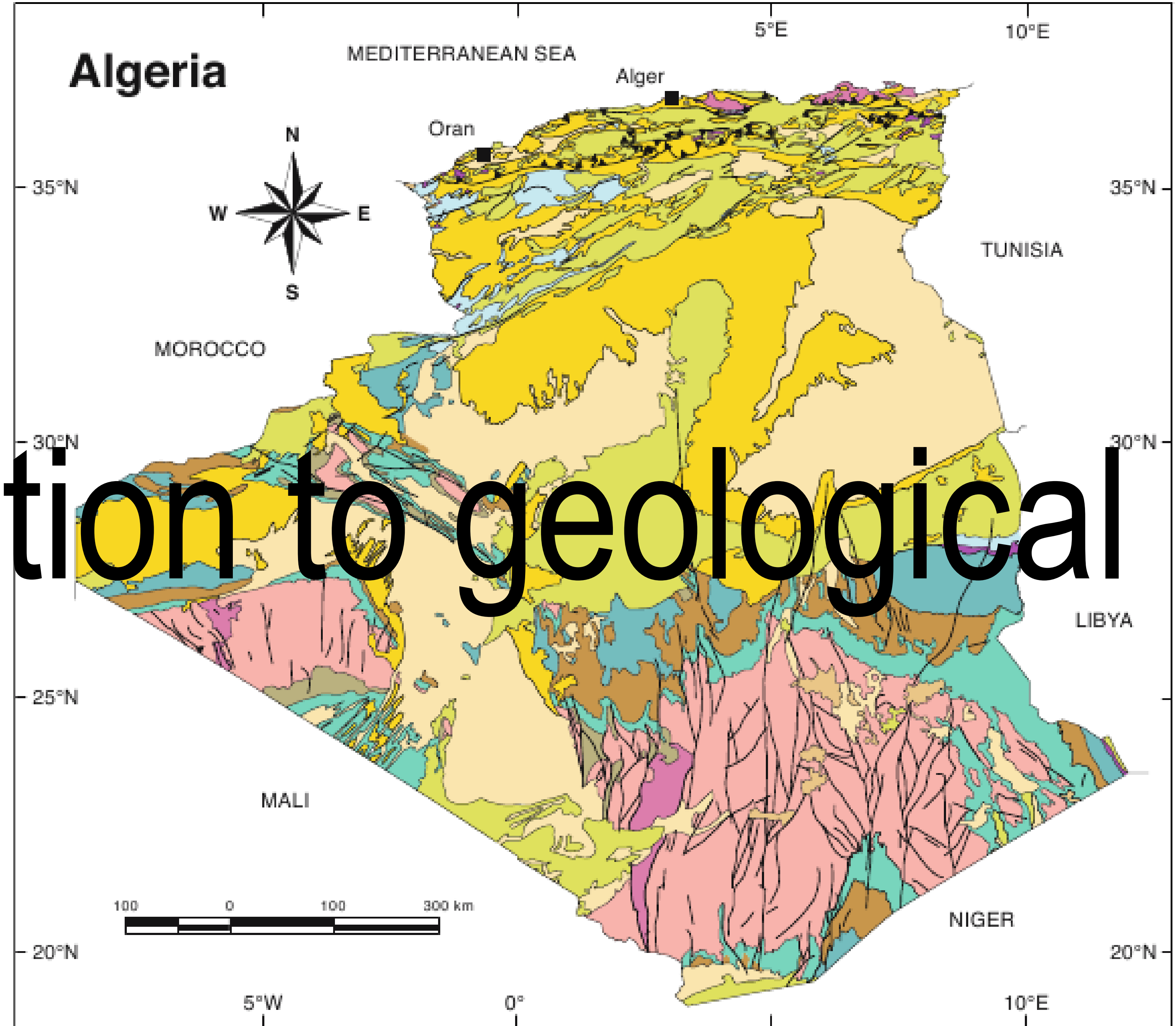
Initiation to geological map



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Introduction

The geological map is a document that every geologist must know how to read, use, and create in the field. Learning to read a map or draw a geological cross-section from it is akin to reading sheet music and practicing scales for a musician.

The geological map is essential for geologists in all specialties and across diverse fields such as mining, oil, civil engineering, hydrogeology, agronomy, natural hazards, and the environment. On this simple sheet, practical for both field and classroom use, various rock formations that crop out on the surface are depicted, along with their geometric and chronological relationships.

It's important to note that creating a single map represents years of meticulous research by a team of specialists – in the field, in laboratories, through documentation, and all the way to the final step of printing the sheet.

خريطة الجيولوجيا للجزائر

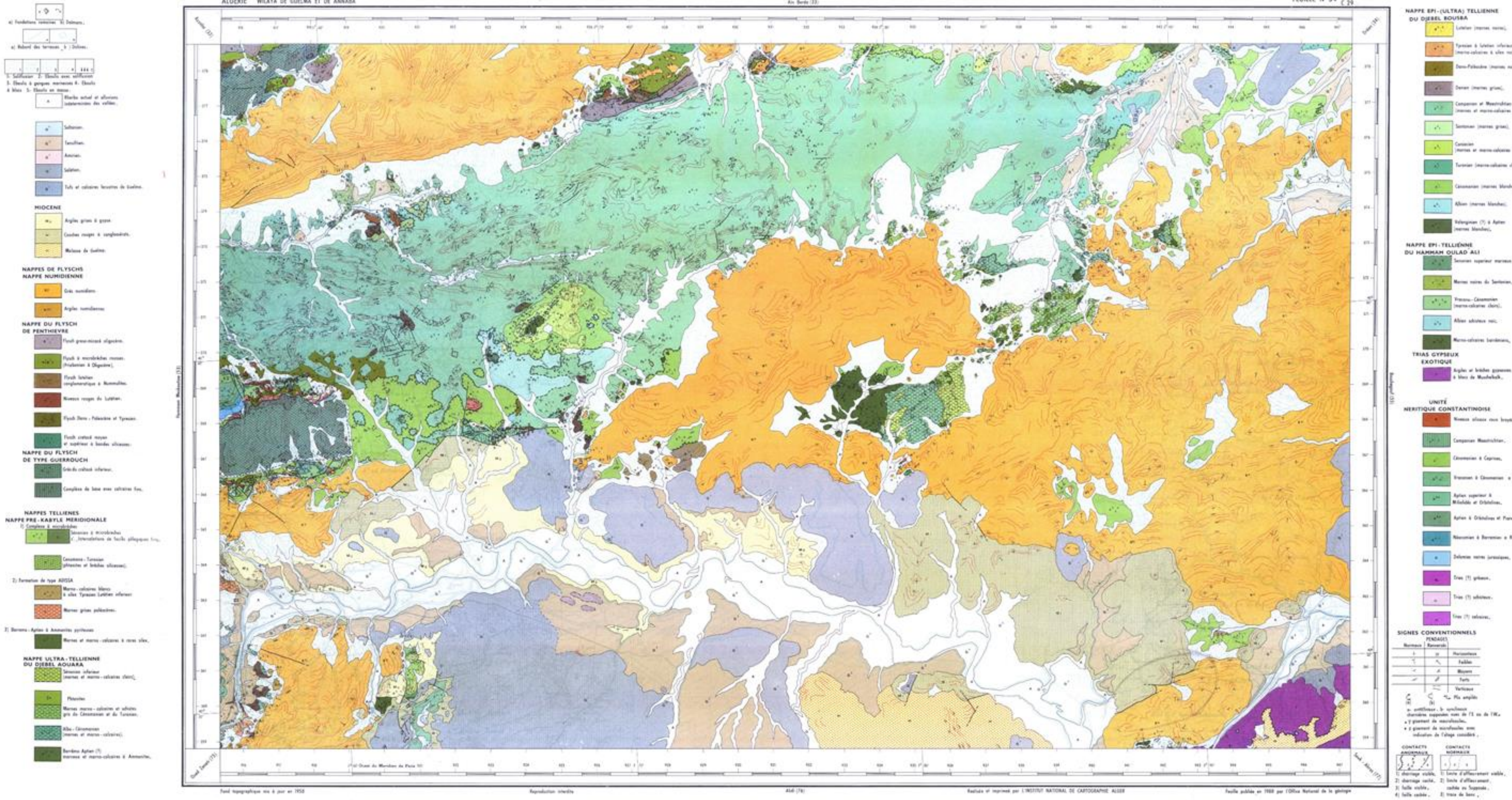
CARTE GEOLOGIQUE DE L'ALGERIE

قالمة

GUELMA

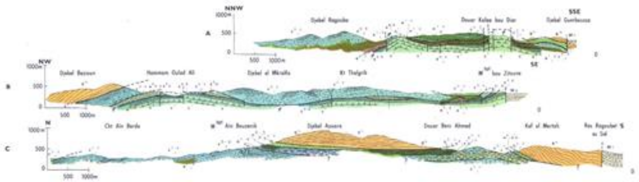
وزارة الصناعة الثقيلة
الديوان الوطني للجيولوجيا
MINISTERE DE L'INDUSTRIE LOURDE
OFFICE NATIONAL DE LA GEOLOGIE
ولاية قالمة و عنابه الجزائر
ALGERIE WILAYA DE GUELMA ET DE ANNABA

FEUILLE N° 54

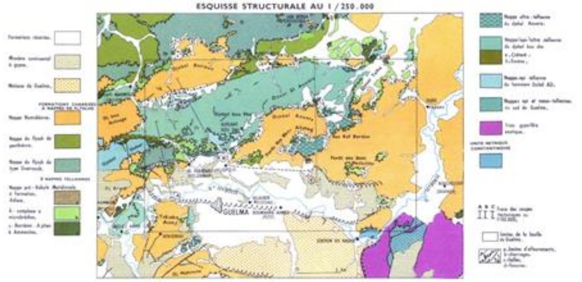


Echelle : 1/50 000

coupes tectoniques au 1/50.000



ESQUISSE STRUCTURALE AU 1/250.000



FUNDAMENTAL DEFINITIONS

In this section, we will revisit some terms you have already encountered in the first semester and introduce new essential terms for understanding this subject. Firstly, we will look at terms related to the topographic map, and then we will explore terms associated with the geological map.

Terms related to the topographic map:

1.1. Orography

It allows representing the terrain's relief, but this representation poses challenges: it is not possible to indicate the attitude of each point on the map, so different methods of relief representation have been devised:

- Contour lines system
- Hachures system (abandoned due to being too imprecise)

1.1.1. Contour Maps

A contour line is the locus of points on the topographic surface at the same altitude, meaning the intersection of the topographic surface with a horizontal plane.

A– Principle of Establishing Contour Lines (Fig. 2)

Consider a series of parallel equidistant horizontal planes (H1, H2, and H3) ideally intersecting a topographic surface (e.g., a hill). The intersections of the hill with these planes are projected onto the plane P. These projections are called contour lines.

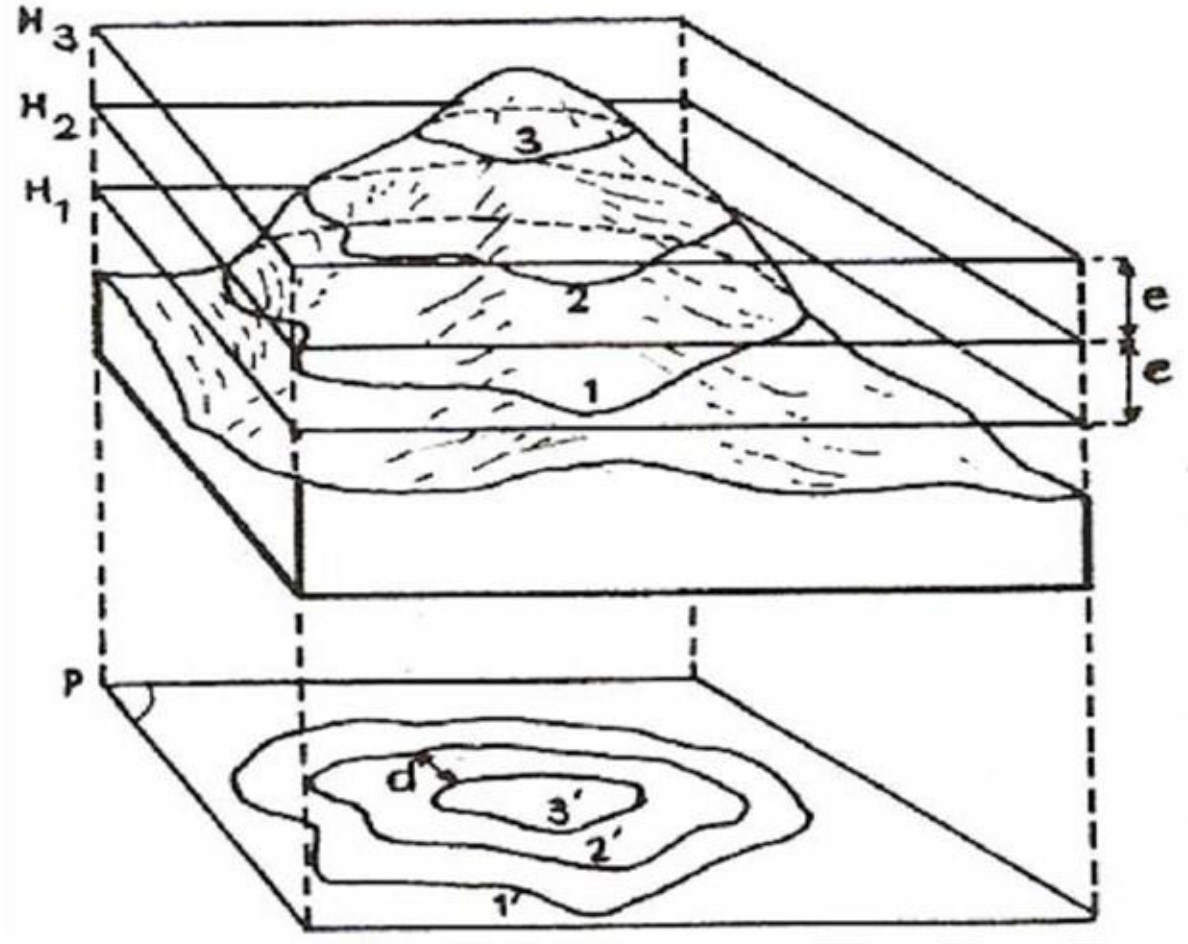


Fig. 2: Principle of establishing contour lines.

The topography of the Earth's surface is depicted through contour lines. A contour line represents the intersection of the topographic surface with a horizontal plane at a specific altitude. It connects a set of points at the same altitude. The difference in altitude between the horizontal planes is called the contour interval.

B– Scale

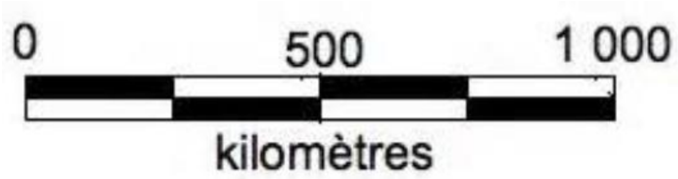
This projection can only be used through reduction, expressed by a fractional number known as the scale. The scale is the ratio of the distance between two points on the map to the horizontally coupled distance between the corresponding points on the terrain.

$E = d/D$

The units used must be the same in the numerator and denominator. For example, a scale of 1/50,000 means that 1 cm on the map represents 50,000 cm or 500 m on the terrain. Common scales include 1/25,000, 1/50,000, 1/100,000, and beyond. The scale is larger when the denominator is smaller.

The map is said to be at a scale of 1:50,000.

On a cartographic document, the scale is indicated in either a graphical form, with a line subdivided into segments,



or a numerical form, expressed as a numerical ratio (e.g., 1/50,000).

C – Contour Altitudes

The altitudes of contour lines are often marked along their trace. In principle, the base of the numbers indicating these altitudes is directed toward the bottom of the slope.

D– Contour Interval and Spacing (Fig. 2)

This is the distance between two successive horizontal planes: on the map, it corresponds to the difference in altitude between two consecutive contour lines. It's important not to confuse contour interval with the spacing of the contour lines on the map (d).

- The contour interval is constant.
- The spacing varies, depending on the terrain.

The contour interval is indicated in the legend at the bottom of the map. In flat areas with low relief, it may be 5 to 10 meters; for mountainous areas, it can reach 20 meters, as too many contour lines would make the map unreadable.

If the contour interval is not provided, it can be calculated by counting, on a consistently ascending or descending slope, the number of intervals between two known contour lines. This count divided by the difference in altitude between the two contour lines will give the contour interval.

1.1.2. Properties of Contour Lines

A – Different Types of Contour Lines (Fig. 3)

- Master Contour Lines: Drawn with bolder strokes, they represent every 5th contour line, typically at intervals of 50 or 100 meters. Altitudes are often indicated on master contour lines. Note that between two master contour lines, there are always 4 normal contour lines.
- Normal Contour Lines: Drawn with finer strokes, they are interspersed between master contour lines.
- Intercalary Contour Lines: Generally drawn in dashed lines. When the topographic surface is flat, contour lines are spaced apart. To provide more precision, an intercalary contour line is added, whose altitude differs by half the contour interval from the two contour lines that frame it.

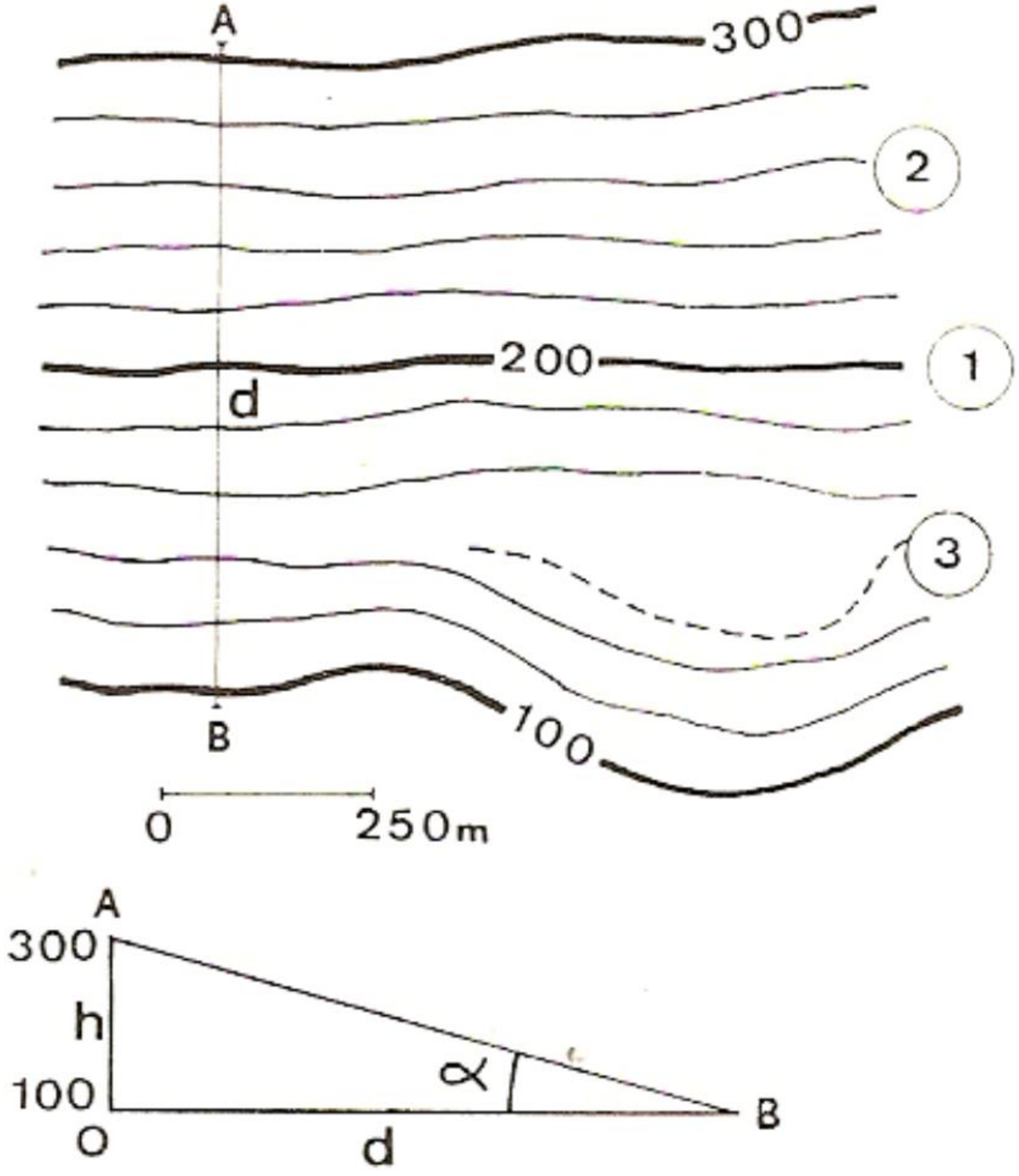
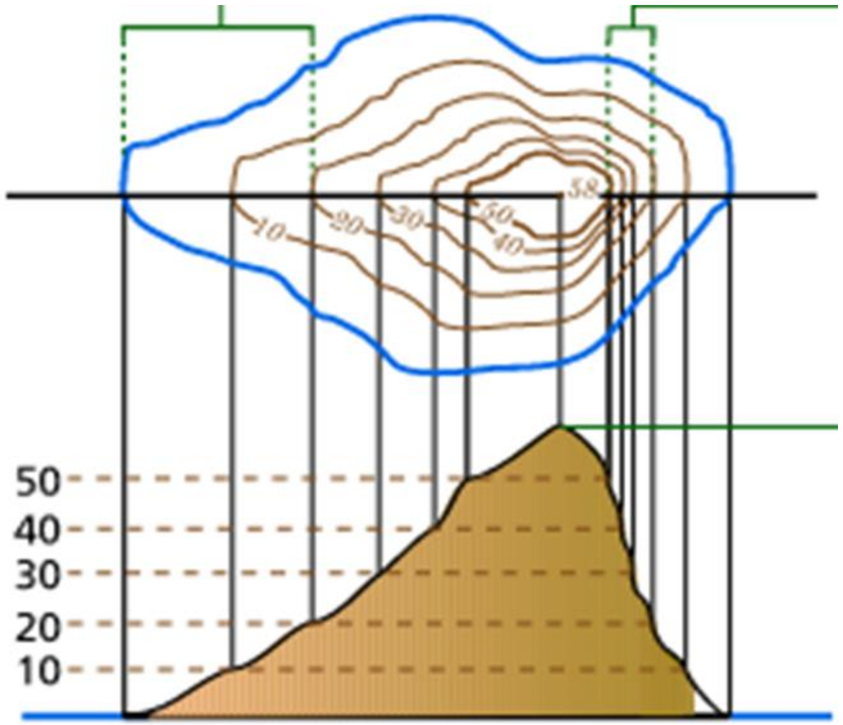


Fig. 3: Different types of contour lines.

B – Contour Line Density

Reflects the terrain relief: steep slopes are characterized by numerous and closely spaced contour lines, while a flat or gently sloping region corresponds to widely spaced and less numerous contour lines (Fig. 3).



C – Benchmarks

Next to the contour lines, there are several noteworthy points where the exact altitude is provided, making it easy to determine the values of nearby contour lines.

Example: Consider a map with a contour interval of 10 meters. Suppose there is a benchmark at the summit of a hill with an altitude of 279 meters. The first contour surrounding this summit, and therefore of lower value, will be the contour line at 270 meters, as it is a multiple of 10.

1.2. Planimetry

This involves representing various elements of the Earth's surface on the topographic map using conventional symbols whose meanings are explained in the map legend.

Common conventions include:

Blue for hydrography (water bodies)
Black for human-made features and toponymy (place names)
Green for vegetation
Bistre (a shade close to brown) for orography (contour lines).

2.Terms related to the geological map:

Here are the definitions of some terms that one should know before delving into the basics of the geological map. It's worth noting that other important terms will be defined throughout the course.

2.1. Stratum

1 – A stratum is the smallest lithological division, bounded by two parallel surfaces, and its thickness is on the order of meters.

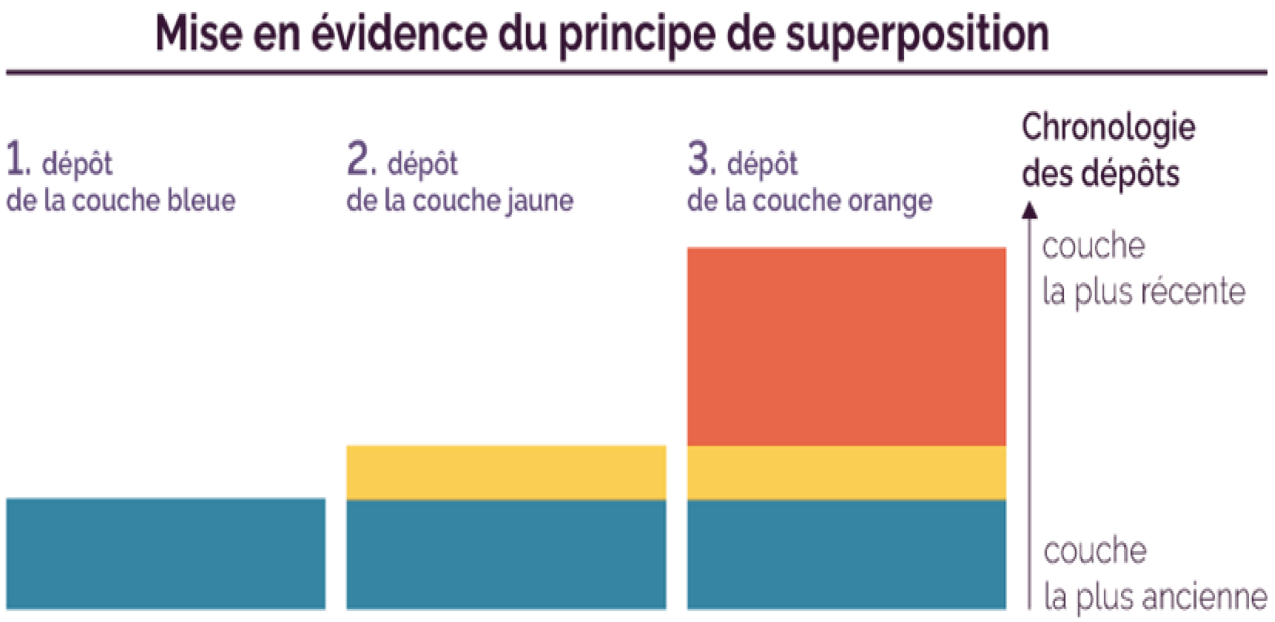
2 – The top surface of a layer is called its roof or upper limit, while the base is its basal part or lower limit. These two surfaces, usually parallel, can be intersected by the topographic surface due to erosion. These intersections are called geological contours and delineate the outcrop of the layer (the visible part of a layer on the surface).

2.2. Concept of Stratigraphy

Stratigraphy is the science that studies the succession of sedimentary deposits, typically arranged in layers or strata. It allows for the establishment of a relative stratigraphic chronology, particularly through the reasoned application of principles known as the principles of stratigraphy.

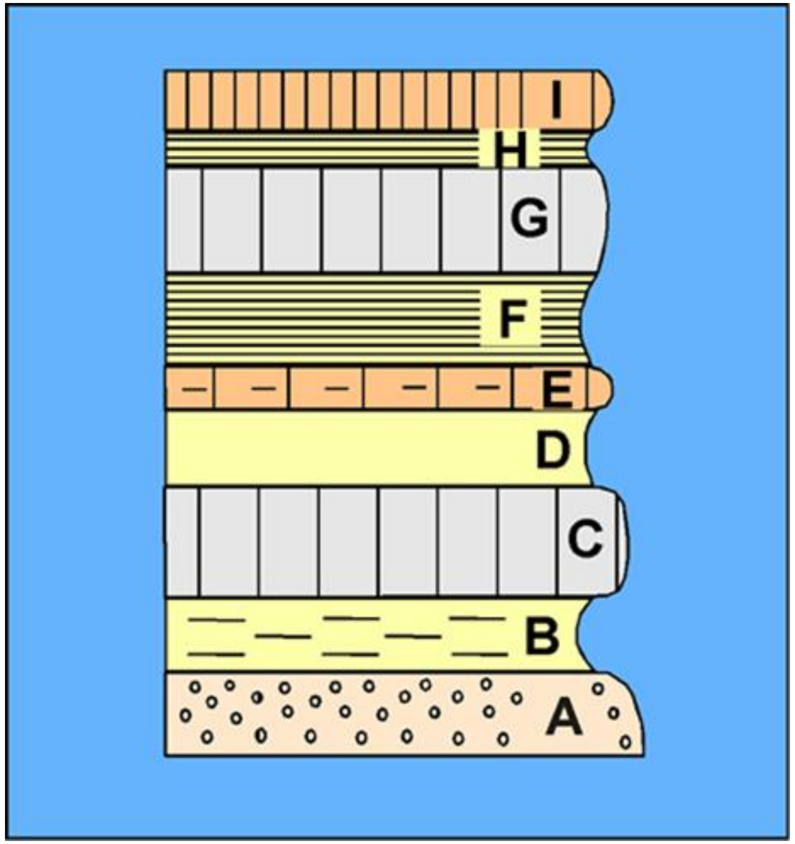
Principle of superposition

This principle is based on the idea that, in the absence of major disturbances, new layers of sediment are deposited on top of older layers. Consequently, the deepest strata are generally the oldest.



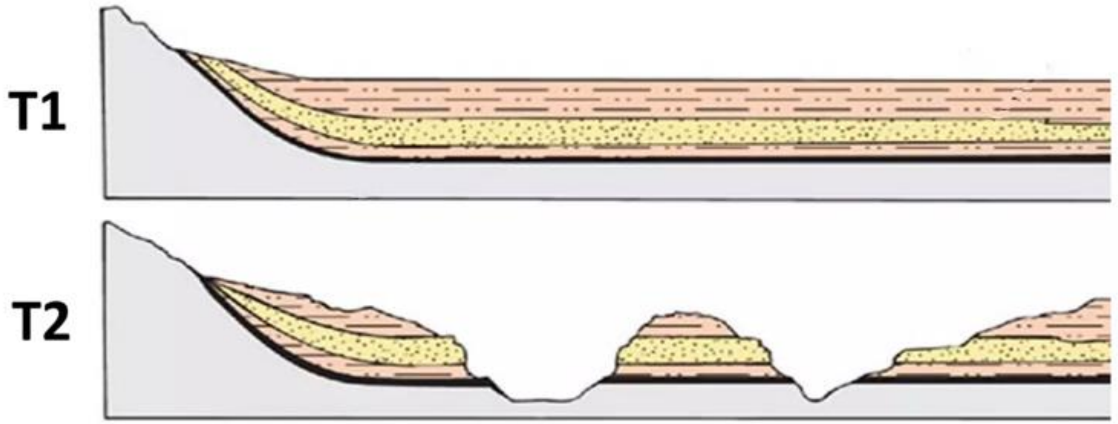
Principle of Original Horizontality

Sediments are initially deposited in horizontal layers due to the force of gravity. Deformations observed in geological layers are often the result of subsequent geological events, such as folding or faulting.



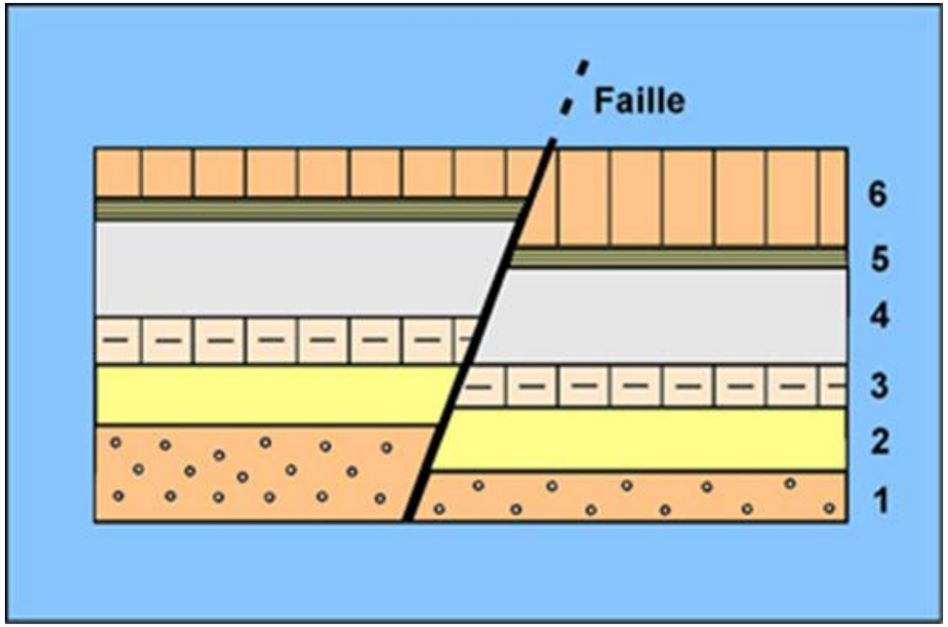
Principle of Lateral Continuity

Geological layers are deposited over extensive areas and can be traced over long distances, provided they are not interrupted by geological processes such as erosion or plate tectonics.



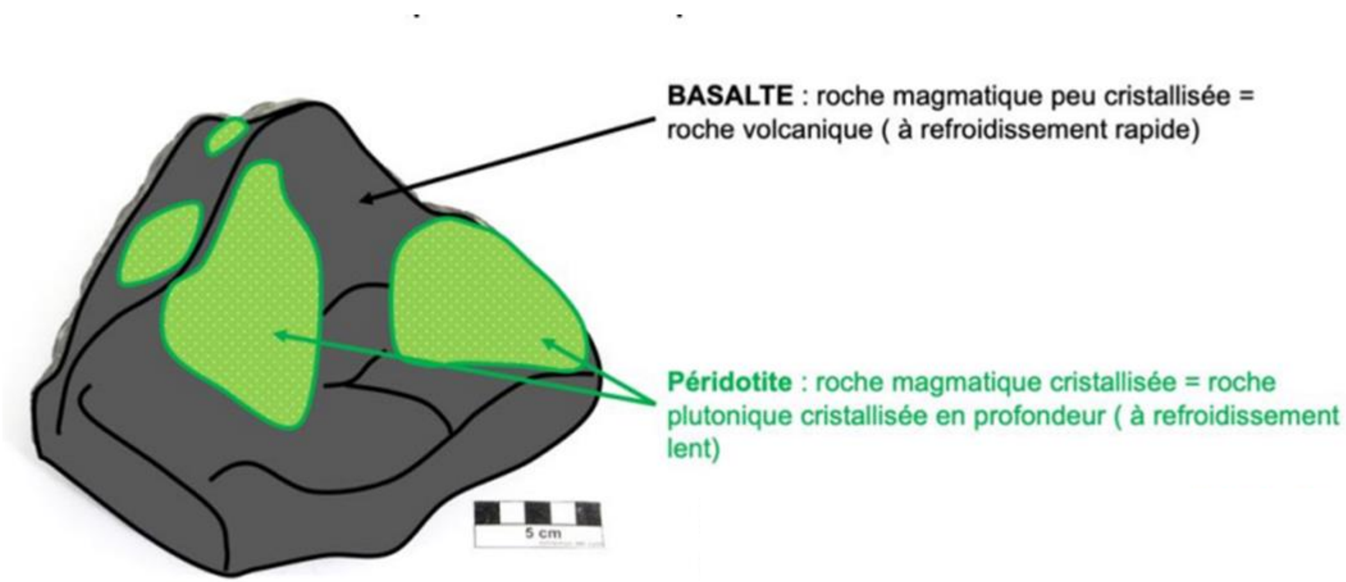
Principle of Cross-Cutting

When a geological layer is cut or crossed by another geological formation, the cutting formation is younger than the intersected layer.



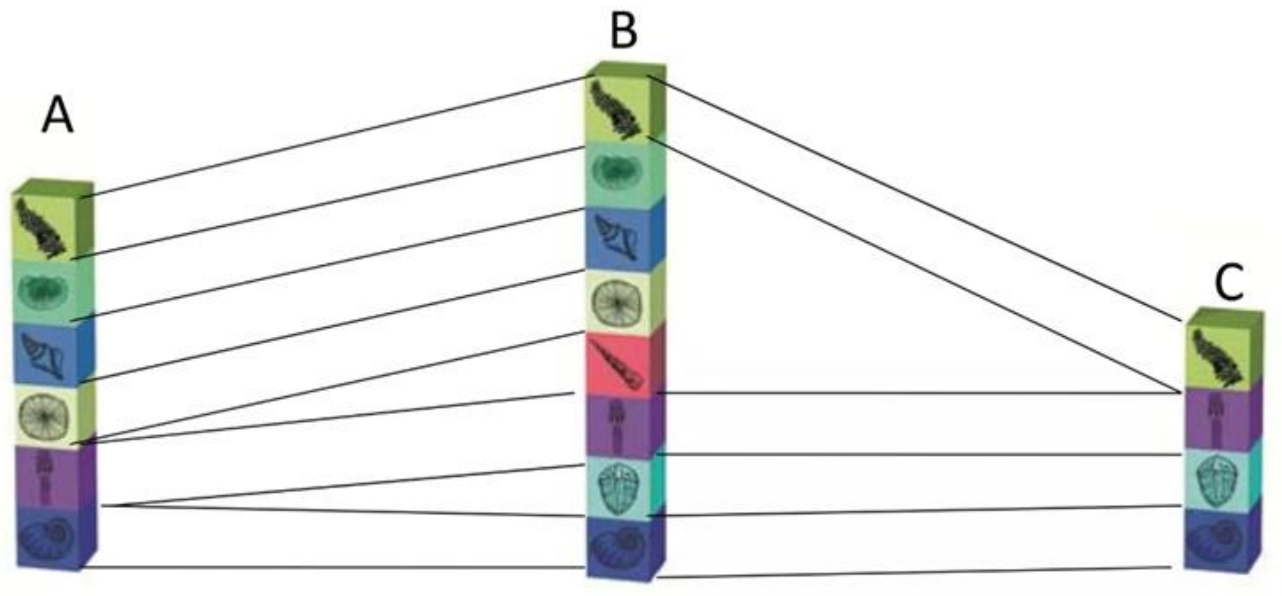
Principle of Inclusions

If a rock or rock fragment is included in another geological layer, it means that the included rock is older than the layer that surrounds it. This observation is particularly useful for dating events such as volcanic eruptions and erosion processes.



Principle of Faunal Succession

This principle is based on the fact that certain species of fossils are characteristic of specific geological periods. By identifying these fossils in different geological strata, geologists can establish correlations between these strata and thus determine their relative ages.



2.3. Facies:
It is the set of petrographic and paleontological characteristics that define a rock. Some of these characteristics help specify the conditions under which the rock was deposited. Certain layers may exhibit lateral variations in facies from one point to another.

2.4. Tectonics:
It is the study of deformations of the Earth's crust and the resulting structures, at different scales, ranging from the global scale (Plate Tectonics) to the scale of samples (microtectonics).

Geological map

A geological map is the representation on a topographic base of the rock formations that appear at the surface of the ground or are covered only by a thin layer of recent superficial deposits. These formations are designated by symbols and colors.

The map frame

The map frame is approximately 60 cm wide by 40 cm high, covering an area of about 600 km2 at a scale of 1/50,000. The frame includes various graduations (in degrees or grades) of longitude (meridians) and latitude (parallels), with some marked on the map. These reference points help locate a point on one map at a different scale or specify the coordinates of notable points for easy identification, such as outcrops or fossil-bearing deposits used for dating.

Dashes spaced 2 cm apart, accompanied by numbers, establish the kilometric grid of the Lambert projection.

At the corners of the map, information is provided about the type of projection, the origin of the topographic base, contour interval, and other details.

In the top left corner of the map, the names of the geologists who surveyed, coordinated, and drew the map are mentioned (the boundaries of their study area are sometimes specified in a small cartouche), along with the name of the Director of the Geological Map Service and the date of map publication.

Under the map, a graphic scale of distances is provided.

In the map margins:

The margins of a map contain essential information for its understanding, such as the legend of the geological formations. Sometimes, additional useful information may be included, such as structural diagrams, cross-sections, etc.

Colored legend boxes:

The legend boxes at the bottom of the column pertain to plutonic and metamorphic rocks of the crystalline basement, as well as volcanic and vein rocks. The top of the column is dedicated to sedimentary formations, arranged from the oldest at the bottom to the most recent at the top.

International cartography tends to standardize colors based on the age of the formations: blue for the Jurassic, green for the Cretaceous, etc. This can be easily adhered to on small-scale maps.

INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

IUGS

www.stratigraphy.org

International Commission on Stratigraphy

v 2023/09

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	numerical age (Ma)
					present
Phanerozoic	Cenozoic	Quaternary	Holocene U/L	Meghalayan	0.0042
			Holocene M	Northgrippian	0.0082
			Holocene L/E	Greenlandian	0.0117
			Pleistocene U/L	*Upper*	0.129
			Pleistocene M	Chibanian	0.774
			Pleistocene L/E	Calabrian	1.80
				Gelasian	2.58
		Neogene	Pliocene U/L	Piacenzian	3.600
			Pliocene L/E	Zanclean	5.333
			Miocene U/L	Messinian	7.246
				Tortonian	11.63
			Miocene M	Serravallian	13.82
				Langhian	15.98
			Miocene L/E	Burdigalian	20.44
				Aquitanian	23.03
		Paleogene	Oligocene	Chattian	27.82
				Rupelian	33.9
			Eocene	Priabonian	37.71
				Bartonian	41.2
				Lutetian	47.8
				Ypresian	56.0
			Paleocene	Thanetian	59.2
				Selandian	61.6
				Danian	66.0
	Mesozoic	Cretaceous	Upper	Maastrichtian	72.1 ±0.2
				Campanian	83.6 ±0.2
				Santonian	86.3 ±0.5
				Coniacian	89.8 ±0.3
				Turonian	93.9
				Cenomanian	100.5
			Lower	Albian	~ 113.0
				Aptian	~ 121.4
				Barremian	125.77
				Hauterivian	~ 132.6
				Valanginian	~ 139.8
				Berriasian	~ 145.0

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	numerical age (Ma)
					~ 145.0
Phanerozoic	Mesozoic	Jurassic	Upper	Tithonian	149.2 ±0.7
				Kimmeridgian	154.8 ±0.8
				Oxfordian	161.5 ±1.0
			Middle	Callovian	165.3 ±1.1
				Bathonian	168.2 ±1.2
				Bajocian	170.9 ±0.8
				Aalenian	174.7 ±0.8
			Lower	Toarcian	184.2 ±0.3
				Pliensbachian	192.9 ±0.3
				Sinemurian	199.5 ±0.3
				Hettangian	201.4 ±0.2
		Triassic	Upper	Rhaetian	~ 208.5
				Norian	~ 227
				Carnian	~ 237
			Middle	Ladinian	~ 242
				Anisian	247.2
			Lower	Olenekian	251.2
				Induan	251.902 ±0.024
	Paleozoic	Permian	Lopingian	Changhsingian	254.14 ±0.07
				Wuchiapingian	259.51 ±0.21
			Guadalupian	Capitanian	264.28 ±0.16
				Wordian	266.9 ±0.4
				Roadian	273.01 ±0.14
			Cisuralian	Kungurian	283.5 ±0.6
				Artinskian	290.1 ±0.26
				Sakmarian	293.52 ±0.17
				Asselian	298.9 ±0.15
		Carboniferous – Pennsylvanian	Upper	Gzhelian	303.7 ±0.1
				Kasimovian	307.0 ±0.1
			Middle	Moscovian	315.2 ±0.2
			Lower	Bashkirian	323.2 ±0.4
		Carboniferous – Mississippian	Upper	Serpukhovian	330.9 ±0.2
			Middle	Visean	346.7 ±0.4
			Lower	Tournaisian	358.9 ±0.4

Eonothem / Eon	Erathem / Era	System / Period	Series / Epoch	Stage / Age	numerical age (Ma)
					358.9 ±0.4
Phanerozoic	Paleozoic	Devonian	Upper	Famennian	372.2 ±1.6
				Frasnian	382.7 ±1.6
			Middle	Givetian	387.7 ±0.8
				Eifelian	393.3 ±1.2
			Lower	Emsian	407.6 ±2.6
				Pragian	410.8 ±2.8
				Lochkovian	419.2 ±3.2
		Silurian	Pridoli		423.0 ±2.3
			Ludlow	Ludfordian	425.6 ±0.9
				Gorstian	427.4 ±0.5
			Wenlock	Homerian	430.5 ±0.7
				Sheinwoodian	433.4 ±0.8
			Llandovery	Telychian	438.5 ±1.1
				Aeronian	440.8 ±1.2
				Rhuddanian	443.8 ±1.5
		Ordovician	Upper	Hirnantian	445.2 ±1.4
				Katian	453.0 ±0.7
				Sandbian	458.4 ±0.9
			Middle	Darriwilian	467.3 ±1.1
				Dapingian	470.0 ±1.4
			Lower	Floian	477.7 ±1.4
				Tremadocian	485.4 ±1.9
		Cambrian	Furongian	*Stage 10*	~ 489.5
				Jiangshanian	~ 494
				Paibian	~ 497
			Miaolingian	Guzhangian	~ 500.5
				Drumian	~ 504.5
				Wuliuan	~ 509
			Series 2	*Stage 4*	~ 514
				Stage 3	~ 521
			Terreneuvian	*Stage 2*	~ 529
				Fortunian	538.8 ±0.2

Eonothem / Eon	Erathem / Era	System / Period	numerical age (Ma)
			538.8 ±0.2
Precambrian – Proterozoic	Neoproterozoic	Ediacaran	~ 635
		Cryogenian	~ 720
		Tonian	1000
	Mesoproterozoic	Stenian	1200
		Ectasian	1400
		Calymmian	1600
	Paleoproterozoic	Statherian	1800
		Orosirian	2050
		Rhyacian	2300
		Siderian	2500
Precambrian – Archean	Neoarchean		2800
	Mesoarchean		3200
	Paleoarchean		3600
	Eoarchean		4031 ± 3
Precambrian – Hadean			4567

Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Italic fonts indicate informal units and placeholders for unnamed units. Versioned charts and detailed information on ratified GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (~) is provided.

Ratified Subseries/Subepochs are abbreviated as U/L (Upper/Late), M (Middle) and L/E (Lower/Early). Numerical ages for all systems except Quaternary, upper Paleogene, Cretaceous, Jurassic, Triassic, Permian, Cambrian and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012), those for the Quaternary, upper Paleogene, Cretaceous, Jurassic, Triassic, Permian, Cambrian and Precambrian were provided by the relevant ICS subcommissions.

Colouring follows the Commission for the Geological Map of the World (www.ccgm.org)

CCGM CGMW

Chart drafted by K.M. Cohen, D.A.T. Harper, P.L. Gibbard, N. Car

To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.

URL: http://www.stratigraphy.org/ICSchart/ChronostratChart2023-09.pdf

Indices of Sedimentary Formations:

In the field, the geologist creating a map first identifies and distinguishes the formations, or sedimentary layers, by their nature (lithology) and facies, such as massive limestone or fine sandstone. By observing their order of superposition, the geologist establishes a lithostratigraphy, a relative chronology of formations from the oldest to the most recent.

The collection of fossils, determined by paleontologists, allows for dating these formations more or less precisely in time and placing them in a stratigraphic scale divided into eras, periods, systems, subsystems, and stages (see the table), which are represented by legend boxes and their indices in the map legend.

In recent decades, the development of radiometric dating methods (or radiochronology, or geochronology) such as the K/Ar (Potassium/Argon) method, as well as paleomagnetism, has enabled a more detailed understanding of the so-called "absolute" age, in millions of years (Ma), of these stratigraphic stages for sedimentary formations and determining the age of intrusive, volcanic, or metamorphic rocks lacking fossils.

For sedimentary formations older than the Quaternary era, the letter in the legend index corresponds to a chronostratigraphic system or subsystem, relatively long, subdivided into stages (see the table). For example:
- k for the Cambrian system;
- t for the Triassic system;
- j for the Middle Jurassic and Upper Jurassic subsystems;
- n for the Lower Cretaceous subsystem, and c for the Upper Cretaceous.

A series attributed without more precision to the Cambrian-Ordovician will be noted as k-o. The number in the index specifies the attribution of the formation to a stage of the system or subsystem. The oldest stage has the number 1. n1, the Berriasian, is the oldest stage of the Lower Cretaceous, and n6, the Albian, is the most recent.

A subdivision within a stage uses letters again; 'a' represents the earliest term. Thus, n3a and n3b are respectively the Lower and Upper Hauterivian.

Conversely, n2-3a indicates that the Valanginian and the Lower Hauterivian are grouped, or undifferentiated, meaning they cannot be distinguished in the field.

With italicized capital letters, indices can also reflect the lithology (rock type) of a formation: j8D represents dolomites from the Upper Jurassic (Kimmeridgian).

The stratigraphic scale continues to be refined, and changes have occurred since the first 1/50,000 maps were produced. The table provides the stratigraphic notations currently recommended by the BRGM for the creation of new 1/50,000 maps of France. It includes some new stage names. Conversely, certain names of marine or continental stages from previously published maps are no longer listed; therefore, they are recalled in the right column.

Indices of Recent Superficial Formations:

Recent superficial formations, which sometimes cover ancient terrains, are mostly of Quaternary age. In this brief period (only 1.6 million years), they are often challenging to date precisely. Their indices use uppercase letters, corresponding to the type of formation and its mode of deposition:

- **F**: Indicates alluvial deposits from rivers. If multiple units can be chronologically distinguished, as in the case of stepped alluvial terraces, the youngest (lowest) has the index as the last letter of the alphabet. From the most recent to the oldest, the alluvial deposits are noted as Fz, Fy, Fx, Fw, even if their actual stratigraphic age is poorly known.

- **G**: Represents glacial formations (moraines, glacial alluvium, etc.) that formed in France only during the Quaternary. They are indexed similar to alluvial formations based on their relative age: Gz,..., Gv, from recent to ancient.

- **J**: Indicates alluvial fans, coarse alluvial deposits spread in a fan shape at the outlets of torrents, indexed like alluvial and glacial deposits.

- **E**: Marks scree, with varied nature sometimes distinguished: blankets or slope aprons of angular gravel and blocks on the slopes at the foot of steep walls and slopes of hard rocks, catastrophic collapses at the foot of walls, surface or mass landslides of clay formations, etc. They can also be indexed.

These relatively thin formations are often not represented on geological cross-sections. They can complicate the interpretation of maps where they are widespread, obscuring ancient terrains, their stratigraphic or tectonic boundaries, and hindering the understanding of the structures they conceal.

The decision to map or not map thin superficial formations is delicate. The surface they cover on a map depends, of course, on their abundance in the region. However, when comparing two neighboring maps, differences can also be noted, attributable to the choices made by the geologists who created the maps.

Indices of Volcanic Rocks

The indices of volcanic rocks (or effusive rocks) are Greek letters corresponding to their petrographic nature, for example:
- β (beta) = basalt;
- ρ (rho) = rhyolite;
- α (alpha) = andesite;
- τ (tau) = trachyte...

The addition of small letters and the legend of the legend boxes allow for distinguishing intrusive basalts (βi) from necks (volcanic vents) or dykes (veins), or tuff beds (α t) on the surface. The age of the rocks is indicated in the legend; if radiometric ages are known, they are provided in the map's description.

Indices of Plutonic Rocks:

Plutonic rocks, intrusive rocks, or oceanic floor rocks (ophiolites) are also indexed by Greek letters:
- γ (gamma) for granites,
- η (eta) for diorites,
- θ (theta) for gabbros.

Different types of granites and their ages can be distinguished in the legend and description.

Indices of Metamorphic Rocks:

Only the most common are mentioned, such as mica schists and gneisses, noted as ξ (ksi) and ζ (dzêta), respectively.

Other Formations:

Colors, textures, or specific symbols may indicate zones of tectonic brecciation (breccias, mylonites), veins, etc. For veins to be visible on the map, their thickness is greatly exaggerated compared to reality.

Indices for 1/80 000 Scale Maps:

Although no longer published, 1/80 000 scale maps are still used, with slightly different indexing rules compared to 1/50 000 scale maps. Some letters for systems and subsystems may vary, but the map legend provides clarification. However, the specific chronological indexing rules within a system, such as the Cretaceous (C), are as follows:

- Lower stages: Indexed with Roman numerals, decreasing from the oldest to the most recent, for example, CIII, CII, CI, read as "C third, C second, C prime." Each stage can be subdivided by lowercase letters as indices, from the oldest to the most recent: CIc, CIb, CIa, read as "C prime c..."

- Upper stages: Indexed with Arabic numerals, increasing from the oldest to the most recent, for example, C1, C2, C3. Each stage can be subdivided by letters as indices, from the oldest to the most recent: Ca2, Cb2, Cc2.

When formations are grouped, the indexing goes from the most recent to the oldest, for example, C1-CII or C3-1.

Geological Tracings:

Geological contours are drawn with fine lines, sometimes dashed in cases of uncertainty. These represent various types of boundaries, except for tectonic contacts: concordant and discordant boundaries, boundaries of superficial formations, volcanic terrains, intrusions, veins, etc.

Tectonic boundaries or tectonic features are depicted with thick lines. These include different types of faults and thrusts. When these features are certain and visible at the surface, the line is continuous. When they are certain but obscured by debris or other superficial formations, the line is dashed within the superficial formations. It's essential to note that this does not imply that these formations might be affected by the fault. In the absence of superficial formations, a fault drawn with dashes signifies uncertainty.

For each map, it is advisable to check the legend to understand the meaning of a tectonic contact represented with dashes.

Dip Signs and Other Tectonic Signs:

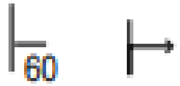
The dip signs for sedimentary terrains are not identical on all 1/50,000 scale maps. Next figure illustrates the most common dip signs. The shape is always that of a T; the direction of the upper bar relative to the north is the measured direction of the layers in the field. The vertical bar of the T, perpendicular, thus indicates the line of steepest slope of the layers or the dip direction, with its tip pointing downward.

On many maps, the value of the dip angle is not indicated next to the sign, or dip signs are too sparse. This lack of detail can be a drawback for precision in practical applications of these documents. To create cross-sections, it will be necessary to know the thickness of the terrains and indirectly determine their dip based on their outcrop width.

In a large fold or monocline, a dip sign can be significant over a relatively large area. However, close and varied dip signs indicate that the sector is heavily folded (folds); each dip sign then has only local significance. There is a specific dip sign for overturned beds. However, it's important to note that some maps may not use it, and attention should be paid to the order of the terrains to determine if they are in normal or overturned sequence.

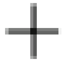
Among tectonic signs, there is also one indicating folds that are too small to be visible in the terrain contours. In general, the meaning of all tectonic signs is provided in the legend of each map.

Dip signs

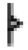


Inclined bedding dip

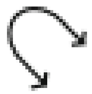

Vertical dip

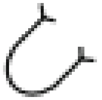

Horizontal dip

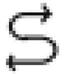
Dip of reversed sequence


Metamorphic schistosity

Folding signs


Anticline


Syncline


Fold

Fold axis and its plunge

The technical legend:

The technical legend primarily concerns useful materials such as quarries, mines, dimension stone, sand and gravel pits, and the location of boreholes, with information sometimes provided in the accompanying notes. Symbols also indicate hydrogeological features (springs, resurgences, hot or mineral springs, etc.), as well as other resources depending on the region.

A symbol resembling an 'F' indicates remarkable fossiliferous deposits that have been crucial for dating the geological formations.

Other information:

In addition to the essential legend mentioned above, some maps provide useful additional information.

Structural diagram:

In tectonically active regions, this simplified small map enhances the understanding of the map's tectonics by highlighting key structures such as fold axes, faults, and thrust faults. Sometimes, tectonic units or structural elements are differentiated using various colors."

General Geological Section:

To the delight of students, some maps include a geological section at the bottom. Its purpose is to provide the reader with a general idea of the geological structures but only in the vicinity of the cutting line.

Lithostratigraphic Column:

Sometimes, a lithostratigraphic column represents the sequence of geological formations, including their age, average thickness, and lithology indicated by symbols. This column simplifies the process of gathering this information for creating a section without having to refer to the map's accompanying notes. If the region has two paleogeographic domains with lateral variations in sediment thickness and facies, two columns may be provided, with correlation lines indicating the correlation of stages between them. Depending on the domains crossed by the section, one, the other, or both columns should be considered.

Boreholes:

In certain tabular regions where only a few formations are exposed on the map, columns obtained from boreholes may be included at the edge of the map or in its notes to provide information about deeper formations."

Map Notices:

Geological maps at 1/50,000 and 1/80,000 scale are accompanied by a booklet called a notice, which provides often essential information that cannot be graphically represented on the map. This includes data collected during the survey, bibliographic references, results from laboratory studies (paleontology, rock mineralogy, geochronology, geochemistry) related to the map's creation, or information from other works concerning the region, such as boreholes, mines, and hydrogeology.

The notices, ranging from about ten pages for relatively old maps to up to 150 pages for some recent maps, offer key information in the following areas:

a) General Presentation of the Region:
Focused on physical geography, this section mainly describes the landscapes of the region, its hydrographic network, and their connections with regional geology.

b) Nature, Age, and Thickness of Formations:
Essential for understanding the map and crucial for creating geological sections and map interpretations, this part of the notice describes the formations, their thickness (necessary for constructing geological sections), and their facies, which will be used to select symbols in the sections. Paleontological data (fossil fauna and flora) used for determining the age (stratigraphy) of sedimentary formations are also included in this section.

For plutonic, volcanic, and metamorphic rocks, their nature is determined based on mineralogy in thin sections, chemical analyses, and their ages established by radiochronological methods.

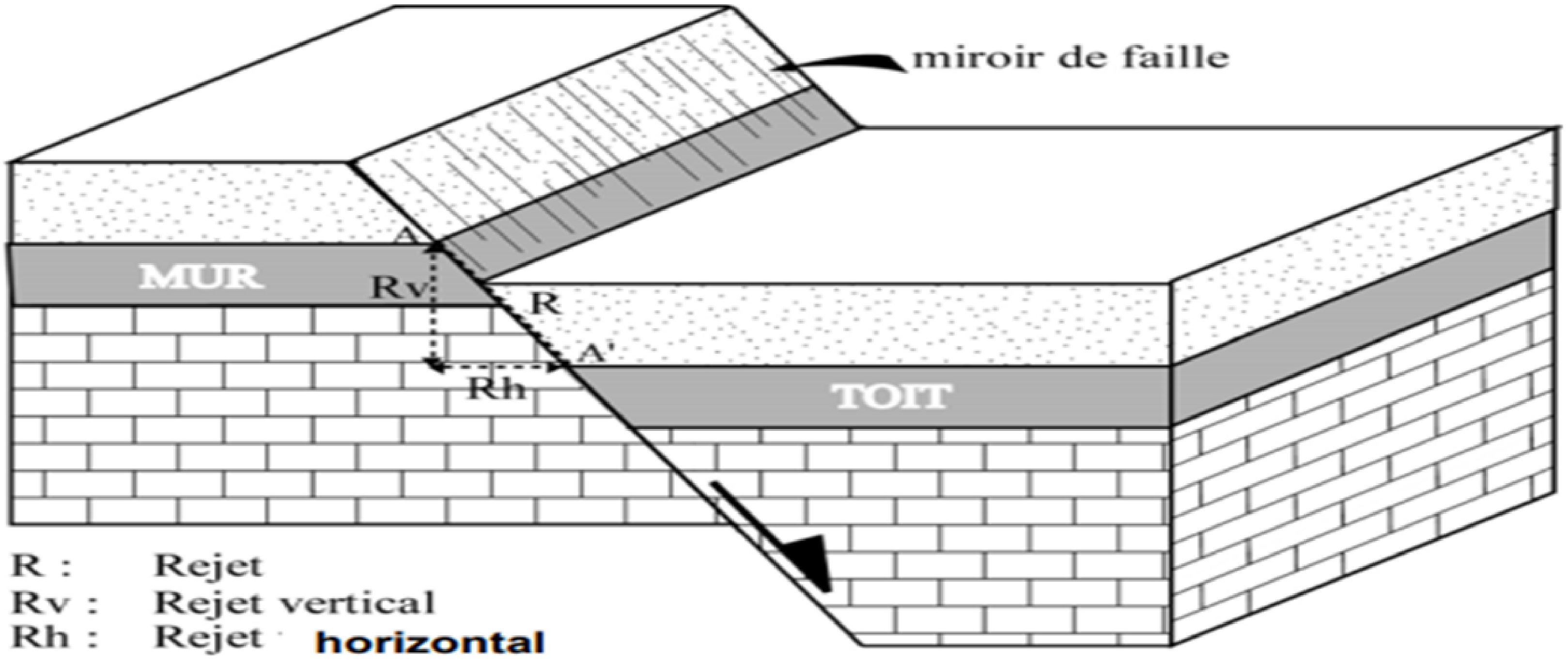
c) Regional Paleogeographic and Tectonic Evolution:
This section of the notice synthesizes sedimentological and stratigraphic data to reconstruct the regional paleogeographic evolution from ancient to modern times. It covers changes in environments (marine, continental), transgressions, regressions, emersions, and unconformities. In deformed regions, there is a description of tectonic structures, highlighting tectonic phases and their characteristics, such as age, nature (compression, extension), and stress direction.

d) Various Resources:
Finally, the notice addresses applied geology, discussing various useful materials such as various ores, coal, petroleum, dimension stone, aggregates, sands and gravels, and hydrogeology."

Structure Notation:

In geology, typically after the deposition of strata, they undergo tectonic forces that disturb their initial arrangement, giving rise to geological structures. Among these structures, we distinguish:

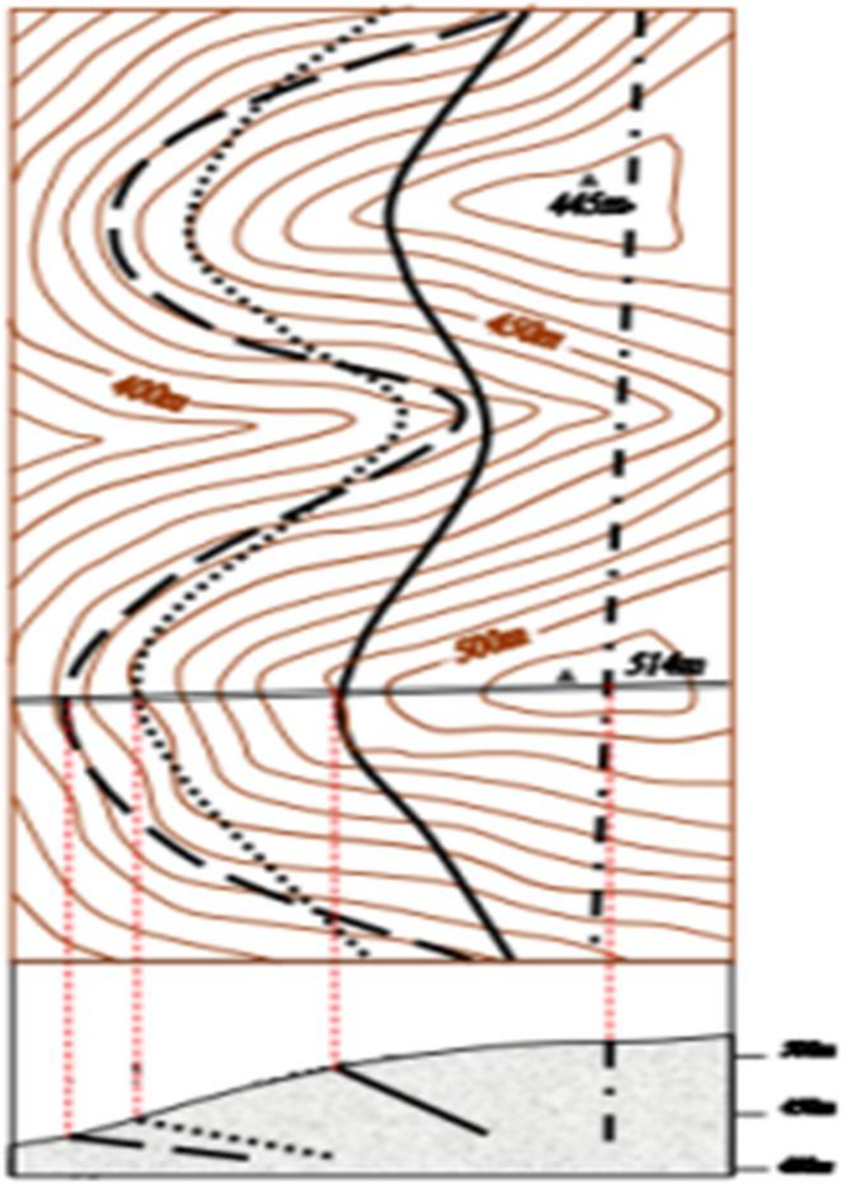
- **Faults:** A fault is a fracture in rocks accompanied by the relative movement of two compartments along the fault plane. The magnitude of this movement is referred to as the displacement or throw.



Fault Notation on Geological Map:

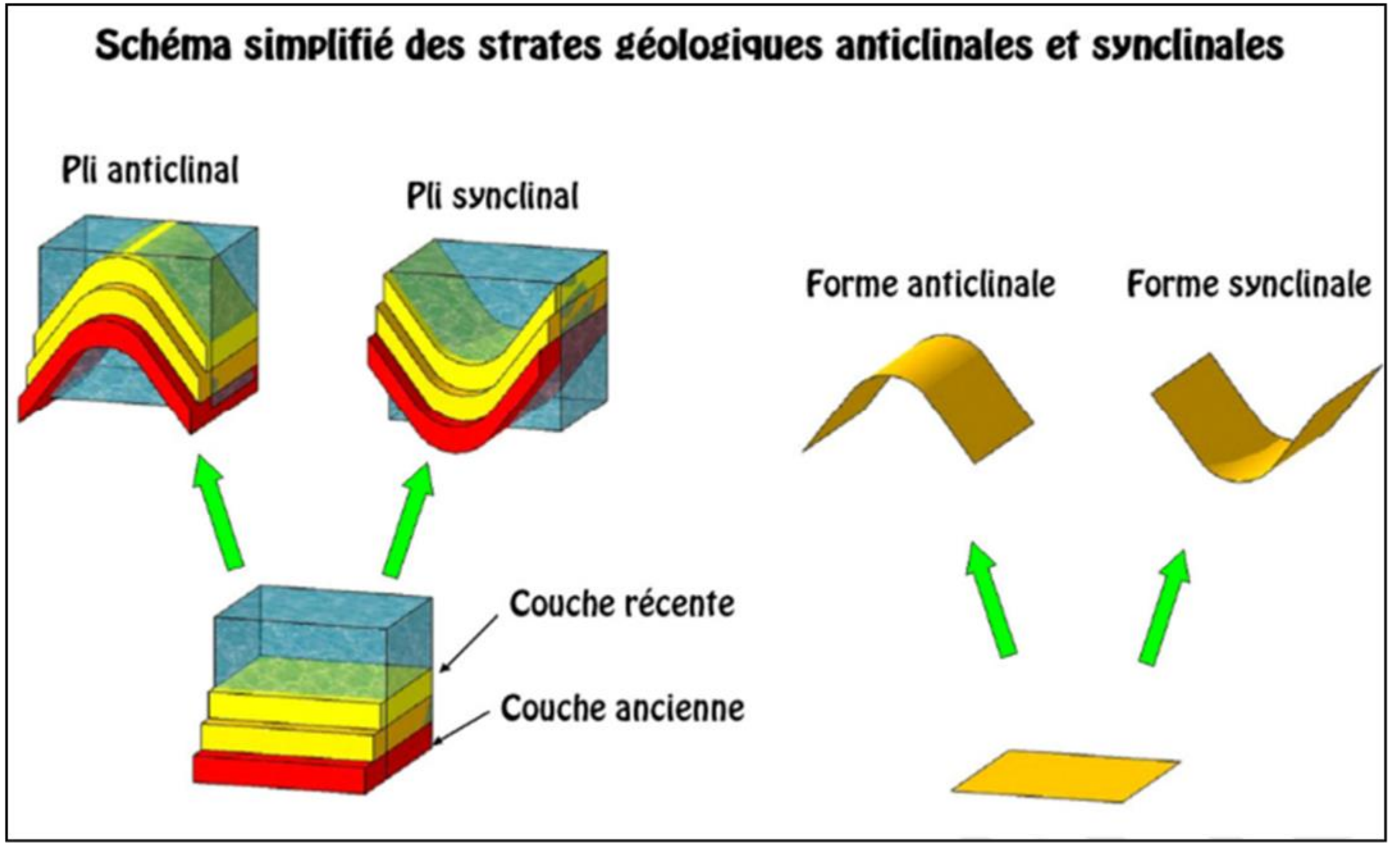
On a geological map, faults are represented by a line that is thicker than the boundaries of layers. This line may be:

- Continuous (certain fault)
- Discontinuous (relay fault)
- Dashed (fault concealed by recent information)

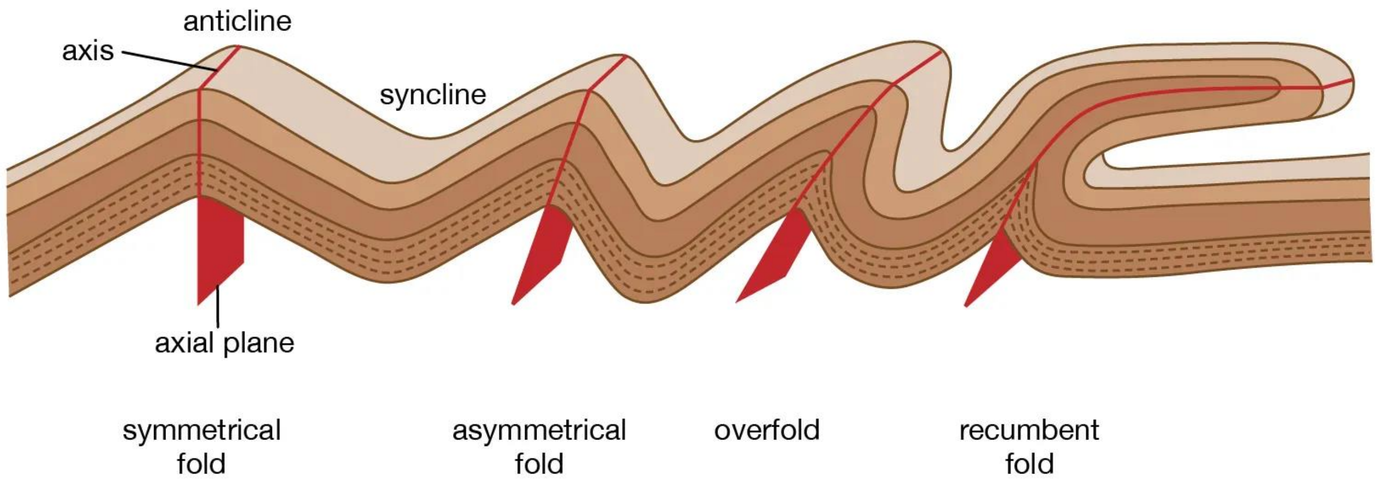


Folds: Folds are the result of tectonic stresses, where sedimentary strata (layers) can deform in a more or less plastic manner. Their dips then become variable and oriented in different directions, and they are said to be folded.

There are essentially two types of folds: the anticline and the syncline.



The Different Types of Folds:
Depending on the geometry of the axial plane, various types of folds can be distinguished.

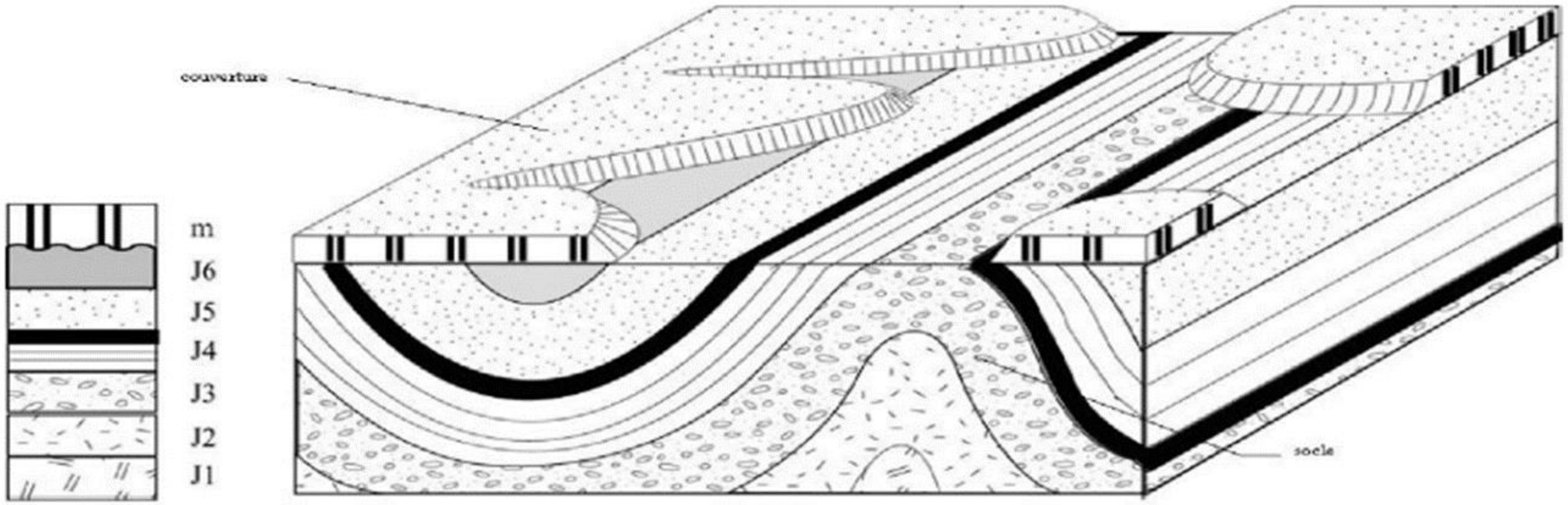


When the axial plane is vertical, it is referred to as an upright or symmetrical fold. The fold becomes progressively overturned, inclined, and recumbent as the axial plane inclines more and more.

Discordant Structures:

A. Discordance: In a sedimentary basin (about 80% of which are in marine environments), the strata are organized in parallel layers, and this arrangement is referred to as concordant. If, during the geological history of this basin, due to tectonic activity, erosion, or variations in sea level cycles, the geometry of the deposits is disrupted, it is termed as discordance.

During a tectonic phase, if sediments are folded and emerge from the water, they are quickly eroded, flattening the terrain and creating an erosion surface. If, subsequently, the sea transgresses and deposits new sediments on this surface, there is then a discordance between the horizontal layer and the folded series. It is observed that the dissected discordant layer, later eroded, rests indiscriminately on the different folded layers. This is known as an angular unconformity.

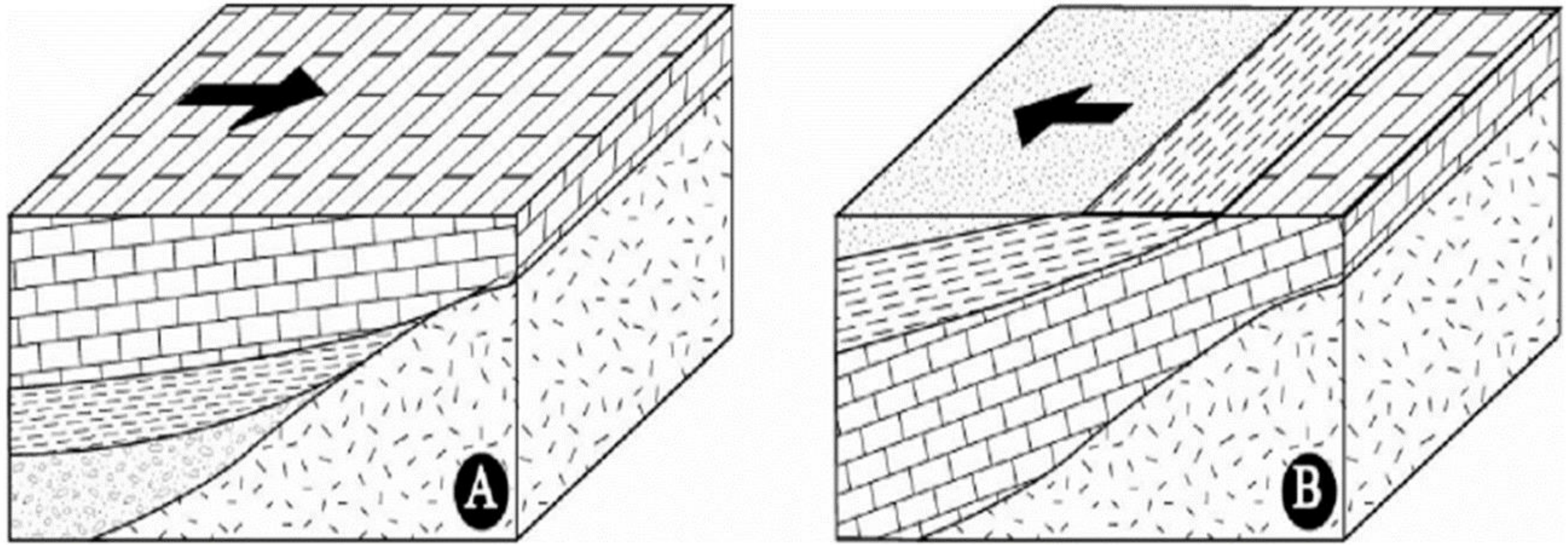


B. Transgression and Regression:

Over geological time, the boundaries of seas can vary for various reasons (tectonic, climatic, etc.), and this occurs in two main ways:

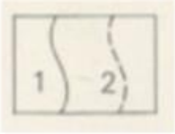
1. Transgression: This happens when there is a rise in sea level, causing the sea to surpass its initial limits. It leads to the deposition of new sediments that advance beyond those deposited earlier (Figure A).

2. Regression: In contrast, regression occurs when there is a drop in sea level, causing the sea to retreat within its initial boundaries. Sediments associated with this phenomenon are generally less extensive than those from the previous period (Figure B).



Other conventional symbols:

There are other conventional symbols; here are some examples:

Signe	Signification
	Traces de bancs
	Contact normal : (1) Contact d'affleurement visible (2) Contact d'affleurement caché
	Gîtes fossilifères
	Eboulement en masse
	Escargotière (gisement néolithiques)
	Carrière