CHAPTER 8

# Natural resources and mankind

**Key words:** Fossil fuel, coal, oil, reservoir rock, geothermal energy, renewable resources, raw material, karst, cave, artesian springs, gravity springs, drilling, underground water.

## Introduction

Modern human life is dependent on energy for lighting, heating, powering industry, transportation and communication. Most of this energy comes from rocks, from the fossil fuels stored in the rocks of the Earth's crust. These fossil fuels are: a) Coal formed from fossil plants, b) Oil formed from fossil animals and c) Natural gas which can originate from both sources. These are characterised as fuel fossils, because they contain energy trapped by living organisms in the past. Coal, oil and gas remain the dominate resources on the global energy market, although the demand for energy increases continuously.
Man is always searching for new geological sources such as geothermal energy (section 8.6.) and methane hydrates. Methane hydrates, also known as "methane ice" consist of methane chemically combined with water. They are often found in the seabed in areas where continental plates meet at depths of 500 - 1,000m. It has been suggested that their energy reserve is twice as that of coal, oil and natural gas combined. Methane hydrates were found for first time in 1971 in the Black Sea and they could help meet future energy needs.

## 8.1. How coal deposits were formed

Coal is a sedimentary rock formed from the remains of trees and other plants under special environmental conditions – for instance under hot and wet tropical climates in areas of swampy ground. The processes necessary for dead plants to be preserved and altered into coal are:

- The quantity of plants must be enough so that a thick deposit can build up.
- The dead plants must accumulate under hot and wet conditions, such as in a swamp, where little oxygen is available and hence they do not rot.
- The plant remains have to be buried by other sediments, such as sands, clay and silts. The weight of these sediments squeezes and compacts the underlying organic remains.
- Chemical changes take place slowly, water and gases escape and the remaining material becomes richer and richer in carbon, leading to long-term preservation.

The amount of concentrated carbon in coal is dependent on the types of plant and the duration and the depth of burial. Coal can classified into four categories (the '*coal series*') according to the thermal capacity of the concentrated carbon:

1. *Peat*: This has a low thermal capacity (40-50% carbon and 50-60% water content) and was mainly formed during the Quaternary Period and continues to form to the present day.
2. *Lignite*: With a good thermal capacity (70% carbon and 20-30% water content). Lignite in Europe mainly dates from the Palaeogene Period to the Lower Quaternary Period (i.e. the Pleistocene Epoch). There are also deposits of Cretaceous lignite in Europe.
   In Greece lignite is the most important source of Energy. Two lignite deposits are mining, the lignite deposits of Ptolemais (N. Greece) formed during the Pliocene period and those of Megalopolis (S. Greece) formed during the Early Pleistocene period.
3. *Bituminous coal*: This has a very good thermal capacity (75-90% carbon, 2-7% water content) and in Europe was mainly formed during the Carboniferous Period, although there are smaller deposits of Jurassic and Palaeogene age.
4. *Anthracite*: This has the best thermal capacity (92-98% carbon content) and is relatively hard and the best quality coal. It was mainly formed during the Carboniferous Period, where tectonic conditions were favorable (i.e. warming during deep burial).
   Most of the coal deposits in W. Europe and N. America were formed around 300-280 million years ago during the Carboniferous Period.

## 8.2. How the oil is formed

Oil is formed in sediments under the sea when large amounts of dead plankton (i.e. billions of organisms!) become incorporated into sea-floor sediments as they die and sink to the seabed. These sediments, under favorable conditions, can be the source rock for oil and gas. This process usually happens in the fine muds of off-shore regions, where there is little oxygen and hence the organic remains do not rot away. The best areas are sedimentary basins, in which the sediments have been buried deep enough to mature and generate oil, but which have not been intensively deformed by an orogeny, only folded enough to produce trap structures to hold the oil.
Oil and gas usually tends to move away (i.e. migrate) from the source rock, through porous rocks such as sandstones. These porous, permeable rocks can be the reservoirs for holding oil and gas. But over these porous rocks there needs to be a seal, a sedimentary unit with low permeability blocking their escape from the reservoir rock.
Oil has become the most important source of energy today, because it has a high energy content, is relatively abundant, can be processed into a range of products (tar, diesel, paraffin, etc.) and can be easily transported. In addition, oil is the raw material for many chemical products, plastics and artificial fibres such as nylon.
Every day, people consume about 88 million 'barrels' of oil globally. Natural gas, however, is used mainly as a fuel for heating.

## 8.3. Why oil is so expensive

The oil is trapped at depth in rocks and the research, drilling, extraction and refinement needed to use this resource is very expensive. In parallel, the price of oil follows economic trends of supply and demand - and as the demand for oil is still increasing, especially from emerging markets such as China and India, as no other abundant and safe alternative is usually available. Political and other economic reasons also play a role in determining the price of oil.

## 8.4. What is the difference between coal and oil?

Both coal and oil are fossil fuels formed million years ago from decaying plants or animals. The main differences are the organic source material and whether they were formed in the sea or on land. Coal was normally formed in wet areas on land from dead plants and is a solid material; oil, however, was formed in the sea from planktonic animals and protists and is liquid.

## 8.5. About renewable resources (e.g. geothermal energy)

Renewable resources of energy come from wind, sunlight, water flow and geothermal heat extracted from inside the Earth. The geothermal resources of the Earth are generally limited to areas near the boundaries of tectonic plates, but they are potentially sufficient to supply the energy needs of humanity. However, only a small amount of this energy may be exploited, because the exploitation of deep resources is very expensive. This energy, however, is sustainable and environmentally friendly and in many cases could replace fossil fuels. It requires only limited areas of surface land and its application in home heating, agriculture; desalinisation and industrial processes can be very efficient and successful.

Geothermal energy has been well known since ancient times (Palaeolithic epoch) as hot springs have been harnessed for bathing as well as in Ancient Roman times. From the beginning of 20$^{th}$ century, geothermal energy has also been used to generate electricity. Since then, many technologies have been developed to better exploit heat from the Earth.

In Greece, due to its geographical position, has many opportunities to develop geothermal resources, in places such as Milos, Nisyros, Santorini, Lesvos islands, Platy, Thermopyles and Soussaki. In many others regions, investigations have also had positive results.

**More examples:**

***Natural resources of Austria***

The main natural resource in Austria is water, providing drinking water and the driving power for hydroelectric power plants. Austria has only limited amounts of other mineral resources, however, such as crude oil and natural gas, iron ore and few rocks for building stones. Most rocks are used for the production of aggregate, including the production of cement. Gravels are extracted from river deposits. The most precious resource, however, are the fertile soils (e.g. Löss or loess).

***Natural Resources of Italy***

*Water:* Providing drinking water and water for hydroelectric power plants. Water for electrical energy is mainly used in the north of Italy.

*Oil:* Drilling for oil in Italy has taken place both on land and on the sea-bed. Apart from Basilicata, which is historically the area with most oil-wells (70% of national oil is extracted from oil-fields in Val d' Agri, Basilicata), there are also concentrations of oil-wells in Emilia Romagna, Lazio, Lombardia, Molise, Piemonte and Sicily.

*Methane:* Methane (i.e. natural gas) is extracted almost exclusively in the south of Italy.

*Coal and lignite:* There are several coal deposits in Sardinia, whilst there are lignite deposits in Calabria, Basilicata and central Italy. There is no on-going mining activity at present.

*Geothermal energy:* At present geothermal energy represents 10% of the energy from renewable sources in Italy, but it is predicted that the figure might soon double. It is exploited mainly in Tuscany.

*Metalliferous minerals:* In Sardinia, where the oldest rocks in Italy are found, deposits of sphalerite (zinc sulphide) and galena (lead sulphide) are exploited. The iron deposits mined on the island of Elba are almost exhausted. Monte Amiata, an ancient volcano, is still rich in minerals containing mercury. In Val Graveglia (Liguria) manganese is mined. Gold is also to found in Italy, albeit in small quantities - the sands in the rivers Ticino, Sesia, Dora, Adda and Orba contain some gold and were exploited at the time of the Roman Empire.
*Materials for building and ornamental stones:* Italy is the major world supplier of pumice, which is obtained principally from the island of Lipari. There are significant porphyry quarries in Trentino, tufa quarries in the south of Italy, granite in Sardinia and alabaster in Sicily. Italy is also an important producer of marble. Italy is also the second largest producer in Europe of crude steel and cement.
*Wind energy and photovoltaic energy:* At present there is an increase in photovoltaic energy production in Italy; in 2012 amounting to 18.3 TWh. Wind energy represented 13.1 TWh in 2012 covering 9.6% of national electricity supplies. Puglia and Campania lead wind-produced energy, accounting for 5% of their area's own electrical energy consumption and 50% of total wind energy generated in Italy.
*Salt:* Common salt (sodium chloride). In Italy there are various salinas, the largest of which is in Sicily (Trapani), which extract salt from sea-water. There are also salt-mines that extract Messinian rock salt at Realmonte and Petralia (Sicily), the latter being the largest salt-mine in Europe.

***Natural Resources of Portugal***

Exploitation of natural resources in Portugal goes back to the Lower Palaeolithic with the extensive mining of flint from sedimentary rocks near Lisbon and quartzite cobbles from the fluvial terraces. The natural resources of Portugal can be divided into metalliferous minerals (16 different metals have been mined historically), industrial minerals (14 mined and 8 quarried), ornamental rocks and energy and hydrogeological resources.
Gold (and to a lesser extent silver) was widely exploited from at least the Bronze Age until the 1980s, but with a climax during the Roman times ($1^{st}$ -$3^{rd}$ centuries B.C.), from large placer, open cast and subterranean mines. Tin (from cassiterite) was also mined, mostly from placers, from the Bronze Age and peaking during the $20^{th}$ Century for the canning industry. As well as tin, this metallogenetic province also yielded tungsten, which was extensively exploited between the 1930s and 1950s for ferberite and scheelite - including as one of the main sources of tungsten for Nazi Germany. Panasqueira mine is still operating as one of the most important in Europe. The most important mine today, however, is Neves-Corvo, extracting copper, tin and zinc from the Iberian Pyrite Belt.
Important industrial minerals are gypsum, feldspar, lithium (Portugal is the world's $5^{th}$ most important producer), quartz and rock salt (halite). The most important industrial rocks are, in order: limestone and granite aggregates, common sand, limestone for cement, clays (ball clay and china clay) and specialist sands. Ornamental and building stones are very important, with 150 different commercial types, including marbles (that have been quarried from at least 370 A.D. in Alentejo), slates and schists, limestone breccias, limestones, diorite and gabbro, granites, porphyries, quartzite, volcanic rocks in the Azores and Madeira archipelagos and serpentinites and nephelinic syenite from the Monchique pluton. Mineral and spring waters are mostly distributed in the Iberian Massif and represent a value of 290 million €/year globally.
Energy resources are scarce representing still 58,3% of the total electricity produced in 2013 by renewable sources such as hydroelectric (28,9%), wind (23,2%), biomass (5,3%) and solar (0,9%) power plants. The production of electricity in country's mainland, based on renewable energy sources, was in 2013 more than 29TWh. Geothermal resources are locally important in the Azores archipelago (20% of the electricity consumed) and uranium was mined between 1951 and 2001 at an average of 143t/year, during the climax in the 1980s, for export. Portugal has the

most important uranium reserves in the EU.
In 2009 there were 1009 mining concessions operating in Portugal, about half of them related with ornamental and building stones. However, the 5 mines exploiting metals still represent 45% of the profit taken by the mining industry in Portugal, representing more than 1100 million € annually and providing work for around 9000 people (in 2010).

***Natural Resources of Spain***
Natural resources in the Iberian plate are abundant and have been intensively mined since early Iberian times (1000 to 200 B.C.) - before the Romans invaded. Metallic minerals were mainly exploited, mainly haematite, sphalerite, cinnabar, cassiterite, chalcopyrite and galena, in the search for iron, copper, tin, mercury and lead. Gold and silver, as native metals, were also intensely mined. The arrival of Romans in Iberia led to agreements with native tribes in different regions and a more effective, ordered and intensive mining system. Most of the main mining areas of these times have remained active until recently and many of them continue in production.
The most important metal ores are associated with intrusive processes related to the Caledonian and, especially, the Variscan orogenies. The successive collision of different continental plates against the continent of Laurentia led to the subduction of the Rheic Ocean between, below the continental block and compression of the continental crust above. This lead to the intense local generation of magma which as it rose produced a hydrothermal phase leading to the generation of enormous mineral resources. The successive phases of the Variscan Orogeny appear today as concentric, parallel bands of different metamorphic units forming the Iberian Massif in SW Iberia and S Portugal. The large band of mineralisation known as the 'Iberian Pyritic Belt' (*Faja Pirítica*) formed at this time and holds what may be the most important metal ore concentration in Europe. A later, lateral migration of hydrothermal fluids that contaminated the continental crust further east led to the formation of the enormous mineral deposits of cinnabar, the main mineral of mercury (Hg) in the region of Almadén (SE Iberia). Large mining operations in these areas are still active today.
Gold mining has been active for a long time in Iberia, the main sources for gold being mainly of sedimentary origin. Post orogenic (i.e. Alpine) alluvial sediments of Oligocene-Miocene age have been mined for gold in NW Iberia (Galicia) in the fluvial deposits of river Sil, in the NW part of the province of Leon and in the southern margin of the Cantabrian mountains, where large amounts of gold were concentrated. The exploitation of these materials by the Roman technique known as "*Ruina Montium*", which provoked the collapse of a hillside by the injection of water at high pressure, led to the formation of a unique landscape in the area known as "*Las Médulas*", which has now been listed as World Heritage. Native silver has also been the subject of intense mining from Roman times to the late 18$^{th}$ Century. The most important sites were also along the Iberian Pyrite Belt, from SW to NW Iberia and the boundary with Portugal, in what is traditionally known as the "Silver trail".
Coal mining has been very active in the Upper Carboniferous rocks of the Cantabrian Mountains. The origin of the enormous coal deposits of Asturias and León (N Iberia) was the large concentration of plant remains in internal or coastal sedimentary basins at equatorial latitudes, during the closure of the Rheic Ocean. Coal mining traditions in Asturias go back to the 18$^{th}$ and 19$^{th}$ centuries, although it probable that some working took place long before, in pre-Roman times. Production of lignite has also taken place from Mesozoic rocks of Lower Cretaceous age in the Iberian Range. This 'brown coal' formed from large amounts of continental plant remains which accumulated on the eastern Iberian margin when it was temporarily emerged (this includes the "*Escucha Formation*" of Teruel Province).
The search for petroleum in Spain has for long not been very successful, despite the apparent potential of Upper Jurassic-Lower Cretaceous sediments, including the presence of folded units as potential oil traps. The reason is probably the intense folding which affected the area, which

led to the migration and/or disappearance of existent oil reservoirs. Nevertheless, some good reserves have now been found and developed from Upper Jurassic deposits of North Castilla (in the region of Bureva, N. Burgos and adjacent areas), in the Cantabrian Sea, off the Mediterranean coast near Tarragona and, more recently, in the Cenozoic basin of the river Guadalquivir (S. Spain).

## 8.6. About soil, rocks and minerals providing essential metals and other materials for agriculture, manufacturing and building

Soil is the product of weathered rocks and composed of rock particles associated with organic materials which have been altered by physical, chemical and biological processes. Soil is the essential basis for agriculture.

Minerals and metals are exploited from specific ore deposits in mines or quarries and provide the raw materials for society. Some specific minerals for the construction of electronic and mechanical devises are very rare and only present in low percentages.

## 8.7. About raw material

A raw material is a material in its primary state as harvested, mined or quarried and before its refinement for use. Examples of raw materials are: wood, bauxite, iron ore, iron, gold, silver, kaolin (china clay), oil, etc.

Any country that has raw materials in abundance can be economically strong internationally as it has the possibility to export these raw materials to other countries, as well as covering its own needs.

## 8.8. About the sustainable exploitation of geological resources

Sustainable exploitation of geological resources such as metals, industrial minerals, water, fossil fuels, etc., can help to ensure the availability of these resources for future generations. Geoscientists support global cooperation and collaborative research that can help wisely manage raw materials and human resources.

## 8.9. Why and how water is stored as underground

Rainfall, melting snow and ice either flows on the Earth's surface as streams and rivers, or is absorbed by the soil into the ground where, depending on the geological conditions, it can be stored underground in rock fractures and in pores between the grains that make up geological formations (e.g. sandstones).

Underground water is the source for aquifers, springs and wells. The upper surface of groundwater is the water table.

## 8.10. How caves and other underground landforms are formed

Caves are underground karstic formations. Karst formations are limited to areas where solu-

ble rocks such as carbonates (limestones and dolomites) and sulphates (gypsum and anhydrite) are present. As these rocks are easily dissolved and hence eroded by water, shallow holes, sinkholes and caves can be formed.
A cave is a natural underground hole, into which a man can enter. As the water flows in a cave, it erodes and washes away the rock and hence it becomes larger and larger. To form a cave, hundreds or thousands of years, or even millions, are needed, depending on the nature of the geological formation. During this long period of time, slowly dripping water from the fractures in the ceiling of cave can lead to deposition of dissolved calcium carbonate as beautiful structures such as stalactites (hanging from the cave roof), stalagmites (growing from the cave floor) and columns, when stalactites and stalagmites meet.

## 8.11. About water management

As water supplies become more and more intensively used, interest in how they are managed grows intensely. An important step for the sustainable use of water resources is to find a balance between human needs and what is needed for natural environments.
The management of water resources is very important for human life, but is very difficult in practice due to the planning needed to develop and distribute these resources, whilst balancing the competing demands for water and ensuring its allocation on an equitable basis. This management has to take into account hydrological, chemical and ecological processes in relation to human activities.
Major problems include: 1. Human overuse of water resources for agriculture and urban areas and its ecological consequences, 2. Pollution control and water allocation and 3. Economic and financial management.
Growing uncertainties over global climate change make management decisions more difficult, meaning that new management strategies will need to be implemented in order to avoid any bad decisions in the allocation of water resources.

## 8.12. About springs

A spring is any natural site where water flows to the surface of the Earth from underground. There are two categories of spring: gravity springs and artesian springs.

There are three types of *Gravity Spring*:

- *Gravity depression springs* occur when the ground surface dips below the level of water table in a geological formation. This type of spring may dry up seasonally.
- *Gravity contact springs* occur when the infiltration of water into a permeable geological formation is restricted by an impervious geological layer and the water is directed to the surface. They often appear as small water holes or seeps on hillsides. This type of spring is usually a good water source.
- *Fracture and tubular springs* occur in geological formation affected by tectonic movements. They are formed when water comes though faults, joints and fissures in rocks. Their discharge is usually concentrated at one point and they are a good water source.

*Artesian springs* occur when water under pressure is trapped between two impervious geological layers; there are two types:

- *Artesian fissure springs* occur when water under pressure reaches the surface through a fissure or joint. They are similar to gravity fracture springs and they are a very good water source.

- *Artesian flow springs* are formed when a confined aquifer flows underground and appears at a lower elevation. They occur on hillsides and are very good water source.

## 8.13. Why underground water is sometimes salty in areas near the coast

The need for water in society today is always increasing and this can lead to the over extraction of groundwater. But when the pumping of water from an aquifer is faster than it can be recharged naturally, the system will be out of equilibrium and any further ground water has to be pumped from deeper and deeper levels, or can be drawn into the aquifer laterally.
If the over extracted aquifer is near the coast, this pumping can eventually draw salt water from the sea into the freshwater aquifer causing contamination (i.e. salinisation) of the previously drinkable (i.e. potable) freshwater resource. Many areas near the coast have problems with the salt water intrusion as a result of over extraction.

## 8.14. Why in some regions does drilling for underground water have to go deeper and deeper?

The quality of groundwater in shallow wells is quite sensitive, while in deep wells the quality changes more slowly – hence they are usually for community supplies. An aquifer depending entirely on rainfall for replenishment, is affected in years of severe draught, and as a result pumping of groundwater has to go to deeper and deeper levels, meaning that the water extraction is more expensive.
In addition, it might not be possible for the aquifer to recharge to its former water level and storage capacity, as the porosity and the permeability of ground may have changed due to compaction as the water was removed. This lost volume is sometimes visible at the ground surface as permanent subsidence.

**Intended Learning Outcomes:**

- Understand how fossil fuels are formed.
- Know about renewable energy sources.
- Recognise the importance of soil, rocks and minerals for agriculture, manufacturing and building.
- Appreciate the value of raw materials for countries in an international, economic context.
- Be aware of the sustainable exploitation of geological resources.
- Demonstrate knowledge and understanding of underground water and its importance for humanity.

## Bibliography:

**Webster D., 1999:** *Understanding Geology*. – 197 pp., Essex (Oliver and Boyd).
**Moura, A. & Velho, J.L., 2011:** *Recursos Geológicos de Portugal*. - 574 pp., Coimbra (Palimage).
**Associaηγo Portuguesa de Energias Renovαveis (APREN)**: www.apren.pt
**Empresa de Desenvolvimento Mineiro (EDM):** www.edm.pt