INTRODUCTION. The Geological Timescale and some basic geological principles

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There is a series of basic principles that one needs to understand prior to setting out on any explanation about the geology of a region:

- The geography and landscape of a region are always changing. The mountains and valleys that surround us or the position of the coastline today have not always been as we know them now, now, neither have these features always been there. The land that we walk on, in the majority of cases, has risen up from the depths of an ancient sea, and the distribution of land and sea will change through time.

- These changes result from complex geological processes: sediments that are transformed into new rocks and erosion of rocks that already exist into sediments; uplift or emergence of land areas, with the consequent retreat of the sea, and flooding of other areas, that are invaded by seas and oceans, where accumulation of sediment starts again that will later be transformed into other rocks, followed by renewed emergence and further destruction, etc.

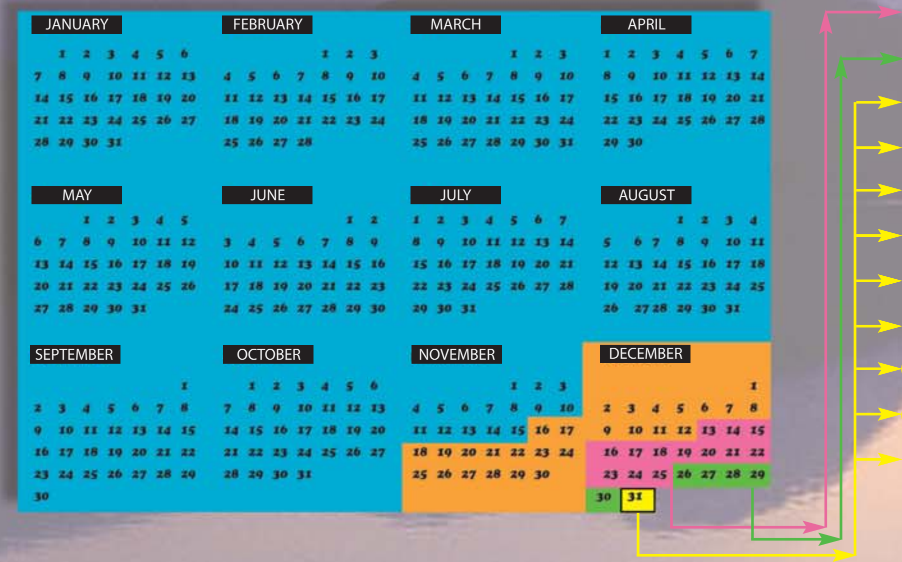
- By studying the internal structure and composition of rocks, their age (that should be measured in millions of years) and the way that they are distributed in a region, geologists can reconstruct the way in which the landscape and geography of the region has changed, where the coastline was situated at different times, where there was a volcano, when the mountains were uplifted that are emerged now, etc. This reconstruction is not simple and requires the accumulation of much knowledge from very distinctive specialist fields within geology. However, once recognised, even with provisional status, such that our understanding will improve with time, it is converted into a story that can be entertained.

- All of these geological processes, without exception, are extraordinarily slow from a human perspective. The duration, the pace, of geological processes is counted in millions of years. The pre-history and history of humans has been instantaneous in comparison with the long history of our planet that began at least 4,600 million years ago.

THE GEOLOGICAL YEAR

If we compressed all of the known geological time of our planet, some 4,600 million years, into a natural year of only 365 days, we would observe:

- That through the Precambrian, about which we know virtually nothing, save that it gave shelter to practically no life, only extremely primitive forms lived through until the 16th of November, almost a complete year.
- That the Palaeozoic era, in which distinct forms of life developed and diversified, reached up to the 13th of December.
- That the Mesozoic era, that of the large reptiles, lived through to the 26th of December, the time at which, for example, the great dinosaurs became extinct.
- That the Tertiary era, with the development of the majority of mammals, reached up to the 30th of December. The first primates did not appear until the 29th of December.
- That the Quaternary era, with the appearance of our more immediate relatives, occupied only part of the 31st of December. In fact, only towards the last minute of the year did Homo sapiens sapiens, ourselves, appear.

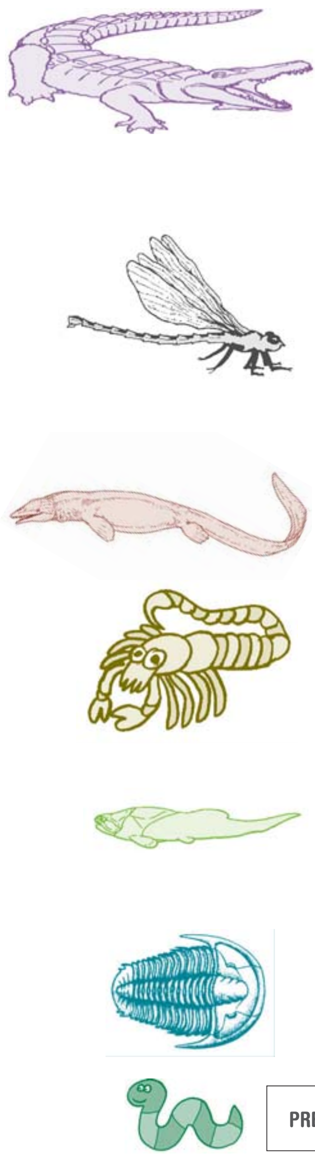


20 : 19 : 00.00	Sudden extinction of large reptiles (65 m.a.)
19 : 99 : 33.91	Appearance of the first primates (40 m.a.)
18 : 17 : 19.19	Appearance of Homo erectus (3 m.a.)
21 : 08 : 58.52	Appearance of Homo habilis (1.5 m.a.)
23 : 52 : 00.11	Appearance of Homo sapiens neanderthalensis (70,000 a.)
23 : 58 : 00.09	Appearance of Homo sapiens sapiens (35,000 a.)
23 : 59 : 48.28	Start of the Christian era (2,000 a.)
23 : 59 : 49.02	Fall of the Roman Empire (1,600 a.)
23 : 59 : 58.57	Discovery of America (500 a.)
23 : 59 : 58.89	French Revolution (200 a.)
29 : 59 : 59.30	Start of the industrial revolution (100 a.)
00 : 00 : 00.48	Average duration of human life (70 a.)

Precambrian · Palaeozoic era · Mesozoic era · Tertiary era · Quaternary era

TABLE OF GEOLOGICAL TIME

Era	Period	Sub-period	Epoch / Series	Millions of years
QUATERNARY			Holocene	0.01
			Pleistocene	1.8
CENOZOIC/TERTIARY		NEOGENE	Pliocene	5.3
			Miocene	23.5
		PALAEOGENE	Oligocene	34
			Eocene	53
			Palaeocene	65
MESOZOIC	CRETACEOUS		Upper	96
			Lower	135
	JURASSIC		Upper MALM	154
			Middle DOGGER	180
			Lower LÍAS	205
	TRIASSIC		Upper	230
			Middle	245
			Lower	250



Era	Period	Series	Millions of years
PALAEOZOIC	PERMIAN		250
		Upper	272
		Lower	300
	CARBONIFEROUS	Upper	325
		Lower	360
	DEVONIAN	Upper	375
		Middle	385
		Lower	410
	SILURIAN	Upper	425
		Lower	435
	ORDOVICIAN	Upper	455
		Middle	470
		Lower	500
	CAMBRIAN	Upper	
		Middle	
		Lower	540
PRECAMBRIAN	Proterozoic		2.500
	Archean		4.600

MILLIONS OF YEARS

Largescale Geological Units in Andalucia

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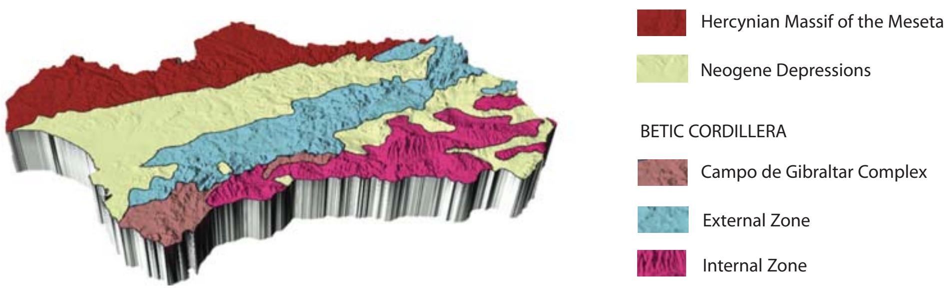
In Andalucía three largescale geological units may be differentiated:

1. **The Iberian Massif or Hercynian Massif** of the Meseta outcrops to the north of Guadalquivir and forms the mountainous lineament of Sierra Morena. It consists mainly of strongly folded and deformed, metamorphic (schists, quartzites and limestone marbles) and igneous (granites and similar) rocks, of very ancient age formed between more than 550 and 250 million years ago (Precambrian and Palaeozoic). They form part of the old Iberian continent whose coasts were covered by the sea that occupied the greater part of the modern Andalucían territory.

2. **The Betic Cordillera** constitutes the second largescale unit, and the first formed from extension. This much younger, large alpine mountain chain, had already started uplifting approximately 25 million years ago (in the Lower Miocene) and continues uplifting today. It runs from Cádiz in the west to Almería in the east, extending to Murcia, Valencia and the Balearics. At the latitude of the Rock of Gibraltar it is inflexed producing a more or less symmetrical structure along the north of Africa. Internally, a complex structure is present as a consequence of the piling up of rocks through thrusting during the slow collision of the Alboran Plate up and onto the Iberian Plate, and later uplifting. The primary internal structure is divided into a younger External Zone, nearer to the Iberian Massif, and an older Internal Zone, closer to the modern littoral zone. Within the latter, several stacked tectonic units can be recognised, in turn, essentially from the bottom towards the top they include the Nevado Filábride Complex, Alpujárride Complex and Maláguide Complex.

3. **The Neogene Basins** or depressions overall comprise the third largescale unit in Andalucía. During the emergence of the Betic Cordillera there were times in which the sea extensively covered depressed regions that are emerged today, such as the Guadalquivir Basin and other intermontane basins like Guadix-Baza, Tabernas, Sorbas or Almería-Níjar. They are young sediments, less than 25 million years old, characterised by having a very limited degree of deformation, such that they hold a great value for studying the recent geological history in this western sector of the Mediterranean.

GEOLOGICAL UNITS



Largescale Geological Units in the arid region of SE Almeria

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Almería is located, from a geological point of view, at the southeastern extreme of the Betic Cordillera. The old Betic relieves (Sierra de Gádor, Filabres, Alhamilla, Cabrera, etc.) constitute the margin and the basement of a series of much younger intermontane marine basins (Tabernas, Sorbas, Almería), that were filled with sediments simultaneously with the emergence of the Betic Cordillera structure. Meanwhile, in the vicinity of Cabo de Gata, numerous similarly recent volcanoe rumbled in full activity. These three geological terrains are clearly distinguishable today in the surrounding Almerían desert landscape.

Characteristic flaggy appearance (schistosity) of dark micaschists in the core of the Nevado- Filábride Complex.

Quartzite crests in the Nevado- Filábride core of the Sierra Alhamilla (photo M. Villalobos).

THE BETIC SIERRAS

The core of the mountains in this region consists of very old rocks, some even around 550 million years old. They are grouped under the generic name of the Nevado-Filábride Complex (alluding to the fact that they make up a good part of the Sierra Nevada, and its eastern extension, the Sierra de los Filabres). They are mainly graphitic micaschists: display dark, yellowish and orange colours with a slaty appearance and a flaggy characteristic, that is to say, they are divided into well-defined, more or less irregular laminations. Quartzites which form rough crests and sharp cliffs, due to their better resistance to erosion, are also common.

Quartzites display dark, yellowish and orange colours, and also have a flaggy appearance, although poorly defined. Metamorphosed limestones and marbles are also found but to a lesser extent, such as those quarried in the Sierra de Macael. Locally rocks related to granite appear, known as gneiss. All of these arose from the transformation (metamorphism) of existing rocks that suffered elevated temperatures and pressures at great depth in the interior of the earth.

Skirting the core of the previously mentioned mountains another band appears, also consisting of very old rocks although somewhat younger than the former, that are grouped under the name of Alpujárride Complex (alluding to the fact that it extends from Alpujarra, where for one part it constitutes the southern flank of the Sierra Nevada, and for the other, the coastal chain: sierras de Lújar, Contraviesa, Gádor, etc.).

Typical purple colour of phyllites or 'Launas' in the material of the Alpujarride Complex (Photo, M. Villalobos).

Alpujarride limestone relief of the Sierra de Gador (Photo, M. Villalobos).

This strip mainly comprises two very distinct types of rock, easily recognisable in the field. One of these are schists, known in the region as 'Launa', which are slightly transformed clays, of vivid blue, red and glossy grey colours. Traditionally they have been used to make impermeable roof slates in the construction industry. The other rocks are limestones and dolomites, composed of calcium and magnesium carbonates, which produce white, grey or black escarpment relieves, for example, the north flank of the Sierra Cabrera, Sierra Alhamilla, the escarpments of Lucainena or Turillas, close to Níjar, or the many cliffs of the Sierra de Gador. All of these limestones and dolomites were formed at the bottom of a tropical sea more than 200 million years ago. Afterwards, in the same manner as the rest of the material from the Alpujarride complex, they suffered transformation (metamorphism) at elevated temperatures and pressures, which came about at great depth in the earth's interior.

Material from the old Betic mountains has suffered an intense deformation expressed as folds of distinct scales and fractures, in addition to their slaty characteristics (schistosity). In some places the rocks are literally destroyed, mashed up by fractures. They are also mineralised, and have historically been the object of exploitation to yield iron (Sierra Alhamilla), lead and silver (Sierra de Gador and Sierra Almagrera), and other minerals.

THE SIERRA DE CABO DE GATA

The Sierra de Cabo de Gata is an individual mountain range, different to the others, formed from volcanic rocks during two stages of volcanicity, one from approximately 14 to 10 million years ago and the other from 9 to 7.5 million years ago. In reality, they represent only a small percentage of rocks of this nature, constituting the bottom of the Alboran seafloor and extending to Melilla, outcropping discretely in the Isla de Alboran.

Detail of stratification in Alpujarride limestone rocks (Photo, M.Villalobos).

Volcanic rocks from this area formed a landscape of volcanoes, submarine or emergent, individual or grouped, to form small islands. These volcanic structures are recognisable in the terrain of Cabo de Gata, in many cases, where they are seen to form steep, more or less conical hills in the area: Los Frailes, Mesa de Roldan, Cerro de los Lobos, La Tortola, etc. Brecciated volcanic rocks (formed from fragments of different composition or aspect) are very abundant, resulting from diverse volcanic processes: differential cooling of distinct parts of lava flows, eruptions, nuee ardentes, avalanches down the sides of volcanoes, etc.

DEPRESSIONS OR *LOW-LYING AREAS*

The rocks that occupy the low-lying areas of the Almerían landscape, modern depressions such as the Almanzora Valley, Andarax Valley, Tabernas, Sorbas Basin, Campo de Níjar plain or El Poniente or El Poniente, consists of geologically young material, accumulated in the last 15 million years, while the Mediterranean Sea surrounded the mountains and the volcanoes of Cabo de Gata forming a small archipelago. The Betic mountains, and in general all of the Iberian Peninsula, were uplifted from the depths of the Mediterranean Sea.

In these marine inlets the products of sedimentary erosion of the emerged land accumulated: boulders, pebbles, gravel, sand and mud. Limestone rocks also formed from the accumulation of the remains of marine creatures. In a changing global climate, the region passed through cold and much warmer periods.

In the warm periods, the seawater temperature (in the western Mediterranean) was similar to those of the tropics today, in the order of 20º C, and coral reefs developed along the margins of islands and emerged lands. Theses coral reefs, like those of Purchena, Cariatiz, Nijar, Mesa Roldan, etc., are amongst the best fossil examples that exist in the world.

In colder periods, the western Mediterranean had a temperature similar to today, and limestones were formed from the remains of red algae, bryozoans, molluscs etc., like those occurring on the actual seafloor of the platform that encircles Cabo de Gata. These conditions, or yet colder ones, prevailed in the region from 5 million years ago.

Geological history and geographical evolution of SE Almeria

Juan C. Braga - José M. Martín

The Betic mountains (Nevado-Filabride and Alpujarride complexes) originated from collision of the African continent with Europe. The Betic rocks are formed from sediments deposited at the bottom of the sea hundreds of millions of years ago. These rocks were buried at many kilometres of depth (beneath other rocks), under such pressure and temperature that they were transformed, changing the appearance of the minerals that make them up (this process is known as metamorphism). Later, they slowly emerged. The structure of the Betic Cordillera was yet to be uplifted at different speeds according to the arrangement of blocks compartmentalised by large regional fractures.

The Sierra Nevada-Sierra de los Filabres block, for example, was the first to emerge from the sea, around 15 million years ago, and has stayed up since this time, as the most elevated relief in Andalucía and one of the most elevated in Spain and Europe. The bottom of the Alborán Sea is subsiding and extending, thanks to fractures through which volcanic material of Cabo de Gata was once extruded. Since emergence of the Sierra Nevada-Sierra de los Filabres, that still continue to be uplifted, the Sierra de la Estancias emerged from the sea around 9 million years ago.

Later, around 7 million years ago, the Sierra de Gádor and Sierra Alhamilla emerged. Although today they seem like high mountains to us, they are believed to be quite young in geological terms, and their rate of uplift on a human scale is very low, For example, the average velocity of uplift for the Sierra Alhamilla since emergence from the sea is less than 2 cm each year.

The last relief to emerge, which is for certain the youngest mountain range of the peninsula, is Sierra Cabrera that came out of the sea 5.5 million years ago.

During the past 2 million years, Almería, like the rest of the planet, has suffered from strong Quaternary climatic variations. In the glacial stages, the sea fell more than 100 metres from its present level and the climate was much colder. In the interglacial stages, as now, the sea was in a position similar to that of today, and the climatic conditions would also have been similar in character.

The process of marine retreat from these basins can also be seen in relation to the present-day geography, in that the interior depressions, those most removed from the modern Mediterranean, were the first to emerge, whilst those closest to the coast have been abandoned by the sea only recently from a geological point of view. For example, the high valley of Almanzora, above Albox, was vacated by the sea around 7 million years ago, however, the sea extended over land surrounding the Bay of Almería until just 100,000 years ago.

With the final retreat of the sea to its current position, for the moment, the impressive geological record for this area, accumulated over a period of 15 million years, is exhibited in Almería under exceptional conditions of preservation. It is an area of maximum educational and scientific value for studying and understanding the evolution of the Mediterranean and the formation of the Betic Cordillera over the past 15 million years.