle of a lithospheric plate whilst others such as Iceland are located on divergent (constructive) plate margins.

I

Igneous rock - rocks, formed through the cooling and solidification of magma / lava.

Ignimbrite - a pyroclastic rock formed by very hot ground-hugging cloud of volcanic ash, blocks and gases, known as pyroclastic flow.

Inner core - is the Earth's innermost part. It is primarily a solid ball with a radius of about 1,220 kilometres. It is composed of an iron–nickel alloy and some light elements.

Intrusive rock - is formed when magma crystallizes and solidifies slowly below the surface (underground), not reaching the surface; also called plutonic rock, igneous intrusive rock.

J

Jurassic - a geologic period that spanned from the end of the Triassic (201 million years ago) to the beginning of the Cretaceous (145 Million years ago). The Jurassic constituted the middle period of the Mesozoic Era, also known as the Age of Reptiles.

Juvenile water - water which has never before been part of the hydrologic cycle.

K

Karst - the landscape produced in limestone areas, which has been eroded by dissolution, producing ridges, towers, fissures, sinkholes and other characteristic landforms.

L

Lahar - a type of mudflow or debris flow composed of a slurry of pyroclastic material, rocky debris, and water. The material flows down from a volcano, typically along a river valley.

Landslide - the movement of a mass of rock, debris, or earth down a slope due to gravity. The materials may move by falling, toppling, sliding, spreading, or flowing. Landslides can be triggered by rainfall, snowmelt, changes in water level, stream erosion, changes in ground water, earthquakes, volcanic activity, disturbance by human activities, or any combination of these factors.

Lapilli - literally "little stones". A size classification term for tephra, which is material that falls out of the air during a volcanic eruption. Round to angular rock fragments, which may be ejected in either a solid or molten state. By the definition lapilli range from 2 to 64 mm in diameter.

Lava - magma that emerges from a volcano´s interior.

Lava cave - A lava cave is any cave formed in volcanic rock, though it typically means caves formed by volcanic processes. Lava tubes are the most common and most extensive kind of lava cave.

Lava dome - a roughly circular mound-shaped protrusion resulting from the slow extrusion of viscous lava from a volcano.

Lava flow - liquid or solidified lava which has erupted from a volcano onto the Earth's surface; a mass of flowing or solidified lava; when magma is erupted in molten or a partially molten state it often has the ability to flow.

Lava fountain - sustained jets of (usually very) fluid lava into the atmosphere. Lava fountains occur commonly on basaltic volcanoes such as Kilauea, or Etna.

Lava lake - large volumes of molten lava, usually basaltic, contained in a volcanic vent, crater or broad depression. The term is used to describe both lava lakes that are wholly or partly molten and those that are solidified (sometimes referred to as frozen lava lakes in this case).

Lava trees - The lava coating around a tree trunk left by an invading liquid lava flow.

Lithosphere - is the rigid, outermost shell of a terrestrial-type planet or natural satellite that is defined by its rigid mechanical properties. Earth's lithosphere includes the crust and the uppermost mantle, which constitute the hard and rigid outer layer of the Earth. The lithosphere is subdivided into tectonic plates. The thickness of the lithosphere is considered to be the depth to the isotherm associated with the transition between brittle and viscous behavior. Oceanic lithosphere is typically about 50–140 km thick, while continental lithosphere has a range in thickness from about 40 km to more than 200 km and overlay a viscous layer called asthenosphere.

M

Mafic - adjective describing a silicate mineral or igneous rock that is rich in magnesium and iron. Most mafic minerals are dark in color, and common rock-forming mafic minerals include olivine, pyroxene, amphibole, and biotite. Common mafic rocks include basalt, diabase and gabbro. Mafic rocks often also contain calcium-rich varieties of plagioclase feldspar. Chemically, mafic rocks are on the other side of the rock spectrum from the felsic rocks. The term roughly corresponds to the older basic rock class. Mafic lava, before cooling, has a low viscosity, in comparison with felsic lava, due to the lower silica content in mafic magma. Water and other volatiles can more easily and gradually escape from mafic lava. As a result, eruptions of volcanoes made of mafic lavas are less explosively violent than felsic-lava eruptions (example volcanoes in Hawaii).

Maar volcano - one of the results from phreatomagmatic eruptions. They are defined by bowl-shaped craters cutting about 10 m to more than 500 m deep into the preeruption surface. After cinder cones, maars are the second most common volcanic landform.

Magma – Hot liquid rock. Igneous rocks are formed from magma.

Magma Chamber - a reservoir of magma in the Earth's crust where the magma may reside temporarily on its way from the upper mantle to the earth's surface.

Magma pipe – Located in the interior of the volcano. It is a vertical space or tunnel shape that is formed from the pressure of magma pushing up.

Mantle - a layer inside a terrestrial planet and some other rocky planetary bodies. For a mantle to form, the planetary body must be large enough to have undergone the process of planetary differentiation by density. The mantle is bounded on the bottom by the planetary core and on top by the crust.

Mantle plume - an upwelling of abnormally hot rock within the Earth's mantle. As the heads of mantle plumes can partly melt when they reach shallow depths, they are often invoked as the cause of volcanic hotspots, such as Hawaii or Iceland, and flood basalts such as the Deccan and Siberian traps.

Marble - composed of the mineral calcite; metamorphosed limestone.

Metamorphic - refers to change. It means a change takes place.

Metamorphic rocks - rocks that began as another kind of rock and have undergone a change. Rocks undergo metamorphosis or change when they are subjected to extreme amounts of pressure and/or heat. Metamorphic rocks were originally igneous, sedimentary or even metamorphic rocks. For example - marble, a metamorphic rock is formed from limestone.

Mid-oceanic ridge – underwater mountain system formed by plate tectonics. It consists of various mountains linked in chains, typically having a valley know as a rift running along its spine. It is geologically active area, with new magma constantly emerging into the ocean floor and into the crust at and near rifts along the ridge axis. They are formed by two oceanic plates moving away from each other and consequently is termed a divergent plate boundary. Hydrothermal vents are a common feature at oceanic spreading centres. The rocks making up the crust below the seafloor are youngest along the axis of the ridge and age with increasing distance from that axis. The young rocks form new oceanic crust and thus in a constant state of “renewal” at the oceanic ridges. Moving away from the mid-ocean ridge, ocean depth progressively increases.

Mesozoic - an era occurring between 252 and 66 million years ago, characterized by the appearance of flowering plants and by the appearance and extinction of dinosaurs.

Mofetta - an opening in the earth from which carbon dioxide and other gases escape, usually marking the last stage of volcanic activity.

Monogenetic volcano - the result of one single (or very few) magmatic pulse(s). The duration of the volcanic activity lasts from hours to years, generating a monogenetic volcano, built up from the pyroclastic accumulation during the eruption, and a lava flow. In all the cases, the final volcanic edifice has a similar shape, which shows a simple truncated cone with generally a bowl-shaped crater at its top. Most of them are basaltic and/or andesitic cinder cones.

Moraines - accumulations of rocks, clays, soil, that are left behind after a glacier or ice sheet melts.

Mudflow - flow of water that contains large amounts of suspended particles and silt. Mudflows occur on steep slopes where vegetation is not sufficient to prevent rapid erosion but can occur on gente slopes if other conditions are met. Other factors are heavy precipitation in short periods and an easily erodible source material.

N

Nappe – large body or sheet of rock that has been moved a longer distance from its original position by faulting or folding. A nappe may be the hanging wall of a low-angle thrust fault, or overthrust, or may be a large recumbent fold. Both processes position older rocks over younger rocks.

Normal fault - when one side of the fault moves downward with respect to the other side. The hanging wall slides down relative to the footwall.

Neogene - the time/ geologic period that took place 23 to 2.6 million years ago. During this period, mammals and birds continued to evolve into roughly modern forms, while other groups of life remained relatively unchanged. Early hominids, the ancestors of humans, appeared in Africa near the end of the period.

Nonfoliated metamorphic rocks are formed around igneous intrusions where the temperatures are high but the pressures are relatively low and equal in all directions (confining pressure). The original minerals within the rock recrystallize into larger sizes and the atoms become more tightly packed together, increasing the density of the rock.

O

Obsidian - black volcanic glass. It is produced when lava high in silica (SiO_2) cools rapidly, and solidifies without time for crystal growth.

Oceanic crust – a type of earth's crust usually found under oceans. Oceanic crust is primarily composed of mafic rocks, or SIMA, which is rich in iron and magnesium. With 5 – 15 km of thickness it is thinner than continental crust and it is denser than continental crust, having a mean density of about 2.9 g/cm^3. The crust is the result of erupted material originating from below the plate, cooled and in most instances, modified chemically by seawater. These eruptions occur at mid-ocean ridges, but also at scattered hotspots, and also in rare but powerful occurrences known as flood basalt eruptions. The oceanic crust is continuous generated in mid-oceanic ridges and continuous consumed in subduction zones. This is the reason the oldest oceanic crust is about 180 million year much younger than the continental crust.

Oceanic trench – Topographic depression of the sea floor, relatively narrow in width, but very long. These are distinctive morphological feature of convergent plate boundaries, along which plates move towards each other at rates that vary from a few millimeters to over ten centimeters per year and are the deepest parts of the ocean floor. A trench marks the position at which the flexed, subduction slab begins to descend beneath another lithospheric slab. Trenches are usually parallel to a volcanic island arc, about 200 km from a volcanic arc.

Olivine - a silicate mineral made of magnesium iron silicate. It ranges in colour from chartreuse green to pale olive.

Ordovician - geological period that spans from the end of the Cambrian (485 million years ago) to the start of the Silurian. Invertebrates, namely molluscs and arthropods, dominated in the oceans. Fish, the world's first true vertebrates, continued to evolve, and those with jaws may have first appeared late in the period.

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Organic Evolution - Change of organisms over geologic time

Orogenesis - The process of mountain formation, especially by a folding and faulting of the earth's crust due to convergent plate movement and collision. It occurs when large pieces of material on the subduction plate (such as island arcs) are pressed into the over-riding plate or when sub horizontal contraction occurs in the over-riding plate. These areas are subject to many earthquakes and volcanoes.

Orogen - or orogenic belt develops when a continental plate crumples and is pushed upwards to form one or more mountain ranges; this involves many geological processes collectively called orogenesis.

Orogeny - an event that leads to a large structural deformation of the Earth's lithosphere (crust and uppermost mantle) due to the interaction between different tectonic plates and related volcanism Overthrust - or detachments is thrust fault with a very low angle of dip and a very large total displacement. These are often found in intensely deformed mountain belts.

Overturned fold (overfold) – has the axial plane inclined to such an extent that the strata on one limb are overturned

Outer core - is a fluid layer about 2,300 km thick and composed of mostly iron and nickel that lies above Earth's solid inner core and below its mantle. Its outer boundary lies 2,890 km (1,800 mi) beneath Earth's surface. Unlike the inner core, the outer core is liquid. This is also referred to as the solid core.

P

Pāhoehoe lava - type of lava flow, with smooth, billowy, or ropy crust.

P-Waves - compressional waves that are longitudinal in nature. P waves are pressure waves that travel faster than other waves through the earth to arrive at seismograph stations first, hence the name "Primary". These waves can travel through any type of material, including fluids, and can travel at nearly twice the speed of S waves. In air, they take the form of sound waves, hence they travel at the speed of sound.

Paleogene - a geologic period that spans from the end of the Cretaceous to the beginning of the Neogene Period. It is the beginning of the Cenozoic Era of the present Phanerozoic Eon. The Paleogene is most notable for being the time during which mammals diversified from relatively small, simple forms into a large group of diverse animals.

Paleokarst - karst features that are on ancient surfaces.

Paleozoic - an era occurring between 541 million and 252 million years ago, characterized by the advent of fish, insects, and reptiles.

Peridotite - a dense, coarse-grained igneous rock consisting mostly of the minerals olivine and pyroxene. Peridotite is the dominant rock of the upper part of the Earth's mantle. The compositions of peridotite nodules found in certain basalts and diamond pipes.

Phyllite - low to intermediate temperatures and pressures; slightly more crystallized which gives the rock a shiny appearance; layers may also be wavy or crinkled Phreatomagmatic explosion - volcanic eruptions, due to interaction of ascending magma with groundwater or surface water.

Periods - Eras are subdivided into periods. The events that bound the periods are wide-spread in their extent but are not as significant as those which bound the eras. Example: the Paleozoic is subdivided into the Permian, Carboniferous, Devonian, Silurian, Ordovician and Cambrian periods.

Permian - a geologic period from the end of the Carboniferous (299 million years ago), to the beginning of the Triassic. It is the last period of the Paleozoic Era. The Permian (along with the Paleozoic) ended with the Permian–Triassic extinction event, the largest mass extinction in Earth's history, in which nearly 90% of marine species and 70% of terrestrial
species died out.

Phanerozoic - current geological eon, and the one during which abundant animal and plant life has existed. It covers 541 million years to the present, and began with the Cambrian Period when diverse hard-shelled animals first appeared.

Pillow lava - lavas that contain characteristic pillow-shaped structures that are attributed to the extrusion of the lava under water.

Polygenetic volcanism/Polygenetic volcanoes - Volcanoes that had more than one period of activity during their history.

Pumice - a term for a lightweight volcanic rock. It is a solidified frothy lava, created when highly-heated, pressured molten rock is shot out from a volcano. Its lightweight is due to air spaces, which are caused by fast cooling and loss of pressure. The loss of pressure makes bubbles by lowering the boiling point of the lava (like the bubble-creation when a carbonated drink is opened). The cooling then freezes the bubbles in the matrix. Dry pumice can float in water.

Pyroclastic /Pyroclastic rock - the products of volcanic explosions; that is, they are fragmental pieces of rock, whether they be minerals, crystals or glass, ejected from the vent; rocks formed by accumulation of material generated by explosive fragmentation of magma and / or previously solid rock.

Pyroclastic flow - a fast-moving current of hot gas and volcanic matter (known as tephra), which reaches speeds moving away from a volcano of up to 700 km/h. The gases can reach temperatures of about 1,000 °C. They are a common and devastating result of certain explosive volcanic eruptions.

Plate tectonics - a theory in geology: the lithosphere of the Earth is divided into a number of plates which float on asthenosphere and travel independently. Much of the Earth's seismic activity occurs at the boundaries of these plates. Heat from the Earth's core causes convection currents in the mantle. These currents slowly move the plates around. In some places the lithosphere, including the crust is destroyed. In other places new crust is formed.

Precambrian - the earliest part of Earth's history, set before the current Phanerozoic Eon. The oldest cyanobacteria-like fossils known are nearly 3.5 billion years old, among the oldest fossils currently known.

Proterozoic - a geological eon representing the time just before the proliferation of complex life on Earth. The name Proterozoic comes from Greek and means "earlier life": the Greek root "protero-" means "former, earlier" and "zoic-" means "animal, living being".

Q

Quaternary - is the current and most recent of the three periods of the Cenozoic Era in the geologic time scale. It follows the Neogene Period and spans from 2.58 million years ago to the present. The Quaternary covers the time span of glaciations classified as the Pleistocene, and includes the present interglacial time-period, the Holocene. The 2.58 million years of the Quaternary represents the time during which recognizable humans existed. Over this short time period, there has been relatively little change in the distribution of the continents due to plate tectonics.

Quartzite - composed of the mineral quartz; metamorphosed sandstone.

R

Recrystallization - a metamorphic process that occurs under situations of intense temperature and pressure where grains, atoms or molecules of a rock or mineral are packed closer together, creating a new crystal structure. Example: clays can recrystallize to muscovite mica. Recrystallization is the most common process in the formation of metamorphic rocks.

Recumbent fold – a fold with a horizontal axial plane, the fold is horizontal. In this case also the strata in one limb are overturned.

Relative ages – placing rocks and geologic events in their proper sequence, oldest to youngest. The age of one geologic feature compared to another.

Reverse fault – when on side of the fault moves upwards with respect to the other side. The hanging wall moves up and over the footwall. Richter scale - a scale ranging in numerical value from 1 to 10. It indicates how violent or calm an earthquake´s seismogram reading was. A numerical value of 1 indicates that the quake had the least amount of energy. A numerical value of 10 would indicate that an enormous amount of energy was expended.

Ridge push - sliding plate force is a proposed mechanism for plate motion in plate tectonics. Because mid-ocean ridges lie at a higher elevation than the rest of the ocean floor, gravity causes the ridge to push on the lithosphere that lies farther from the ridge.

Rift - In geology, a rift is a linear zone where the lithosphere is being pulled apart and is an example of extensional tectonics.

Rifting - Rifting is the process by which the continental lithosphere stretches. A continental rift is the belt or zone of the continental lithosphere where the extensional deformation (rifting) is occurring. These zones have important consequences and geological features, and if the rifting is successful, lead to the formation of new ocean basins.

Rift valley - is a linear-shaped lowland between several highlands or mountain ranges created by the action of a geologic rift and fault. A rift valley is formed on a divergent plate boundary, a cristal extension, a spreading apart of the surface, which is subsequently further deepened by the forces of erosion. The rifting process is associated with specificvolcanism. When the tensional forces were strong enough to cause the plate to split apart, a center block dropped between the two blocks at its flanks, forming a graben. The drop of the center creates the nearly parallel steeply dipping walls of a rift valley when it is new. That feature is the beginning of the rift valley, but as the process continues, the valley widens, until it becomes a large basin that fills with sediment from the rift walls and the surrounding area. One of the best known examples of this process is the East African Rift. On Earth, rifts can occur at all elevations, from the sea floor to plateaus and mountain ranges in continental crust or in oceanic crust. They are often associated with a number of adjoining subsidiary or co-extensive valleys, which are typically considered part of the principal rift valley geologically.

Risk management – identification, assessment, and prioritization of risks in order to minimize, monitor, and control the probability or impact of unfortunate events like natural hazards.

Rhyolite - a very acid volcanic rock (typically with >69% SiO_2 content); it can be considered as the extrusive equivalent to the plutonic granite rock.

Rock fall - is the rapid, free-fall of rock from a steep cliff face. Rock fragments fall from the face of the cliff because of the action of gravity.

S

Schist - intermediate to high temperatures and pressures; crystals are larger with the grains aligned in parallel to subparallel layers.

Seismogram - a picture of wavelengths made by a seismograph machine. The actual recording on paper by the machine.

Seismograph - a machine that measures and records vibrations on the Earth´s surface or crust.

Seismologist - a scientist who studies the vibrations caused by earthquakes. The discoveries and findings of seismologists have helped us to create theories and gain knowledge about the Earth´s interior and about the movements of the Earth. Seismologist make predictions about sites and approximate times for future earthquakes and volcanic eruptions based on their knowledge gained from previous movements they have observed.

Seismic waves - waves or Earth tremors generated by a sudden release of energy in a specific point called hypocenter. The waves can be measured by a seismograph machine. There are three kinds of seismic waves - primary waves are often called P waves, secondary waves are often called S waves and surface waves or L waves that do the most damage.

Shield volcano - usually built almost entirely of fluid lava flows. It is named for its low profile, resembling a warrior's shield lying on the ground. This is caused by the highly fluid (low viscosity) lava they erupt which travels farther than lava erupted from stratovolcanoes.

Silurian – a geologic period, spanning from the end of the Ordovician (443.8 million years ago), to the beginning of the Devonian (419.2 million years ago). A significant evolutionary milestone during the Silurian was the diversification of jawed and bony fish. Multi-cellular life also began to appear on land.

Slab – portion of a tectonic plate that is being subducted. By slab pull and slab suction are other two mechanisms driving plate tectonics apart of convection currents.

Slab subduction - is the mechanism by which lithospheric material is mixed back into the Earth's mantle.

Slab pull - the portion of motion of a tectonic plate that can be accounted for by its subduction. Plate motion is partly driven by the weight of cold, dense plates sinking into the mantle at oceanic trenches. Together with slab suction account for almost all of the force driving plate tectonics.

Slab suction – occurs when a subducting slab drives flow in the nearby mantle. This flow then exerts shear tractions on nearby plates. This driving force is important when the slabs (or portions thereof) are not strongly attached to the rest of their respective tectonic plate. They cause both the subducting and overriding plate to move in the direction of the subduction zone. It is the weakest of the three major forces involved in plate motion (the others are slab pull and ridge push), but still together with slab pull (which is the strongest force) contribute to the all of the force driving plate tectonics.

Slate - formed at very low temperatures and pressures, rock breaks along nearly perfect parallel planes; used in pool tables and as roofing material

Solfatare - fumaroles that emit sulfurous gases, like SO2 and H2S.

Spatter cone - a miniature volcanic cone on a crater floor or lava flow from which lava is ejected in drops or gobs.

Stratigraphy - is a branch of geology concerned with the description of rock successions and their interpretation in terms of a general time scale. It provides a basis for geologic time divisions, classification of rock bodies and to develop an internationally acceptable stratigraphic terminology and rules of procedure in the interest of improved accuracy and precision in international communication, coordination, and understanding. It provides rules for rock bodies (rock units) classification according to their properties: litostratigraphic unit, biostratigraphy, cronostratigraphic, magnetostratigraphic. It provides a basis for historical geology which aim is to reconstruct the ancient worlds.

Strombolian eruption - discrete explosions at periodic intervals of a few seconds to minutes or hours, named after Stromboli, a volcano in the Aeolian Islands, Italy. Deposits consist of lava spatter, vesicular bombs, scoriaceous lapilli, and ash.

Supervolcano - a volcano that can make a volcanic eruption where the measured deposits for that eruption is greater than 1,000 cubic kilometers. This is thousands of times bigger than most volcanic eruptions which happened a long time. Supervolcanoes can occur when magma in the Earth rises into the crust from a hotspot, but cannot break through the crust. More and more pressure builds up in a large and growing magma pool until the crust can no longer take the pressure.

S-Wave - Secondary waves (S-waves) are shear waves that are transverse in nature. Following an earthquake event, S-waves arrive at seismograph stations after the faster-moving P-waves and displace the ground perpendicular to the direction of propagation. Depending on the propagational direction, the wave can take on different surface characteristics; for example, in the case of horizontally polarized S waves, the ground moves alternately to one side and then the other. S-waves can travel only through solids, as fluids (liquids and gases) do not support shear stresses. S-waves are slower than P-waves, and speeds are typically around 60% of that of P-waves in any given material.

Strike-slip (also transcurrent, wrench, or lateral) fault – rock displacement in a horizontal direction. The fault plane is essentially vertical.

Subduction - is a geological process that takes place at convergent boundaries of tectonic plates where one plate moves under another and is forced or sinks due to gravity into the mantle. Rates of subduction are typically in centimeters per year, with the average rate of convergence being approximately two to eight centimeters per year along most plate boundaries. The subducting litosphere plate in a subduction zone is a plate with oceanic crust, and moves beneath the other litospheric plate, which can be made of either with oceanic or continental crust.

Subduction zone – region where the subduction process occurs.

Submerged continent - or sunken continent, is a continental mass, extensive in size, but mainly undersea. The terminology is used by some paleogeologists and geographers in reference to some land masses. The two main examples in this class are the Kerguelen Plateau and Zealandia.

Surface Wave - travel along the Earth's surface. They can be classified as a form of mechanical surface waves. They are called surface waves, as they diminish as they get further from the surface. They travel more slowly than seismic body waves (P and S). In large earthquakes, surface waves can have an amplitude of several centimeters.

Surface water – water in streams, rivers, lakes, wetlands, and reservoirs; natural water that has not penetrated much below the surface of the ground.

Symmetrical fold – fold in which the axial plane is vertical. It has two symmetrical limbs.

Syncline – folded rocks, the fold is concave upward.

T

Tectonic klippe - an eroded, isolated remnant of the older rock or nappe, which is completely surrounded by the younger, underlying rock. The klippe is the remnant portion of a nappe after erosion has removed connecting portions of the nappe. This process results in an outlier of exotic, often nearly horizontally translated strata overlying autochthonous strata.

Tectonic window – a patch of younger, underlying rock, which is exposed and completely surounded by the older rock. It is a consequence of erosion, which cut into the nappe so deeply into the underlying nappe. Windows generally occur in topographic basins or deep, V-shaped valleys. Windows can be almost any size, from a couple of metres to hundreds of kilometres.

Tectonic plate – are bodies of brittle external layer of Earth made of crust and uppermost mantle together referred to as the lithosphere. The thickness of the lithosphere is considered to be the depth to the isotherm associated with the transition between brittle and viscous behaviour. The plates thickness is different in case of oceanic crust and continental crust and could vary from less than 50 km to over 200 km thick.

Tephra (pyroclasts) - solid material ejected into the air during a volcanic eruption.

Tertiary - former term for the geologic period from 66 million to 2.58 million years ago - the time from the end of the Cretaceous period to the start of the Quaternary period. Today, we use a different system, but the name Tertiary is still common for the first part of the Cenozoic Era. Instead of Tertiary, Neogene and Paleogene are in use. This is the period of the emergence of mammals, following the extinction of the DINOSAURS.

Terrestrial planet - or telluric planet, or rocky planet is a planet that is composed primarily of silicate rocks or metals. Within the Solar System, the terrestrial planets are the inner planets closest to the Sun, i.e. Mercury, Venus, Earth, and Mars. The terms "terrestrial planet" and "telluric planet" are derived from Latin words for Earth (Terra and Tellus), as these planets are, in terms of structure, "Earth-like".

The rock cycle - illustration of the interrelationships between earth materials and processes - the three rock types are transformed into one another by processes of weathering and erosion, melting and exposure to heat and pressure.

Thrust fault – are reverse faults that dip less than 45°.

Torrent - fast-flowing water, like a rainstorm or creeks and rivers that overflow their banks.

Triassic - is a geologic period which spans 50.9 million years from the end of the Permian (252 million years ago), to the beginning of the Jurassic (201 million years ago). The Triassic is the first period of the Mesozoic.

Tsunami - a series of large waves produced by the displacement of a large volume of water due an undersea earthquake or landslide.

Tuff ring –one of the results from phreatomagmatic eruptions. They are commonly less than 50 m high and are defined by craters with small depth to width ratios at or above ground level and low eject rims of hydroclastic debris.

U

Underground water - means a supply of water that may be developed by any type of well or spring from beneath the surface of the ground whether the water flows from the well or spring by natural force or is withdrawn by pumping, other mechanical device, or artificial process.

V

Vent (main pipe) - A volcanic vent is that spot in the Earth's crust where gases, molten rock, lava and rocks erupt. Volcanic vents can be at the top of some of the largest volcanoes on Earth, like Hawaii's Mauna Kea, or they can be openings in the Earth's crust down at the bottom of the ocean. The shape of the volcanic vent can sometimes define whether the volcano is explosive or not.

Volcanic activity – Volcanoes can be active, inactive or extinct. Active volcanoes still have eruptions. Inactive volcanoes have infrequent eruptions and extinct no longer have eruptions.

Volcanic ash - in a volcanic eruption, magma is blown apart by volcanic gases and steam. The products are volcanic gases, lava, steam, and tephra (fragments). The solid material produced and thrown into the air is called tephra, regardless of composition or fragment size. If the pieces of ejecta are small, the material is called volcanic ash, defined as such particles less than 2 mm in diameter, sand-sized or smaller.

Volcanic block - a solid piece of rock, measures more than 64 mm, that has been expelled from a volcano during an eruption and existed before being ejected by a volcanic eruption.

Volcanic bomb - a volcanic block with streamlined appearance, often expelled in a molten state.

Volcanic eruption – A volcanic activity that allows magma, gases, ash and rocks to move up and emerge from the interior of a volcano. Eruptions are often sudden and violent.

Volcanic remnant hill – eroded remains of a former volcano.

Volcano – An opening in the earth's crust. Magma, gases, rock fragments, lava and ash are expelled from the opening or vent. It is often shaped like a mountain.

Volcanoclastic /Volcanoclastic rock - is a rock, composed primarily of volcanic material. This material may be pyroclastic (fragments derived from explosive volcanism) or hyaloclastic (fragments formed by thermal shock when hot lava comes in contact with cool sea or lake water). Volcaniclastic includes all volcanic particles regardless of their origin.

Volcanologist - a scientist, who studies volcanoes.

Volcanic arc – is a chain of volcanoes formed above a subducting plate, positioned in an arc shape as seen from above. Offshore volcanoes form islands, resulting in a volcanic island arc. Generally, volcanic arcs result from the subduction of an oceanic tectonic plate under another oceanic tectonic plate, and often parallel an oceanic trench. The water in oceanic plate drastically lower the melting point of the mantle. The subducted oceanic plate is a subject to greater and greater pressures with increasing depth. The pressure squeezes water out of the plate and introduces it to a mantle. Here the mantle melts and forms magma at depth under the overriding plate. The magma ascents to form an arc of volcanoes, parallel to the subduction zone.

W

Water - a colorless, transparent, odorless, liquid which forms the seas, lakes, rivers, and rain and is the basis of the fluids of living organisms. A compound of hydrogen and oxygen (H2O), freezing at 0 °C and boiling at 100 °C.

Water cycle - also known as the hydrological cycle or the hydrologic cycle, describes the continuous movement of water on, above and below the surface of the Earth.

Weathering - is the breaking down of existing rocks, and minerals due to physical, chemical and biotic processes through the contact with the Earth's atmosphere, waters, and biological organisms.

GEOLOGICAL HERITAGE

Anthropocene - define s Earth's most recent proposal for a geologic time interval as being umaninfluenced, or anthropogenic, based on overwhelming global evidence that atmospheric, geologic, hydrologic, biospheric and other earth system processes are now altered by humans. The Word combines the root "anthropo", meaning "human" with the root "-cene", the standard suffix for "epoch" in geologic time.

Conservation - using natural resources carefully and wisely.

Cultural heritage – is the legacy of tangible and intangible representations developed by a community and passed from generation to generation. Cultural heritage includes tangible cultural heritage such as buildings, monuments, landscapes, books, works of art, and artifacts, and intangible cultural heritage such as folklore, traditions, language, and knowledge, and natural heritage including culturally significant geodiversity and biodiversity components or representations.

Fossils - preserved body remains or moulds, impression, trace of any once-living form in the past geological times, like teeth, bones, shells, exoskeletons, imprints, petrified remains, oil, etc. The process of preservation is called fossilisation and the totality of fossils is known as the fossil record.

Geoconservation – a relatively new area of nature conservation aiming to preserve the natural diversity of the non-living environment (geodiversity). Also could be defined as the identification and care of sites which make a special contribution to our Earth heritage and which can illustrate the Earth history. The strong evolution of geoconservation during the last years makes it a new branch of applied geosciences with its own concepts and specific activities in geodiversity assessment, geoeducation, geotourism and geoparks. In this sense the aim of geoconservation is to identify the geodiversity values in connection with biodiversity and cultural values for a proper management and conservation.

Geodiversity – is the variety of earth materials, forms and processes that constitute and shape the Earth at the global and local level. Geodiversity components are variable in time as result of former processes or ongoing ones and being continuously transformed including complete removal.

Geoeducation – all tools, materials and indoor and outdoor activities describing educational experience dedicated to teach and learn about Earth geodiversity and its impact on life and human activities. Geoeducation provides people with the knowledge of how the human and natural worlds work at local, regional and global scales, and to use different perspectives to understand the world. Geoeducation is part of geoconservation and in a broader sense of education for sustainable development.

Geoheritage or Geological heritage – part of geodiversity identified as being important from the cultural, scientific, educational and touristical point of view and worthing to be preserved.

Geopark – Global Geoparks are unique geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development on the benefit of local communities.

Geoproduct - a product related to geopark activities, inspired by local geodiversity or geologic heritage and having a socio-economic impact.

Geosite – or geological site or geotop is an area were geodiversity has special or distinguishing features expressing a specific geologic framework worthing to be preserved and managed for research, education or tourism.

Geotourism - is tourism which sustains and enhances the identity of a territory, taking into consideration its geology, environment, culture, aesthetics, heritage and the well-being of its residents. Geological tourism is one of the multiple components of geotourism.

Global warming - scientist are concerned about global warming due to the greenhouse effect. If the atmosphere continues to get warmer, there is a concern, that the polar ice caps would melt and then a new ice age could begin.

Greenhouse effect - caused by too much carbon dioxide in the atmosphere. Carbon dioxide is produced by fossil fuels when they are burned. Carbon dioxide traps the sun's heat. That is why it is called the greenhouse effect. The trapped heat causes global warming.

Mental map - is a person's perception of their area of interaction.

The Case Study on Geology of the Novohrad-Nógrád Geopark

Novohrad-Nógrád UNESCO Global Geopark (Transnational Slovak-Hungarian Geopark).

Geological Framework.

The geological heritage of the Novohrad-Nógrád Geopark (Transnational Slovak-Hungarian Geopark) represents depositions over the last 30 million years, from the upper Oligocene on, commencing with the initial opening of the Pannonian basin. The geology of the region is the product of the collision of accreted terrains with a consequence of highly complex volcanism spanning 20 million years, the destruction and reactivation of marine basins, burial and the conservation of terrestrial palaeohabitats.

These events created a unique landscape to which man has added his contribution. Cave dwellings were carved in the sedimentary rocks, the crests of the andesite and basalt dykes and the rising peaks of volcanic vents are marked by the ruins of medieval castles.

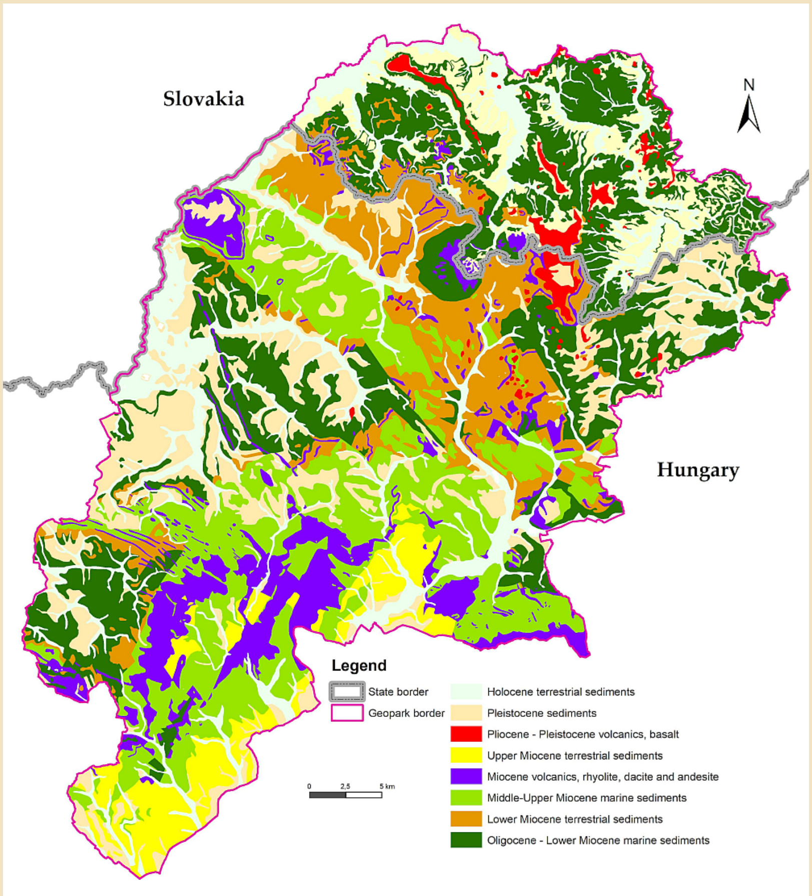


Fig. 1.40. Simplified Geological Map of the Novohrad-Nógrád Geopark

The Case Study on Geology of the Novohrad-Nógrád Geopark

International Geoheritage.

There are volcanic sites of international interests like the Somoska basalt and the Bér columnar andesite as well, some are illustrated by photographs attached to volcanism.

Besides these, some fossil sites of the geopark are also recognised globally.

The Bone Ravine.

It is the most important fossil locality on the Slovakian side. Animals got trapped in a Plio-cene maar-lake and their skeletons got fossilised. Predominantly mastodons, rhinoceroses and tapirs, but panda bear, remnants of monkey, hyena bones were also excavated. It is a type locality for NM 16 zone of the European Neogene Biostratigraphic Scale.

The Ipolytarnoc Fossils Nature Conservation Area.

It is a world-recognised "Prehistoric Pompeii" due to a volcanic catastrophe, which destroyed and at the same time conserved a terrestrial paleohabitat some 17 million years ago. This Lagerstatten is considered one of the prime fossil sites in Central Europe. The site itself is the main gateway to the Geopark and it has become one of the most visited geotouristic destinations in Hungary.

Shark-teeth: The Lower Miocene reworked shoreline sandstone layers bear a very diverse shark community with wide habitation range that includes 19 genera with 16 certain species. This so called "shark tooth-bearing bed" also contain a mixture of remains from rays, dolphins, manatees and crocodilians.

Petrified trees: A whole forest was destroyed and silicified by the volcanism, at least 7 coniferous, 4 deciduous and 1 palm species co-existed, including a newly identified fossil laurel holotype.

Leaf impressions: A recent paleobotanical study identified 64 taxa among the large collection of macrofloral remains, this extremely laurophyllous flora is classified as „Florenkomplex Ipolytarnóc".

Ichnofossils: Abundant and well-preserved fossil vertebrate footprints have been excavated, studied and reinterpreted since the year of 1900, so far at least 40 taxa of vertebrates are known with 11 certain species.

The Case Study on Geology of the Novohrad-Nógrád Geopark

Ex situ fossils - Bükkábrány trees: In front of the Visitor Centre 7 million-year old, still wooden, white cypress and redwood-relative fossil tree trunks, rescued from the Bükkábrány lignite open-pit mine are sheltered.

Fig. 1.41. Million-year-old footprints at Ipolytarnoc Fossils

Sedimentary Rocks.

There are Oligo-Miocene and Middle-to Upper Miocene marine sedimentary rocks (limestone, marl, shale, sandstone, calcarentite etc) and diverse Miocene- to Holocene terrestrial sediments (conglomerate, sand, aleurite, aliginite, variegated clay, browncoal, lignite, loess, travertine etc) which were deposited on the basins of the Geopark. Some of these sediment layers yielded exceptional fossils like the so called Ipolytarnoc beds.

Fig. 1.42. Fluvial sediments of the Paris-gorge at Nógrádszakál (Hungary)

The Case Study on Geology of the Novohrad-Nógrád Geopark

Magmatism

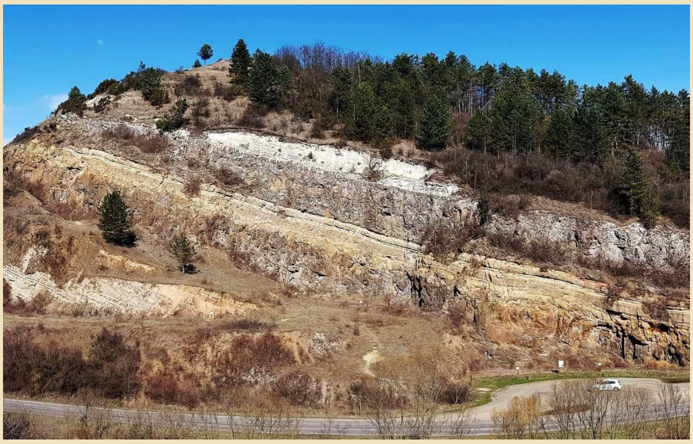
The main exposed igneous rocks of the Geopark are diverse extrusive (volcanic) ones, the intrusive (plutonic) rocks are not so varied. The later are deeply eroded vents and feeder dykes of andesite and basalt volcanoes and exposed magmatic, subvolcanic bodies (laccoliths) with the contain of garnet and peridotite fragments (xenoliths) in basalt lava from the upper mantle. There are large granodiorite blocks in Miocene lahar with outside origin.

The huge variety of Neogene volcanism includes pumice flows, rhyolitic ignimbrites, dacite and andesite composite volcanoes formed both in submarine and terrestrial environment, a basalt plateau which is noted amongst the largest uninterrupted examples in Europe, maar diatremes and not only columnar basalt but also rare examples of columnar andesite

Fig. 1.45. Composite andesite volcano of Sámsonháza (Hungary)

Fig. 1.46. Faulting in calcarenite on the walls of the Szentkút hermit caves (Hungary)

The Case Study on Geology of the Novohrad-Nógrád Geopark



FFig. 1.45. Composite andesite volcano of Sámsonháza (Hungary)

Metamorphism.

Granulite xenoliths in volcanic rocks and quartzite, schist, gneiss, phyllite, slate etc pebbles in gravel can be found with some metamorphism along the contact zones of igneous and sedimentary rocks, but outcropping large intact bodies of metamorphic rocks are not known within the Geopark.

Geological Structure.

The Savian orogeny created a horst and graben structure with normal faults within the territory of the Geopark. Vertical movements along dip-slip faults reached 250-400 m. Later orogenies, up till the Rhodanian produced additional sets of longitudinal and transversal faults.

Fig. 1.46. Faulting in calcarenite on the walls of the Szentkút hermit caves (Hungary)

The Case Study on Geology of the Sierras Subbéticas Geopark

Sierras Subbéticas UNESCO Global Geopark (Spain)

Geological Framework.

Sierras Subbéticas Geopark constitutes an exceptional example of the External Subbetic Zones of the Betic Cordillera, a critical part of the Alpine Cycle in the Iberian Peninsula. It contains rock deposited in a marine platform to the south of Sierra Morena (Variscan Domain) during the Mesozoic. Therefore, the rocks of Sierras Subbéticas can provide information about the complex evolution of the Tethys Ocean since the last 250 ma. This encompasses phenomena like fluctuation of the water column, advance and retreat of the coastline, evolution of fossils organisms, etc.

During the Miocene (20-10 ma ago), the collision between Africa and Iberia caused the uplift of the Betic Cordillera. The rocks deposited in the Mesozoic marine platform conform nowadays the mountains and valleys of the geopark. Recent erosive processes have modelled an impressive and renowned karst landscape.

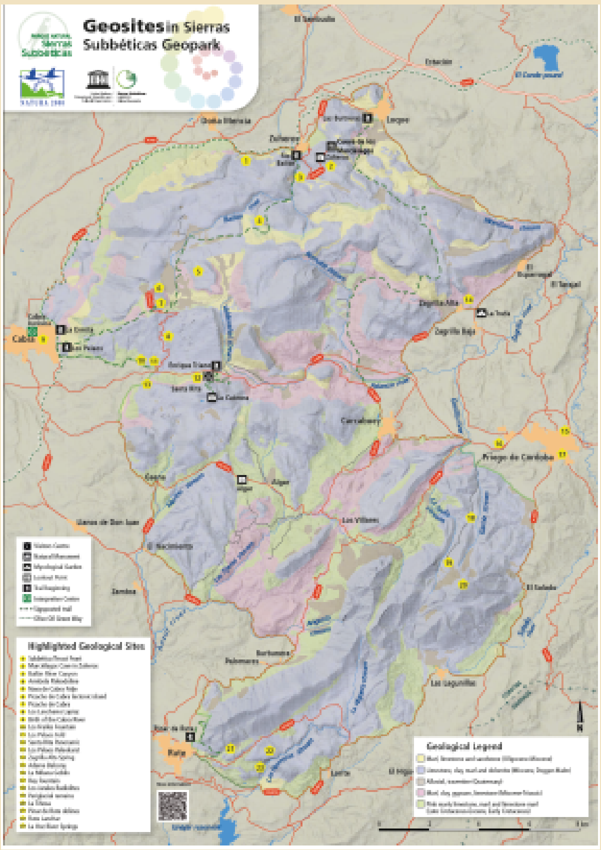


***Fig. 1.47. Simplified geological mp of Sierras* Subbéticas Geopark indicting the location of the main geosites.**

The Case Study on Geology of the Sierras Subbéticas Geopark

International Geoheritage.

There are two internationally reputed items in Sierras Subbéticas Geopark. The intense kastification of carbonate and dolomite rocks has resulted in a plethora of solution and precipitation structures, beautifully preserved. These include poljes, dolinas, sinkholes, lapiaz, canyons, ponors, springs, caves, galleries, speleothems, travertines and even palaeokarst expressions, all the possible structures that one can expect in a karstic environment.

The other widely known aspect of Sierras Subbéticas is the impressive abundance and diversity of ammonites. This cosmopolite group of Mesozoic molluscs, common in ancient Jurassic and Cretaceous oceans, is particularly well represented in this Geopark. Apart from their paramount aesthetic value, the ammonites from Sierras Subbéticas has a clear scientific relevance, providing a solid biostratigraphic constrain to the entire region. Many species has been defined and formerly described here and nowadays they forms part of biostratigraphic schemes used for the age assignation of coeval territories. In addition, the Jurassic Cretaceous boundary outcropping in the geopark has been intensely studied, and it has been postulated as a Global Boundary Stratotype Section.

Fig. 1.48. La Nava Polje, one of the most
spectacular karst structure in Sierras Subbéticas Geopark.

The Case Study on Geology of the Sierras Subbéticas Geopark

Fig. 1.49. Outcrop of the Ammonitico Rosso Formation in Sierras Subbeticas, the unit that most characteristically exhibits the Jurassic ammonite fauna.

Sedimentary Rocks.

Sedimentary rocks are by far the most abundant in the geopark. From base to top they consist of Triassic red beds including evaporates and minor limstones, a Jurassic sequence of limestones showing different facies with minor intercalations of marls, and a thick and monotonous sequence of Cretaceous marls. Above this Mesozoic series, minor Tertiary marls and sandstones are scattered throughout the territory.

Magmatism

The igneous rocks in the geopark are scarce, consisting all of mafic subvolcanics of different ages. Dispersed in the territory, there are minor outcrops of Triassic diabase rocks showing ophitic texture, and close to the eastern margin, there is an intrusive laccolith of dolerites intensely weathered, Lower Jurassic in age.

The Case Study on Geology of the Sierras Subbéticas Geopark

Fig. 1.50. Sky view of the Jurassic laccolith outcropping to the southwest of Priego de Córdoba.

Metamosphism.

There is not metamorphic rocks mapped in the territory, although within the soil surrounding the laccolith mentioned above, it is possible to find some small grains of marble as product of the contact metamorphism associated to the injection of the mafic subvolcanics.

Geological Structure.

The Mesozoic rocks comprising the geological framework of the geopark were all deformed during the Alpine Orogeny, in the Miocene. The deformation pattern consists of a northward thin-skinned thrust and fold belt with the detachment levels located in the Triassic red beds. Associated to this deformation, the geopark shows very didactic examples of tectonic klippes, folds and normal faults. In addition, the northern border of the geopark represents the thrust front facing toward the northern foreland Guadalquivir basin.

The Case Study on Geology of the Sierras Subbéticas Geopark

Fig. 1.51. Betic Thrust Front at the northern border of Sierras Subbéticas Geopark.

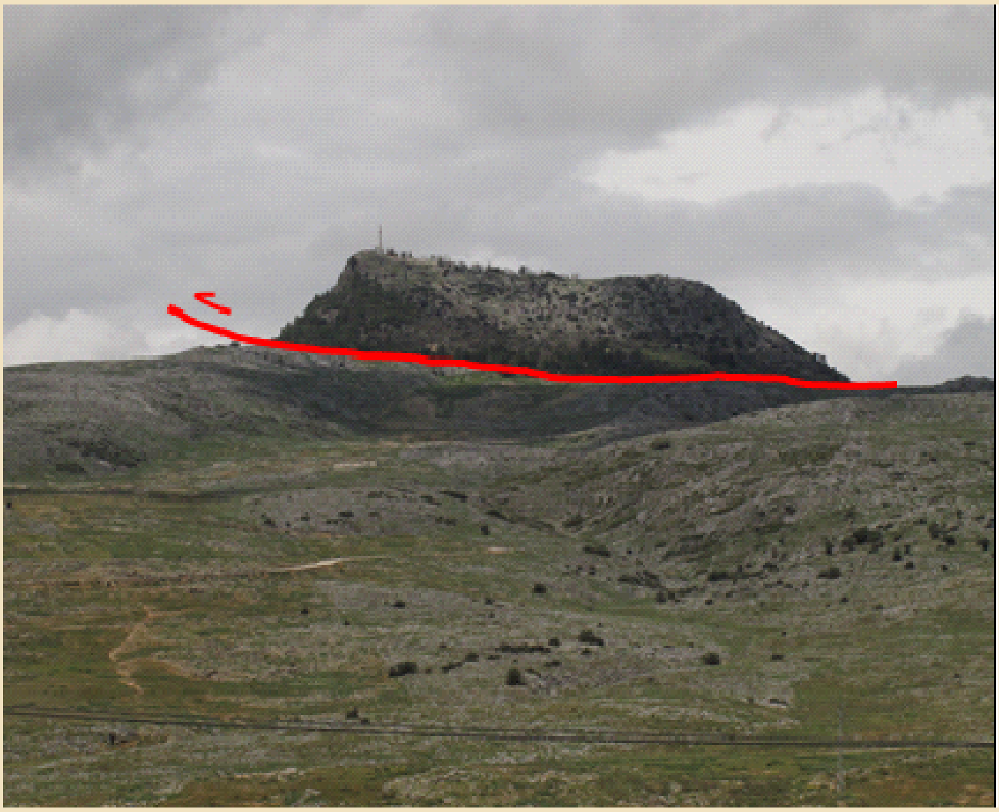


Fig. 1.52. The Picacho de Cabra, a tectonic clippe conformed by Lower Jurassic dolomites thrusting over middle to upper Jurassic limestones.

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