INSTRUCTIONS FOR THE WRITTEN TEST

WRITTEN TEST 1 : 3 HOURS

The test is divided in sections. They can be partially linked. So it may be interesting to try to answer the questions of one section before beginning to the next one.

PLEASE ANSWER ON THE ANSWER SHEET

MARKING THE QUESTIONS :

If only one answer is required (only one answer) :
- Correct answer chosen : +1 point
- Wrong answer or several answers chosen : 0 point

If several possible answers :
- For each correct answer : + 1 point
- For each wrong answer : -0,5 point

No question can be marked under 0 (zero). If number of negative points exceeds the positive points, the question will be marked zero : +1-1,5 = 0

IESO 2017 - WRITTEN TEST NUMBER 1

50 YEARS OF DEVELOPMENT IN THE VAR VALLEY

The Var alluvial plain is an estuary associated with the longest river in the French Southern Alps. Between the mountains and sea, over a distance of 110 km, the Var is a vast depression (average width = 1.2 km), which reaches the Mediterranean coast. Such an environment presents many challenges, including conservation of the unique biodiversity associated with the estuary, and the sustainable economic development of the area. Indeed, the Côte d'Azur is experiencing a period of growth in the pristine and utilizable areas of the lower valley. With the help of figures and your knowledge, we will take several approaches to understand the complexity of this vibrant environment.

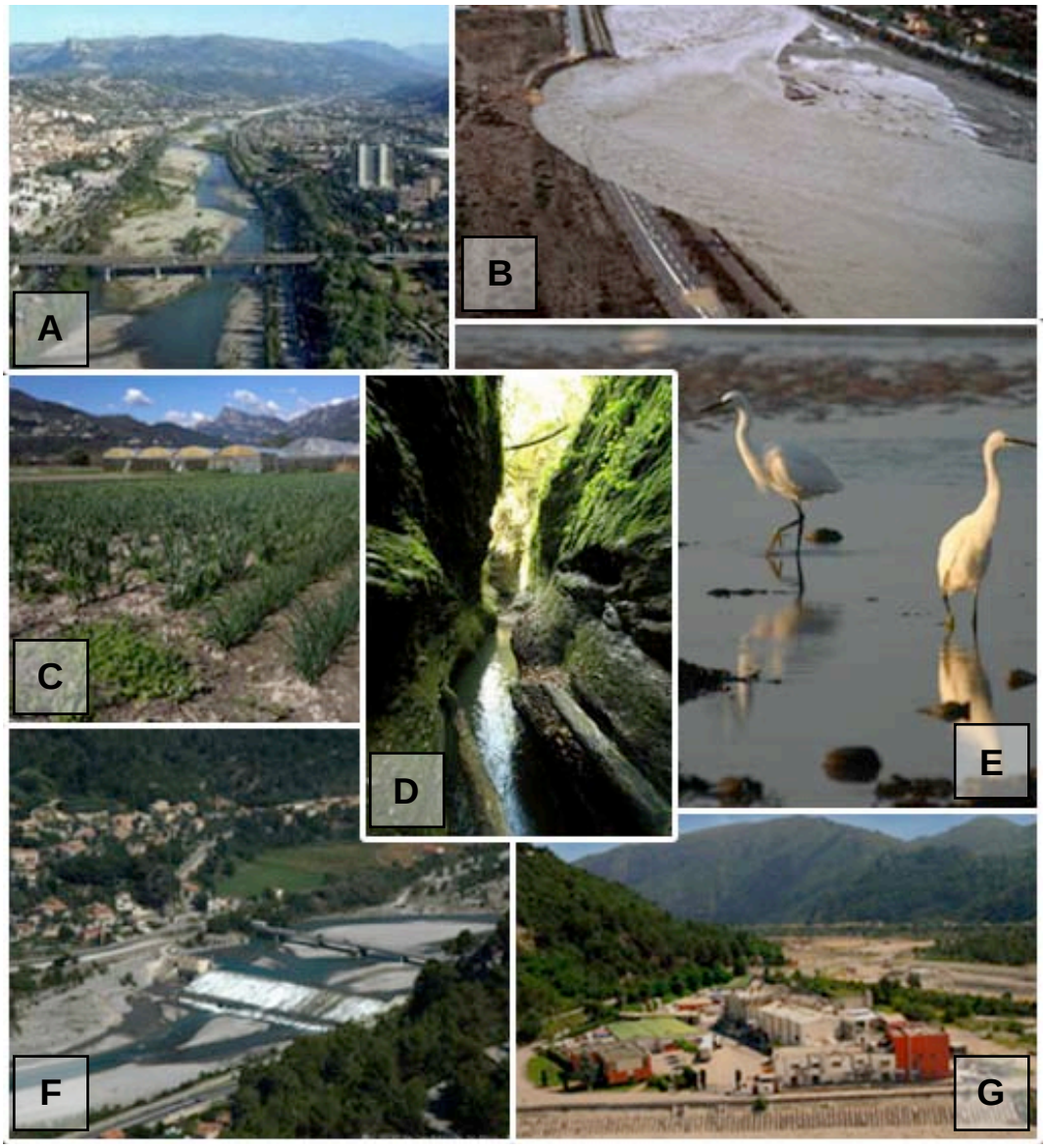


FIGURE 1 : (A) A view of the Var plain looking north; (B) Illustration of the major flood of 1994; (C) Agricultural activity in the valley of the Var; (D) and (E) Illustration of the preserved environments in the plain; (F) containment and dam to control the flow of the river; (G) Industrial activity in the plain.

SECTION 1 : OVERVIEW OF THE PETROLOGICAL DIVERSITY OF THE VAR VALLEY, STUDY TRACKS

The lower valley of the Var is a geographical area, which initially presents a landscape with relatively homogenous rock types. However, on closer inspection, one can observe very diverse rocks, reflecting a complex geological history. The photographs below illustrate this diversity.

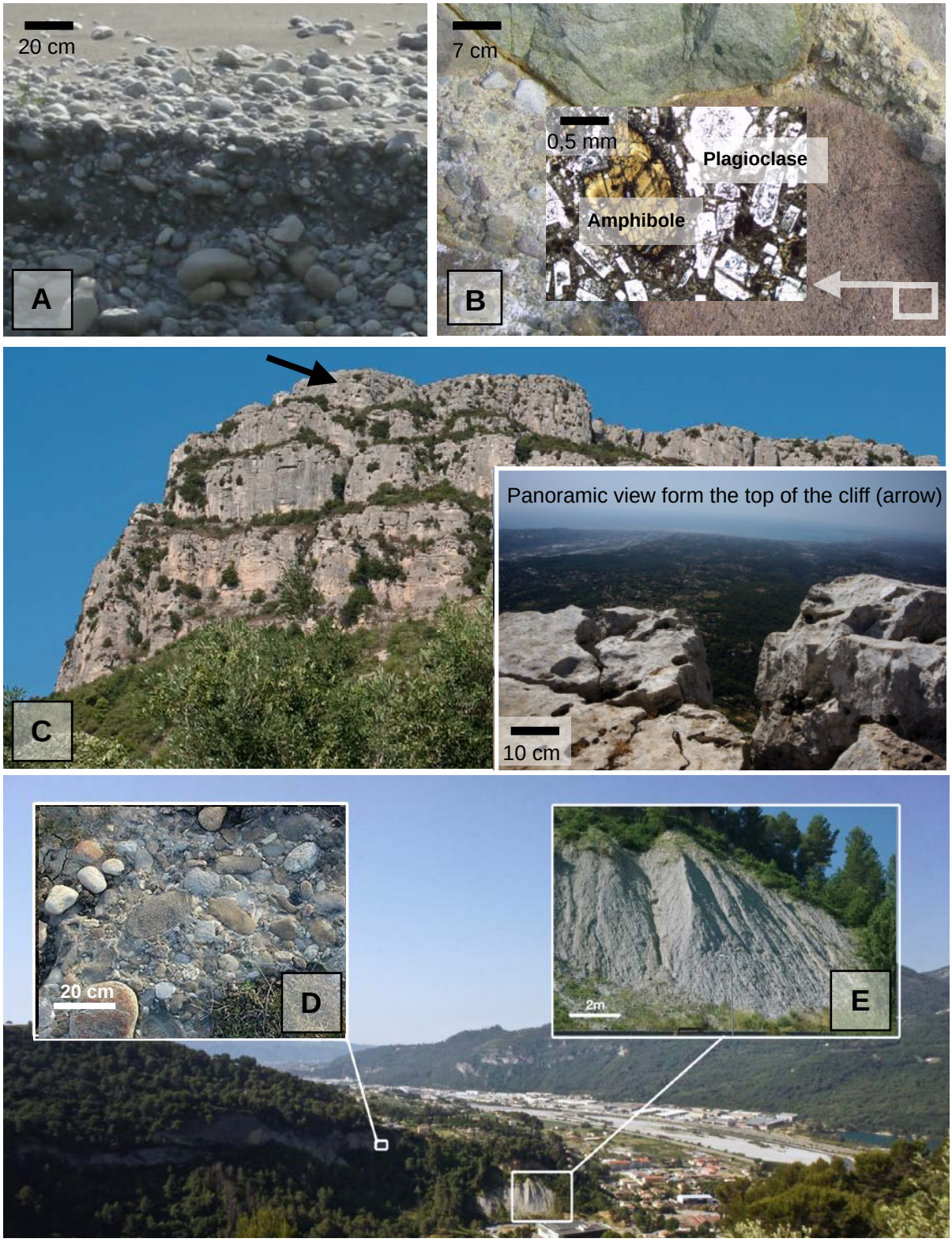


FIGURE 2 : Photographs of the large-scale geological formations that make up the landscape of the Var Plain.

Question 1: Refer to figure 2. On your answer sheet, match the picture letter with the number of the corresponding description: (some descriptions do not correspond to any photograph)

1- an alluvial deposit indicating transported, deposited and poorly consolidated sediments.
2- a metamorphic rock showing substantial deformation.
3- a turbidite indicating a graded sequence.
4- a sedimentary breccia at the bottom of a slope characterized by unsorted angular particles.
5- a volcanic breccia composed of a fine matrix, showing load-casts around blocks of microlitic rocks.
6- a homogeneous and poorly consolidated clay deposit.
7- a conglomerate of well-consolidated pebbles.
8- a crystalline rock of granitic type because of its homogeneous massive appearance.
9- a well-consolidated, sedimentary rock.

Question 2: Refer to figure 2. The following statements describe geological processes favorable to the formation of different rock types.On your answer sheet, match the picture letter with the number of the corresponding description: (some descriptions do not correspond to any photograph)

1- Continental sedimentation with little or no transport
2- Aeolian sedimentation.
3- Deposition of volcanic material.
4- Continental deposition and consolidation after a long transport
5- Continental deposition after a long transport
6- Shallow oceanic sedimentation (less than 2,000 meters)
7. Sedimentation of fine particles in a calm environment.



FIGURE 3 : Photograph of pebbles that constitute the conglomerates of the Var valley.

Question 3 : Refer to figure 3. Beside the rock descriptions, correlate the pebbles photographs and one of the description (some descriptions do not correspond to any photograph) :

1- An andesite-type of volcanic rock.
2- A granitic-type of rock composed of minerals visible to the naked eye.
3- A metamorphic rock like gneiss with bands of minerals with contrasting colors that highlight important deformations.
4- A well consolidated rock composed of particles about one millimeter size. This is called a red sandstone because of its color.
5- A very homogeneous rock that does not reveal any minerals to the naked eye.
6- A metamorphic rock displaying schistosity.

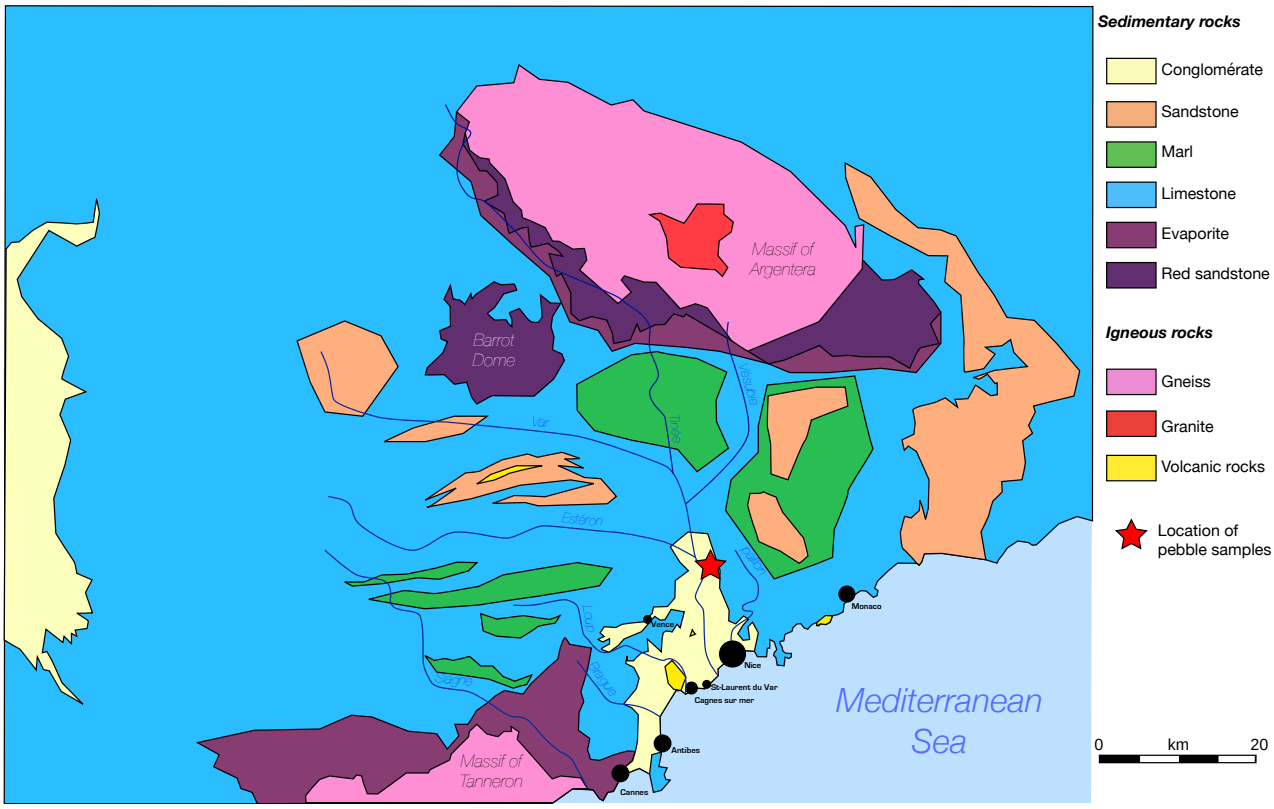


FIGURE 4 : Simplified lithological map of the region crossed by the Var and its tributaries. Pebbles photographs are from the location marked by the red star.

Question 4 : From the map (Figure 4), we can estimate the minimum distance traveled by the rock fragments which have become the pebbles observed in figure 3 : (only one answer)

	pebble A	pebble B
1-	80 km	200 km
2-	35 km	35 km
3-	30 km	15 km
4-	80 km	80 km

To understand this region, it is necessary to consider all aspects of the recent and older history of this territory, for which rocks are the evidence. We will check later, in order to understand the management issues of the lower Var valley.

SECTION 2 : HYDROLOGY OF THE VALLEY, EVOLUTION OF AN IMPORTANT AQUIFER

The city of Nice and the neighboring communes draw a significant amount of water from the aquifer of the Var plain for domestic use. Also, It is a local resource for the agricultural activity that historically took place on the valley land.

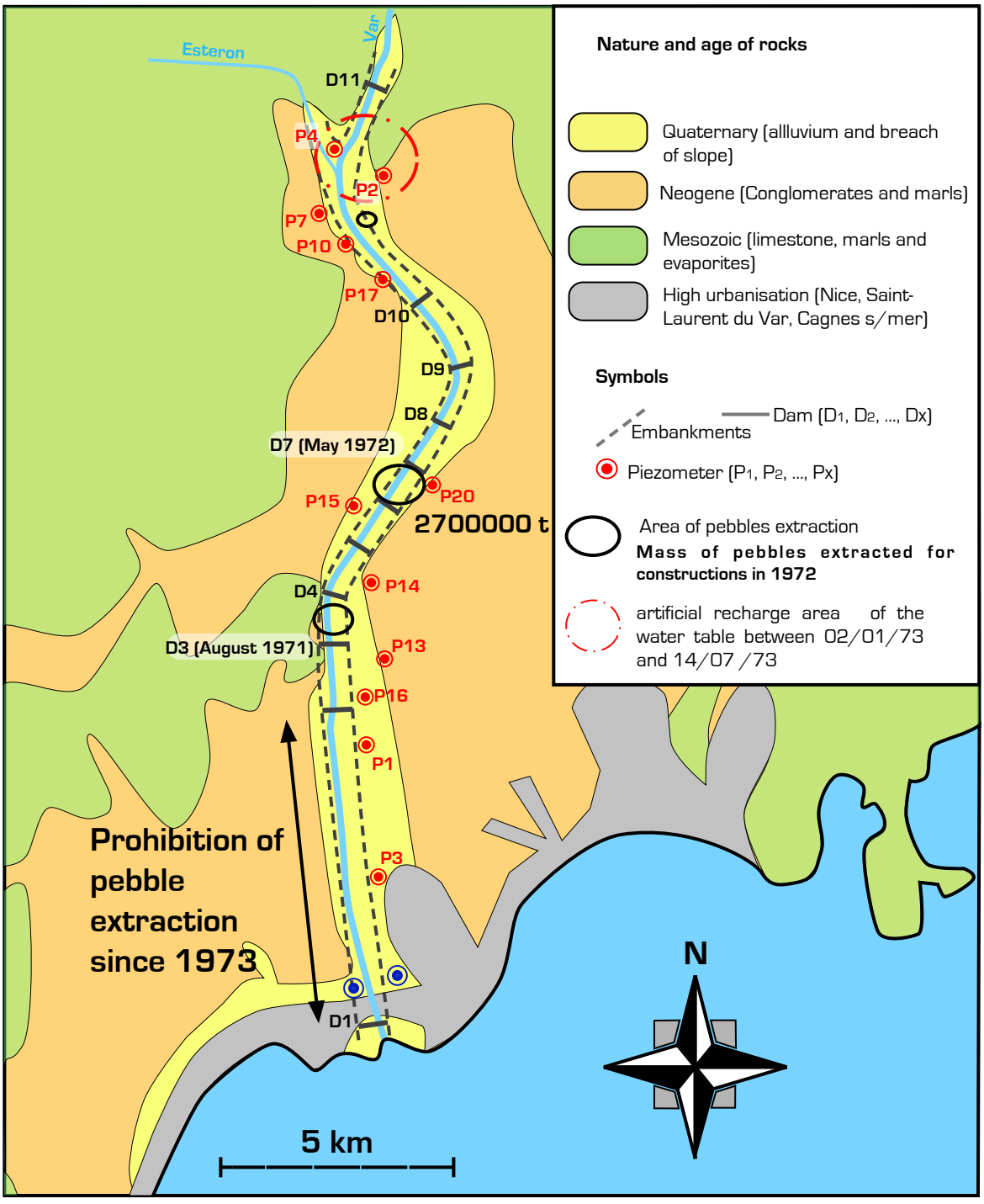


FIGURE 5 : General location map of the Var plain. The background map shows the major geological features (reviewed in more detail later), indicating the measuring equipment and devices along the course of the Var. Specific activities are located in zones : areas of pebble extraction in the river bed, and an artificial supply area of groundwater by lateral irrigation from the Var. In 1973, the groundwater in the conglomerates around the Var was re-supplied by major irrigation works (canals dug and spread over the entire area).

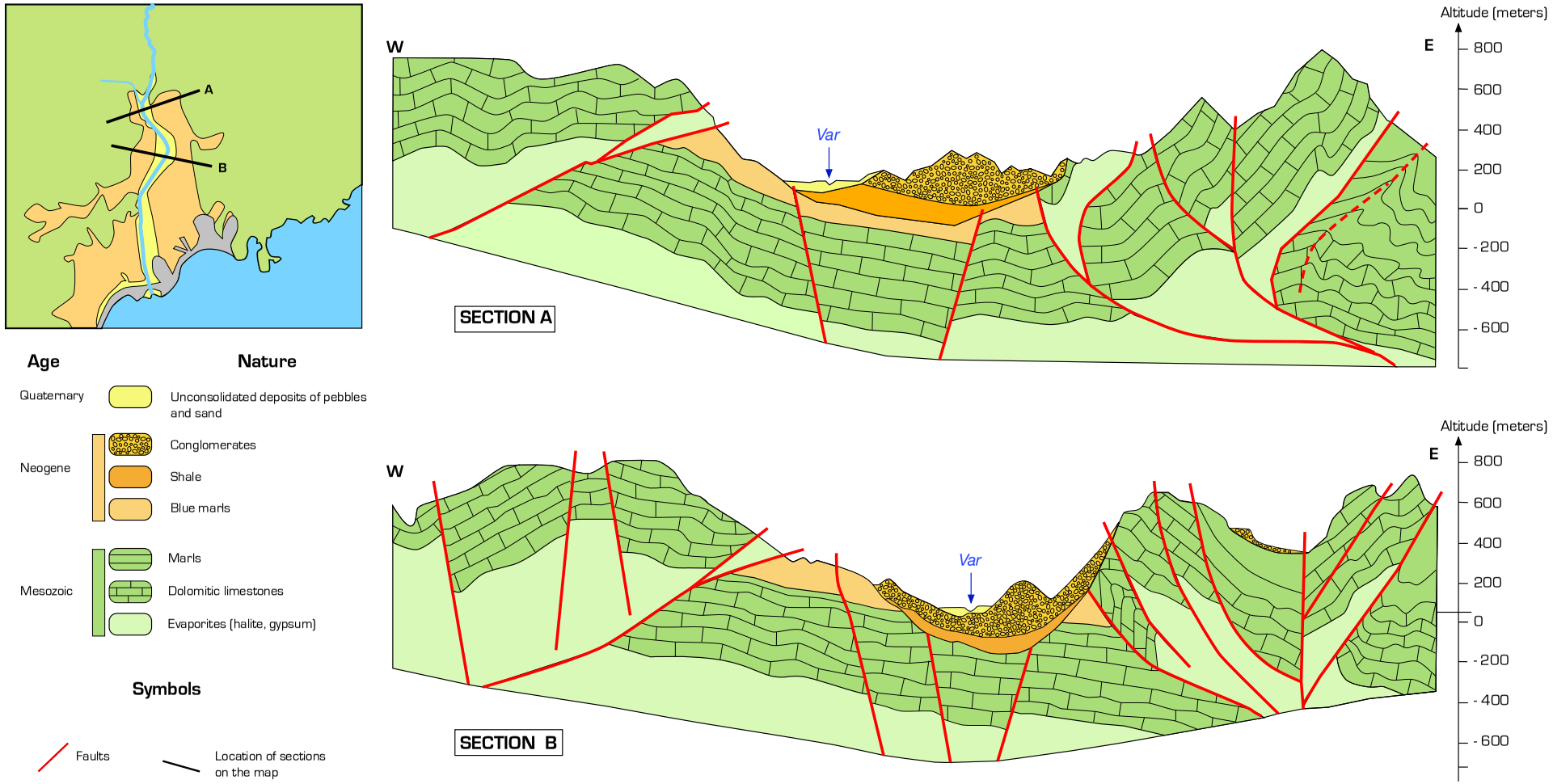


FIGURE 6 : Geological cross sections (section lines A-A' and B-B' shown in the map) along the Var valley.

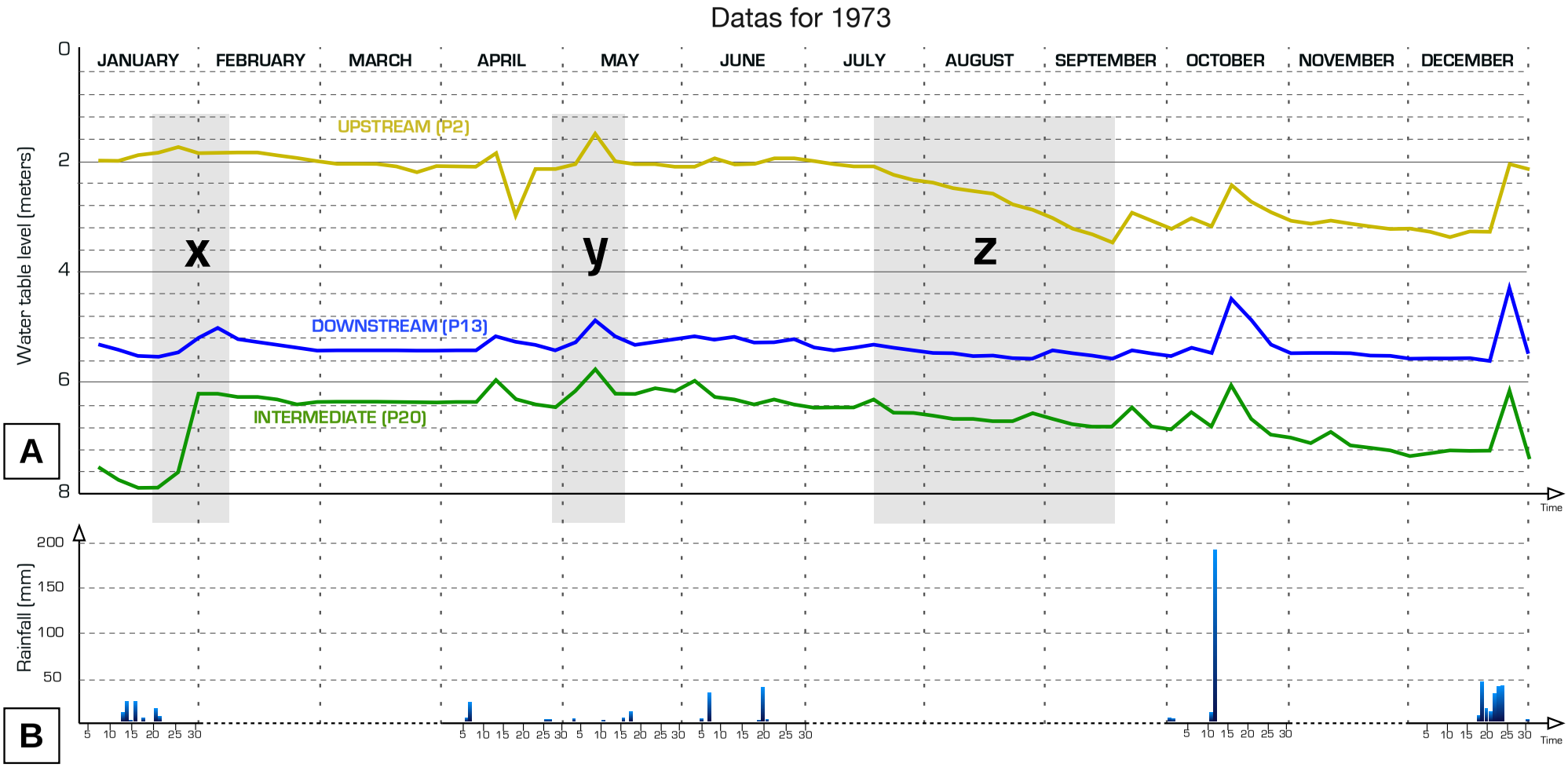


FIGURE 7 : Datas of the water table level (A) and rainfall (B) in the Var valley Each bar in figure B represents rainfall on a particular day. P refers to piezometer

Test code : WT-1

Question 5 : On a large-scale, identify the rocks that can constitute a good groundwater reservoir. Aquifer is a medium that contains and transmits water: (several possible answers)

1- Clay and limestone because they are impermeable.
2- Conglomerate and limestone because they are permeable.
3- Conglomerate and clay because they are impermeable.
4- Sandstone and limestone because they are permeable.
5- Clay and limestone because they are permeable.
6 - Clay and conglomerate because they are permeable.

Question 6 : On a large-scale, identify the rocks that can prevent the passage of water from one aquifer to another: (Only one answer)

1- Clay because It is permeable.
2- Conglomerate because It is permeable.
3- Limestone because It is permeable.
4- Clay because It is impermeable.
5- Limestone because It is impermeable.
6- Conglomerate because It is impermeable.

Question 7 : The data given in figure 7 (piezometers P2, P13 and P20) are related to the groundwater contained in aquifers. Those aquifers are essentially composed of (only one answer) :

1- Evaporites.
2- Limestones.
3- Conglomerates.
4- Alluvial deposits.

Question 8 : Refer to figure 7, choose all correct statements pertaining to zone x (several answers possible) :

1- The water table rises.
2- The water table rises at the same speed along the watercourse.
3- The water table goes down.
4- The water table rises less upstream than in the downstream segment.
5- The water table drops less upstream than in the downstream segment.
6- The water table level changes following precipitation of 100 mm over a period of 3 hours.
7- The water table level changes following precipitation of 100 mm over a period of 10 days.
8- The water table level changes following precipitation of 30 mm over a period of 10 days.
9- The water table level changes following precipitation of 30 mm over a period of 3 hours.

Question 9 : Refer to figure 7, choose the correct statement pertaining to zone y. The water table : (Only one answer)

1- increases due to the May rainfalls.
2- goes down due to the May rainfalls.
3- goes down due to snowfall.
4- increases due to snow melt.
5- increases due to snowfall.

The contacts between the different aquifers along the Var valley aren't continuous. As It is visible on the transects upstream and downstream (see figure 6), the Neogene shale layer separate or not two aquifers, depending on the river level. In period of low water (figure 8A), the conglomerate aquifer is isolated from the river and loses its source of recharge. In period of flood (figure 8B), river supplies the groundwater into the conglomerate aquifer.

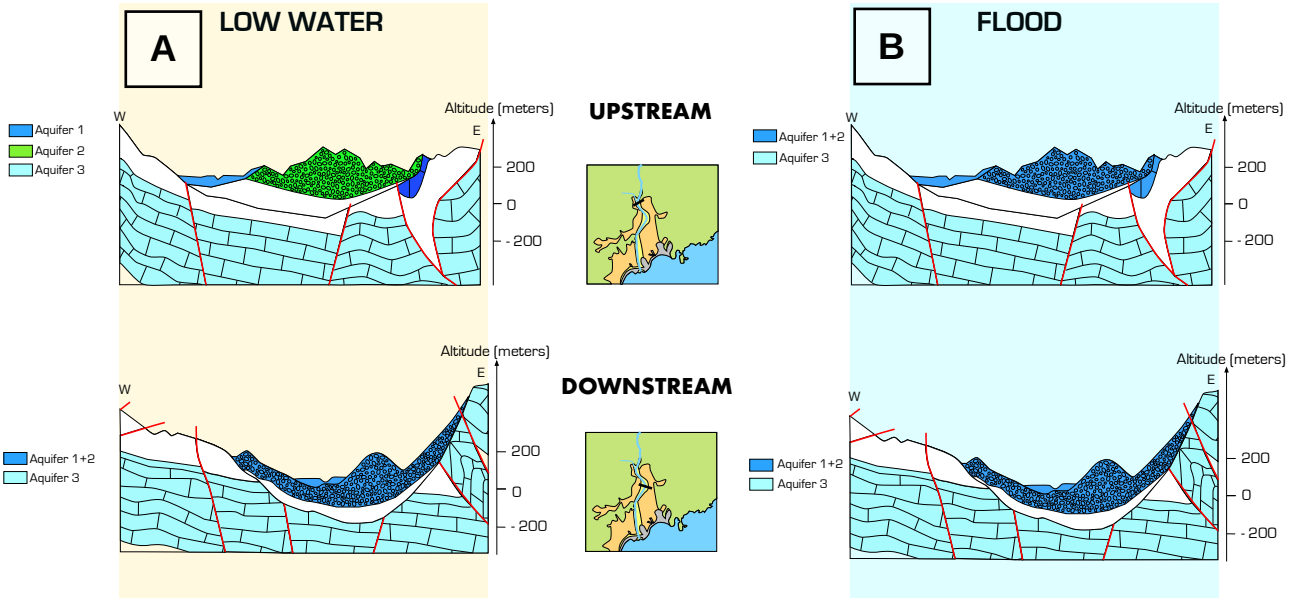


FIGURE 8 :Transect along the Var Valley during a low water period (A) and a flood period (B).

Question 10 : Refer to figure 7 and 8. Choose all correct statements pertaining to zone z (several possible answers) :

1- The level of the upstream groundwater is lowered more than elsewhere due to local drought.
2- The level of the upstream groundwater is lowered more than elsewhere because the Var no longer supplies groundwater, its level being too low.
3- The level of the upstream groundwater is lowered more than elsewhere because the Var no longer supplies groundwater, its bed being isolated from the conglomerate by clay.
4- The level of the upstream groundwater is lowered because water is no longer supplied artificially.
5- The level of the upstream groundwater is only lowered due to the seasonal drought.

Question 11 : In 1973, between the piezometers P15 and P20, 2,700,000 tons (tons = 1000 kg) of pebbles were extracted. Which volume corresponds to this mass ?(density of pebbles = 2000 kg.m^{-3})

1- 1.35×10^{9} m^3	5- 0.74×10^{9} m^3	9- 0.74×10^{-9} m^3
2- 1.35×10^{9} kg	6- 0.74×10^{9} kg	10- 0.74×10^{-9} kg
3- 1.35×10^{6} m^3	7- 0.74×10^{6} m^3	11- 0.74×10^{-6} m^3
4- 1.35×10^{6} kg	8- 0.74×10^{6} kg	12- 0.74×10^{-6} kg

Question 12 : Over a year, the water table in piezometer P2 and P13 : (only one answer)

1- increased by one meter
2- remained unchanged
3- decreased by one meter
4- increased by 0.1 meter
5- decreased by 0.1 meter

Question 13 : Over the next five years, the change in groundwater level has continued the global trend (see question 12). The accepted explanation is extraction of the pebbles from the river-bed. What is the logical explanation to account for these two facts? Removing the pebbles would : (only one answer)

1- reduce the size of the reservoir.
2- modify the slope of the river-bed; hence, the water would flow faster, leaving less water in the reservoir.
3- modify the slope of the river-bed, which would then erode the upstream segment of the river-bed.
4- destroy the aquifer, and the groundwater contained escapes to the surrounding land.

Date of datas	**1970**	**1971**	**1972**	**1973**
January 30th	4	3.95	5.8	5.3
March 28th	3.78	3.7	5.8	5.55
May 21st	3.8	3.7	3.52	5.56
August 20th	4.3	4.87	4.98	6
September 17th	4.03	5.51	5.1	6.24

TABLE I : *Water table level (meters) data collected at the P20 piezometer station from the period January 1970 to September 1973. During this period, dams were constructed (see previous figures).*

Question 14 : Refer to table 1. Which problems are linked to changes in water table level (Figure 7) ? (several possible answers)

1- Water becomes more polluted because it is deeper but its volume remains constant.
2- Water needed for domestic use and agriculture is more difficult to extract.
3- The total volume of water contained in this groundwater system decreases.
4- Water flows faster at depth; therefore, its extraction is more difficult.

Question 15 : Among the solutions meant to improve water supply, which ones would have limited the observed trend of the water table level ? (several answers possible)

1- Two embankments were placed on either side of the riverbed.
2- The groundwater was artificially recharge upstream.
3- The extraction of the pebbles was totally forbidden.
4- Dams were constructed across the watercourse.
5- Deeper wells were dug.

In conclusion, utilization of resources at the mouth of the Var can be managed over the long term only if interactions between the hydrosphere and the geosphere are understood. It is, therefore, necessary to better understand the interactions. Presently, we intend to collect valuable recordable data.

SECTION 3 : SEISMIC CONTEXT OF THE VAR VALLEY AND SURROUNDING AREA

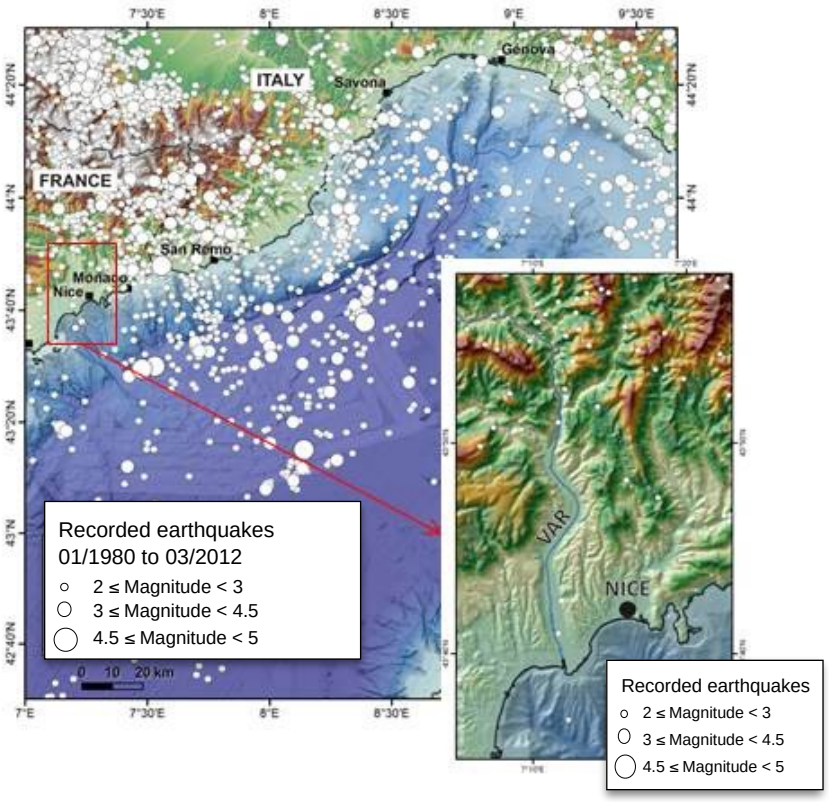


FIGURE 9 : Seismic map (location of earthquake epicenters detected by the seismometers) of the area and a zoom on the lower valley of the Var (area of interest). Earthquake foci never exceeded 30 km depth.

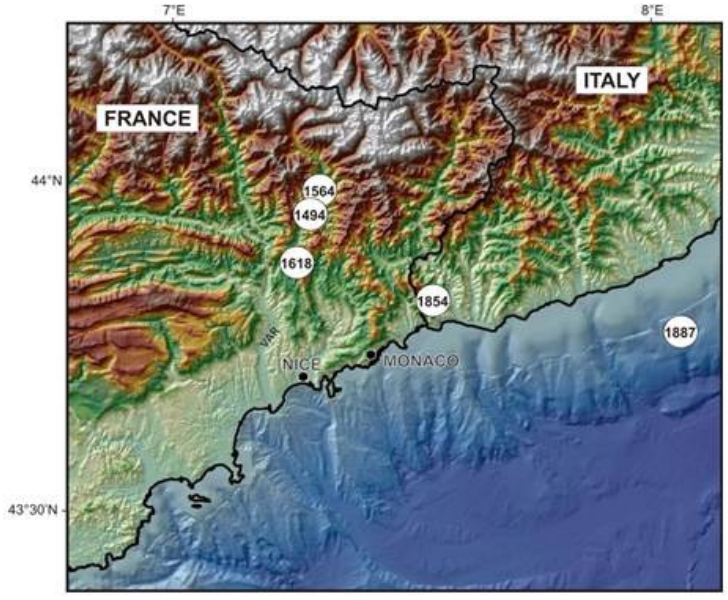


FIGURE 10 : Historical seismicity map (location of earthquake epicenters (before seismometer were used), based on the assessment of ground motion during an earthquake based on witness accounts and observation of destruction): macroseismic epicenters of A.D.1494 (maximum intensity VIII), A.D.1564 (maximum intensity VIII), A.D.1618 (maximum intensity VII-VIII), A.D.1854 (maximum intensity IX) and A.D. 1887 (maximum intensity VIII).

A

I. Not felt except by a few people under especially favorable conditions.
II. Felt only by a few persons at rest, especially on the upper floors of buildings.
III. Felt quite noticeably by persons indoors, especially on the upper floors of buildings. Many people recognize it as an earthquake.
IV. Felt indoors by many, outdoors by a few during the day. At night, some woke up. Dishes, windows, doors disturbed ; walls make cracking sound. Sensation like a heavy truck striking the building.
V. Felt by nearly everyone ; many woke up. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks stopped.
VI. Felt by all, many frightened. Some heavy furniture moved ; a few instances of plaster falling down. Damage slight.
VII. Damage negligible in buildings of good design and construction ; slight to moderate in well-built ordinary structures ; considerable damage in poorly built or badly designed structures ; some chimneys broken.
VIII. Damage slight in specially designed structures ; considerable damage in ordinary secure buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, columns, monuments, walls. Heavy furniture overturned.
IX. Damage considerable in specially designed structures. Power cut. Damage great in secure buildings, with partial collapse. Buildings shifted off foundations.
X. Some well-built wooden structures destroyed ; most masonry and frame structures with foundations destroyed. Rails bent.
XI. Few, if any, (masonry) structures remained intact. Bridges destroyed. Rails bent greatly.
XII. Damage total. Lines of sight and level are distorted.

B



FIGURE 11: (A) Macroseismic Intensity Scale (assessment of the ground motion based on witness accounts and observation of destructions). (B) Approximate correspondence between macroseismic intensity and magnitude for a crustal earthquake (hypocenter between 0 and 30km).

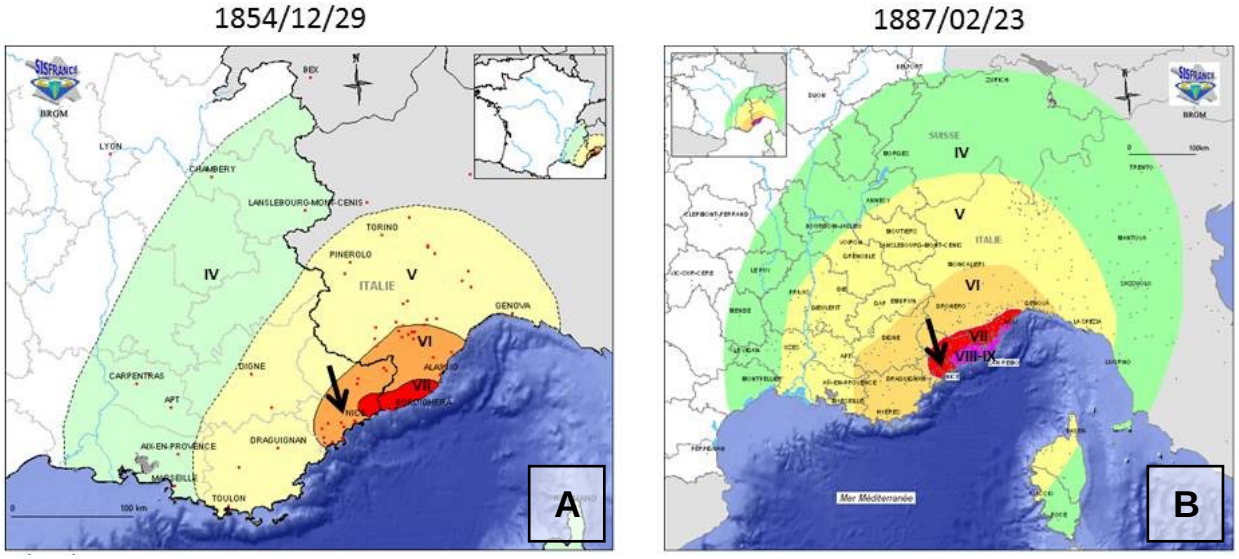


FIGURE 12: Isoseismal maps prepared after the earthquakes of A.D.1854 (A) and A.D.1887 (B).The colored zones indicate the fields of equal ground motion intensity.The Var valley is indicated by the black arrow.

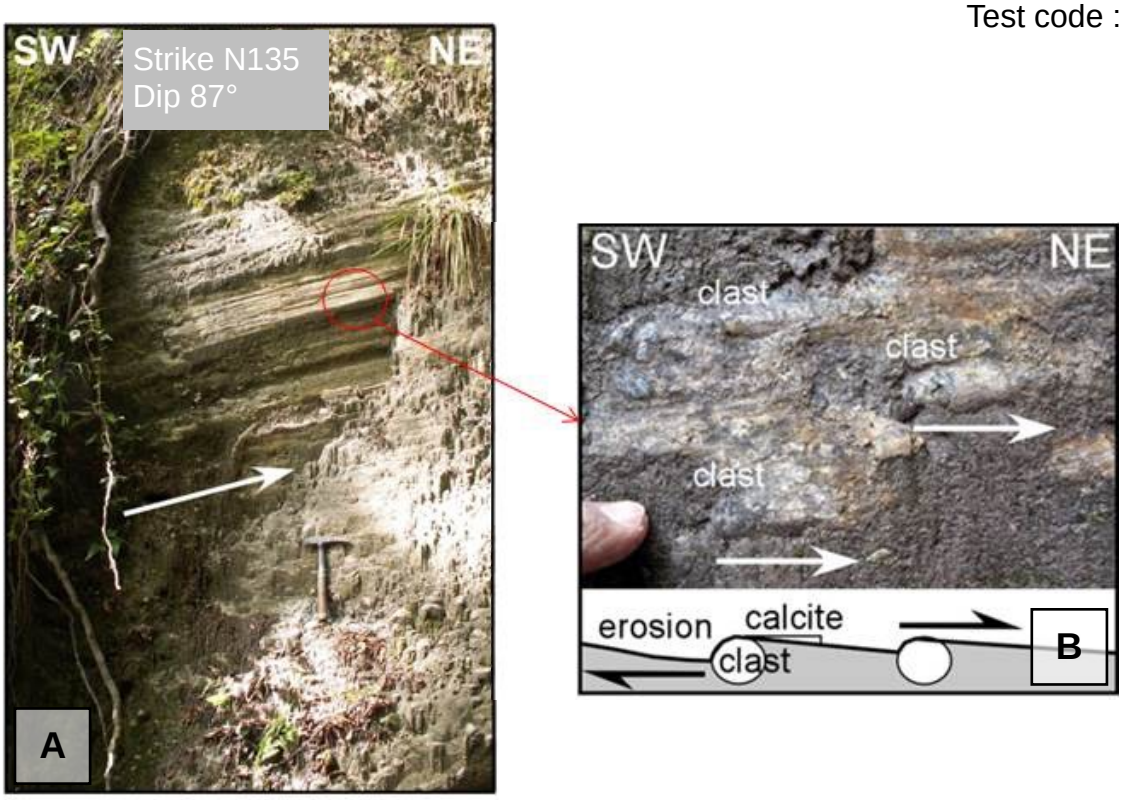


FIGURE 13 : (A) A recent fault plane that has not been displaced since its formation. The photograph was taken near the epicenter drawn on figure 14. (B) Explanatory diagram of the kinematic evidence observable at the outcrop.

Question 16 : The seismicity recorded by seismometers on the figure 9 shows : (several answers possible)
1- earthquakes of magnitude greater than 7.
2. Only a few earthquakes per year.
3- earthquakes of magnitude less than 5.
4- high seismic frequency (more than 10 earthquakes of magnitude 3 or more per year).

Question 17 : Refer to figure 9. The spatial distribution of seismicity is : (several answers possible)
1- diffuse.
2- aligned along one or more faults.
3- mainly concentrated offshore.
4- mainly located onshore.
5- characterized by shallow foci.

Question 18 : Over the period from 1980 to 2012 (figure 9), the Var valley had a seismicity rate ——— the regional seismic average
1- greater than
2- similar to
3- lower than

Question 19 : Searching for traces of ancient earthquakes in historical witness accounts and historical records : (several possible answers)

1- Some historic earthquakes have led to the destruction of buildings.
2- No earthquake caused human injury or physical damage in the region.
3- The maximum magnitude of historical earthquakes is the same as the magnitude of the instrumental earthquakes for the 1980-2012 period.
4- The maximum magnitude of historical earthquakes is greater than 6.
5- There are no historical earthquakes affecting the Var valley.
6- All historically recorded earthquakes have a magnitude higher than the instrumental earthquakes of the period 1980-2012.

Question 20 : Based on these data, indicate the most responsible decision for the situation you have described :

1- The seismic risk in the Var valley is not high enough to warrant the use of seismic building standards.
2- There is a real seismic risk in the Var valley. Seismic standards must be adopted.
3- There is a real seismic risk. Seismic standards enabling buildings to withstand ground motion of intensity around XII must be adopted.



FIGURE 14 : Structural map of the Var valley showing the relative motion (circle with colored zones. The two lines inside represent possible motion directions on a non-observed fault - arrows symbolize relative motion linked to each possible fault) ; along a fault during a recent earthquake. Legend : A–crystalline bedrock, B–Mesozoic sedimentary cover, C–Plio-Quatenary sedimentary deposits. Near the location of the epicenter plotted on the map, the fault plane of figure 13 have been observed.

Considering data recorded on the seismic event described in figure 14, some uncertainty still remains on the original fault. 2 possibilities : a dextral displacement along a fault oriented NW-SE or a sinistral displacement along a fault oriented NE-SW.

Question 21 : Considering all the figures, choose the options from the list below which would lead you to infer the presence of a fault in the Var valley (several answers possible) :

1- Historical data before the use of seismometer.
2- Instrumentally recorded seismicity.
3- Observational data of the ground (the fault plane previously described).
4- The terrain around the Var valley (mountains, gorges, small valleys).
5- The path of the river.

Question 22 : Considering all the figures, choose the options from the list below which enable you to suspect the presence of an fault with a recent activity in the Var valley (one possible answer) :

1- Historical seismicity.
2- Instrumentally recorded seismicity.
3- Observational data of the ground (the fault plane previously described).
4- The terrain around the Var valley (mountains, gorges, small valleys).
5- The path of the river.

Question 23 : Considering all the figures, choose the options from the list below which enable you to suspect the presence of a fault whose trajectory would run approximately SW-NE (several answers possible) :

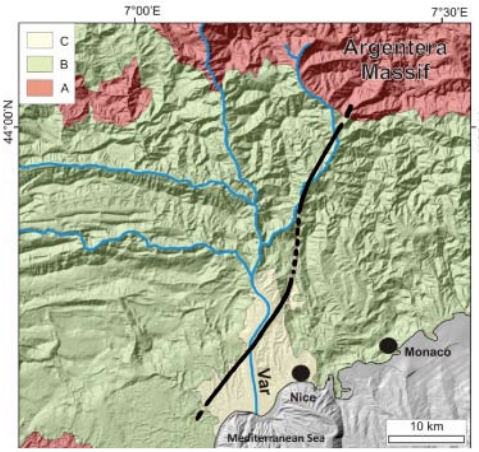
1- Historical seismicity.
2- Instrumentally recorded seismicity.
3- Observational data of the ground (the fault plane previously described).
4- The terrain around the Var valley (mountains, gorges, small valleys).
5- The path of the river.

Question 24 : Considering all the figures, choose the options from the list below which enable you to suspect the presence of a fault whose trajectory would run approximately SE-NW (several answers possible) :

1- Historical seismicity.
2- Instrumentally recorded seismicity.
3- Observational data of the ground (the fault plane previously described).
4- The terrain around the Var valley (mountains, gorges, small valleys).
5- The path of the river.

Question 25 : Choose the most probable fault trace from the four given in figure below.

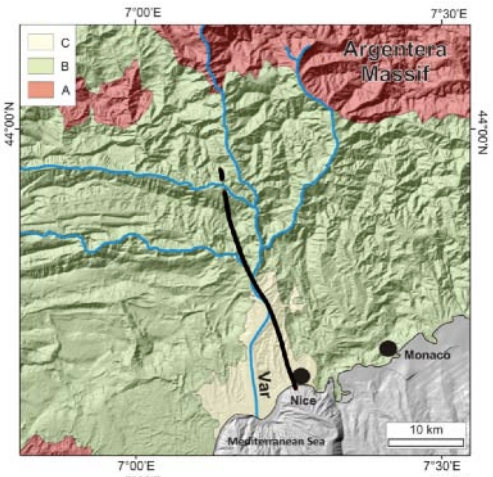
1-



2-



3-



4-



Understanding the origin of seismic events should enable one to better characterize seismic hazard. We are interested in the geodynamic situation affecting the Var valley.

SECTION 4 : RECENT AND THE PRESENT GEODYNAMIC SITUATION OF THE REGION

The figure below shows the simplified tectonic structure of the region around the Var plain. Some of the topics can be related to some of the previous sections :

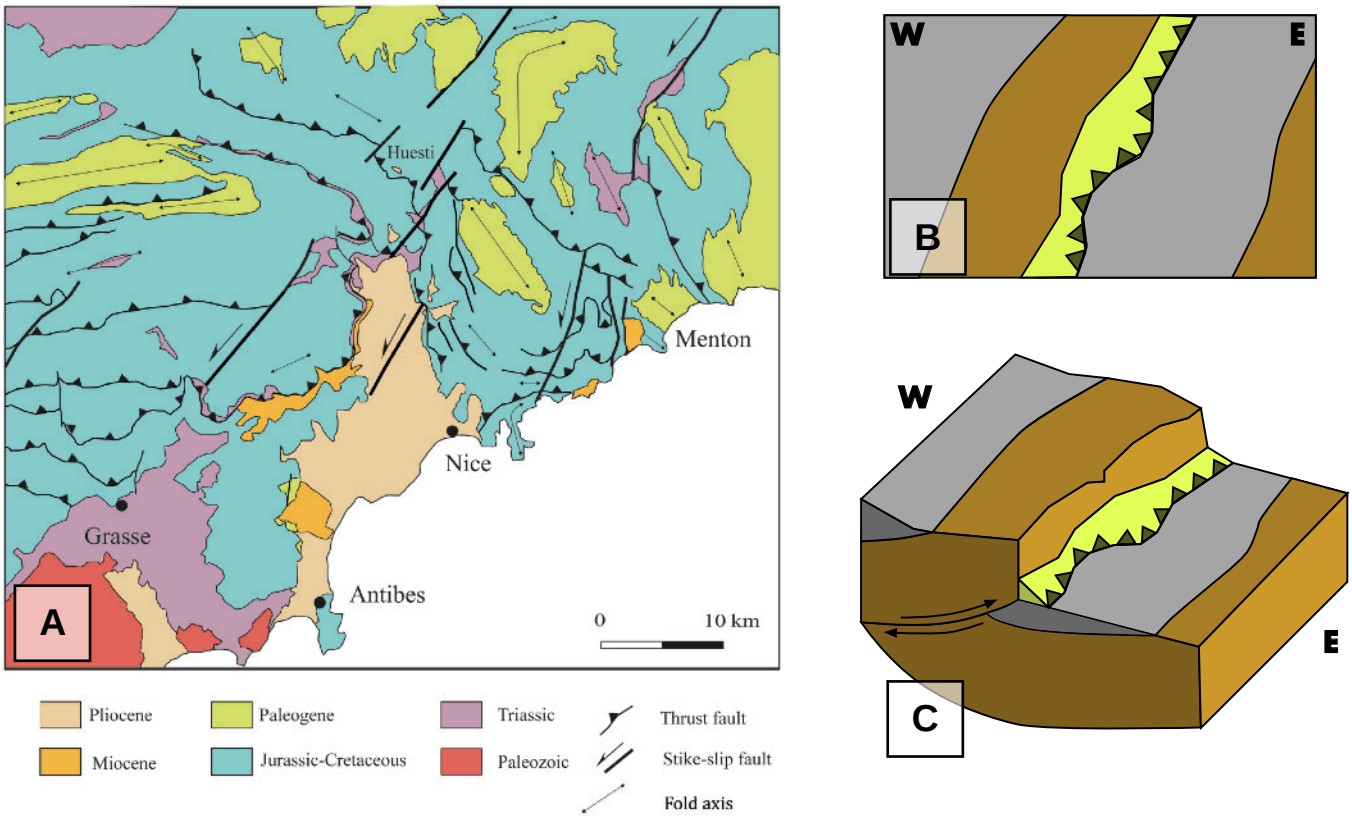


FIGURE 15 : (A) Schematic sketch of the southern Alps in the area of Nice; (B) and (C) Corresponding sketch between a thrust fault in 3D and its representation on a geological map.

Question 26 : A fold with its axis oriented NE-SW indicates a shortening direction oriented : (one answer possible)
1- NE-SW.
2- SSE-NNW.
3- NW-SE.
4- ESE-WNW.

Question 27 : Refer to figure 15. The observed tectonic structures indicate : (several answers possible)
1- A zone that is subjected to extension.
2- A zone that is subjected to shortening.
3- A main shortening direction oriented along the principal N-S axis.
4- Two main shortening directions oriented along the N-S and NE-SW axes.

The local tectonics has moved characteristic structures to surprising places. We focus on Mount Huesti.

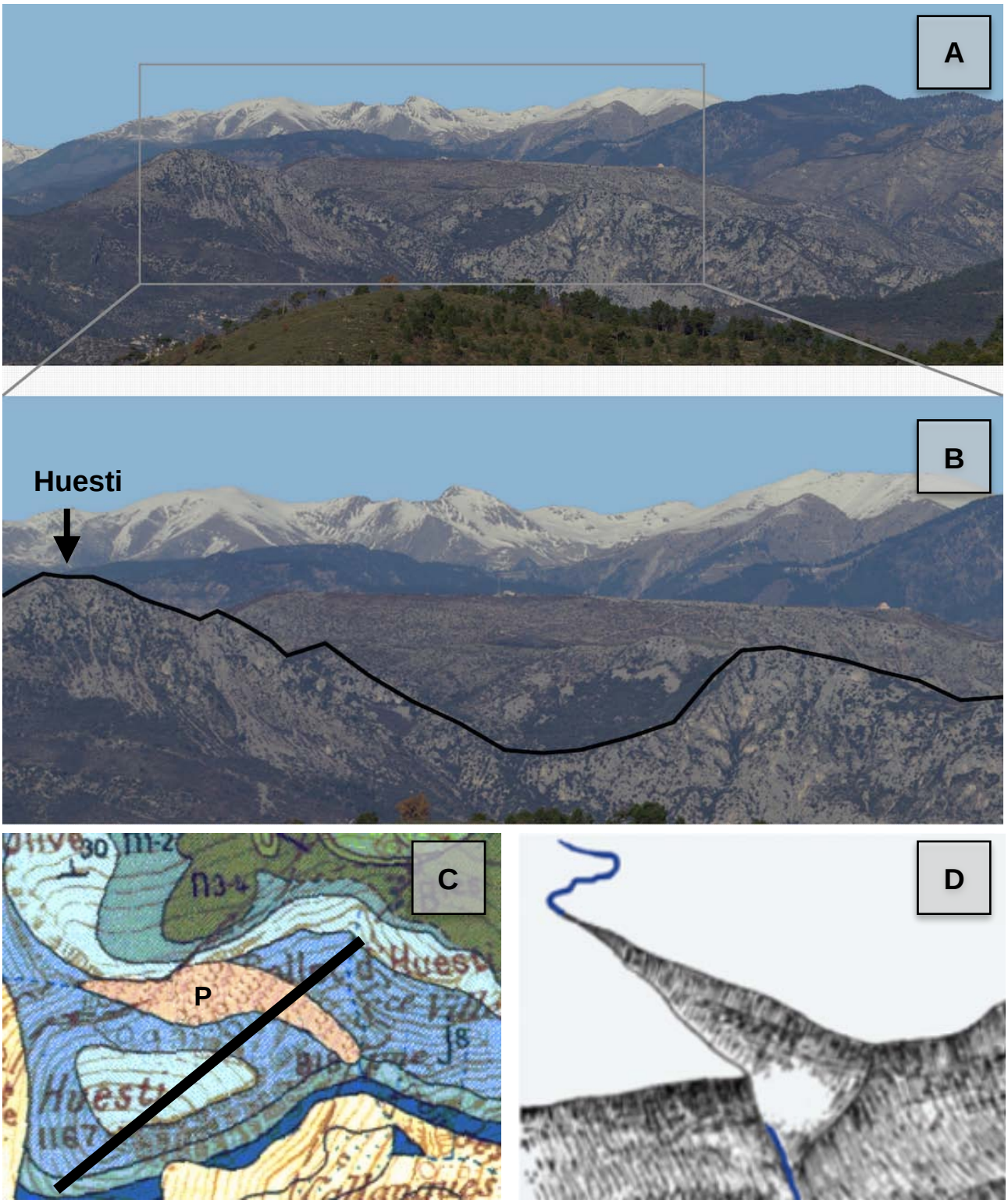


FIGURE 16 : (A) A panoramic view of the southern Alps north of the Var valley; (B) A panoramic view of Mount Huesti (1167 meters elevation); (C) Geological map of Mount Huesti. The thick black line shows the orientation of the photograph in B. Colors indicate the age of the rocks: all blues-Jurassic, green-Cretaceous, orange (p on the map)-Pliocene, yellow-Quaternary (superficial landslide); (D) Sketch of a canyon.

Question 28 : For each of the geological formation designated by the letters x, y, and z, indicate the corresponding ages by using the following letters: J for Jurassic, C for Cretaceous, P for Pliocene, and Q for Quaternary.



Question 29 : The Pliocene pebble conglomerate, like most conglomerates, was probably deposited and consolidated… (only one answer)
1- In abyssal plain environment.
2- In a fluvial environment, near the mouth.
3- In a high mountain far from any river.
4- on the seashore, far from a river mouth.

Question 30 : Using the cartographic data, the tectonic event that gave rise to Mount Huesti, having an elevation of 1167 meters, could be dated to : (several answers possible)
1- Mio-Pliocene.
2- Jurassic-Cretaceous boundary.
3- Cretaceous to Pliocene.
4- Post-Pliocene.

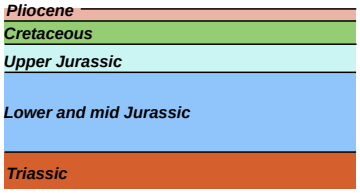
This type of tectonic structure is called a thrust fault. It involves the displacement of one block over another, aided by a lubricating layer, normally an evaporite (Triassic rocks in the region).

Question 31 : After examining the map below, choose the correct course of the thrust fault (numbered 1-4) that brought Mount Huesti into existence.



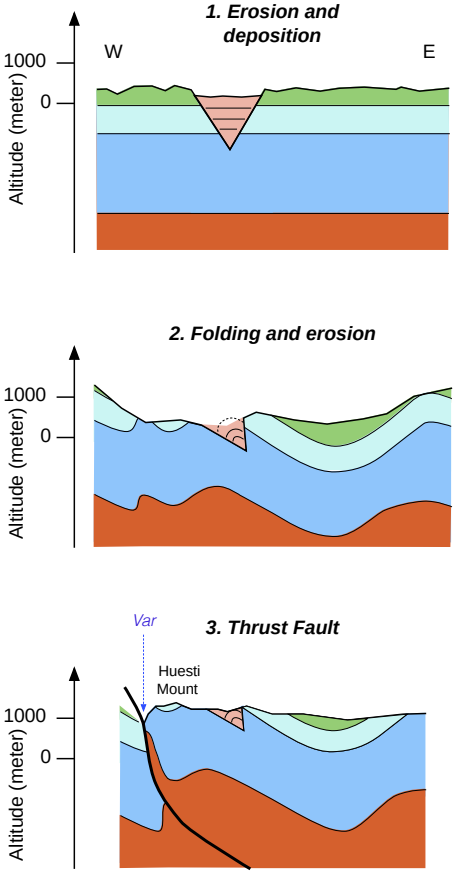
Caption : t_3 are Triassic rocks (evaporites) ; $j_{1\text{-}2\text{-}6\text{-}7\text{-}8\text{-}9}$ are Jurassic rocks (limestones) ; $n_{1\text{-}3\text{-}4\text{-}6}$ and c_1 are Cretaceous rocks (marl and limestones); p_2 are Pliocene rocks (conglomerate) ; B, E and $F_{x\text{-}z}$ are Quaternary rocks (unconsolidated deposits).

Question 32: After considering all the previous information, choose the scenario whose sequence of deposition and deformation best explains the formation of Mount Huesti (on map) .

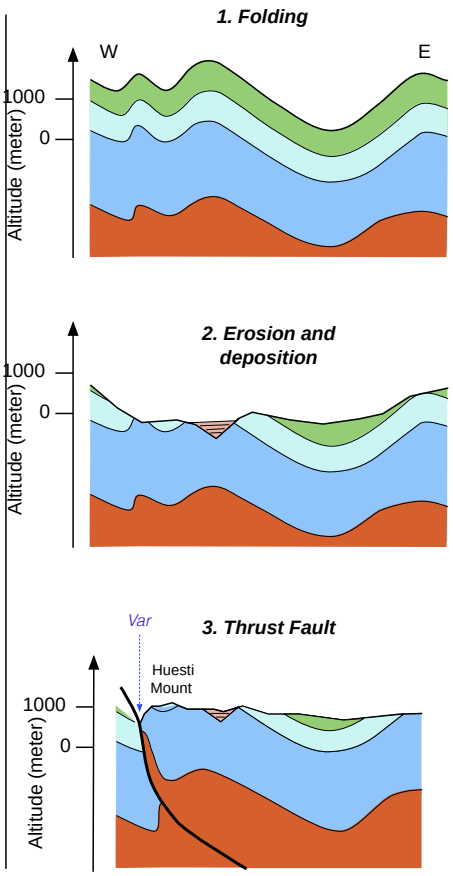


Stratigraphic position of sedimentary units observed on the map

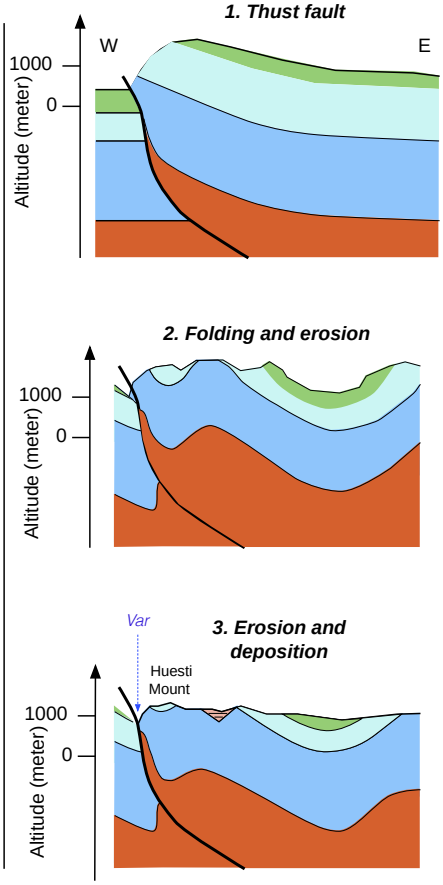
SCENARIO 1



SCENARIO 2



SCENARIO 3



To better understand the geodynamical context, let us focus on the present situation in the western Mediterranean Sea.

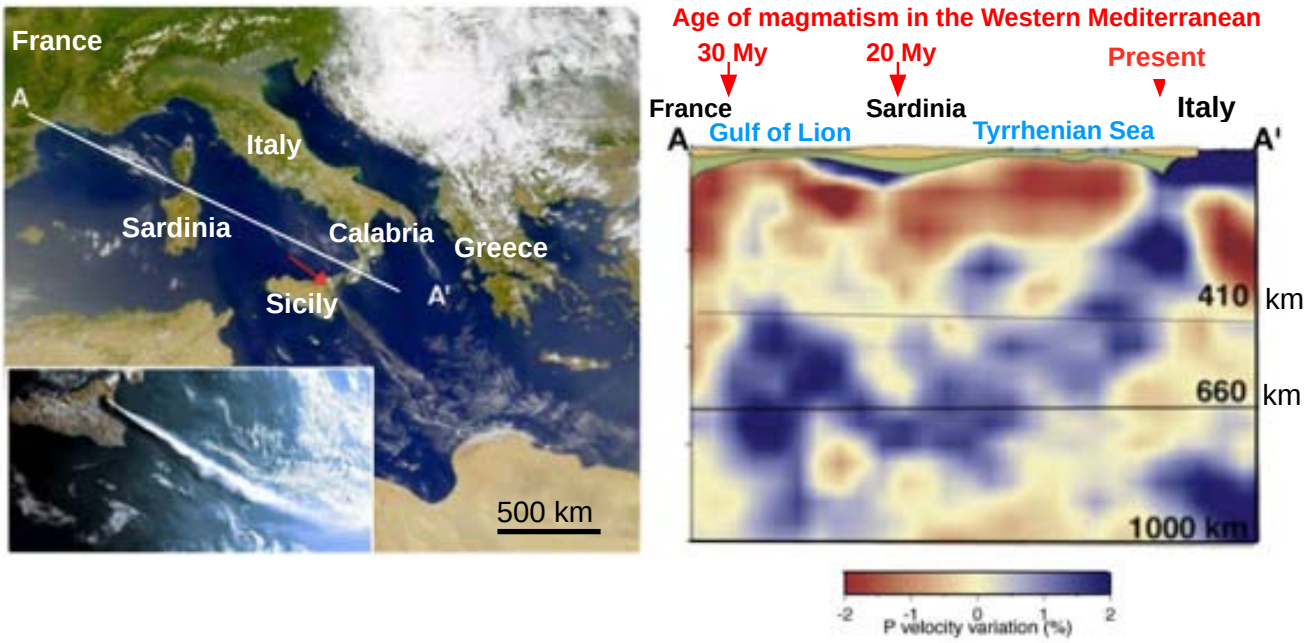


FIGURE 17 : (A) Satellite imagery of the western Mediterranean Sea. Inset is a zoom showing Sicily marked by the red arrow, indicating a volcanic activity; (B) results of seismic tomography performed along A-A' in (A). Information about magmatism over time can be seen in the upper part of the tomogram.

Question 33 : Tomography is a method, which enables color-coded representation of : (several answers possible)

1- the motion of different chemical materials at depths below the earth's surface.
2- depth of mafic/felsic rock.
3- wave speed anomalies in the Earth.
4- depth of total melt of rock.
5- differences in temperature and/or density detected from variations in the speed of seismic waves.
6- differences in direction of crystal alignement in metamorphic rock.

Question 34 : Refer to figure 17. The results of tomography suggest subduction in this area of the Mediterranean. The evidence provided by tomography is : (only one answer)

1- a long, blue area beginning on the surface at Calabria (South of Italy) and towards the NW up to the core-mantle boundary.
2- not clear. There is no logic between the red and blue anomalies presented.
3- an oceanic lithosphere thrusts towards the NW up to the lithosphere-asthenosphere boundary.
4- a cold material (coming from superficial strata) diving towards the upper mantle-lower mantle boundary.

Question 35 : Refer to figure 17. There are indications of (only one answer) :

1- two subduction fronts, one of which is located between the Gulf of Lion and Sardinia.
2- a subduction zone whose front is located between the Gulf of Lion and Sardinia.
3- a subduction zone whose front is located between Sardinia and Calabria (South of Italy).
4- a subduction zone whose front is located to the east of Calabria (South of Italy).

Question 36 : With reference to the known subduction model, the results of tomography are compatible with localized, active volcanism: (only one response)
1- in southeastern France.
2- from southeastern France to Sicily.
3- that could explain the collision between two continental plates which gave rise to the Alps.
4- in Sicily.

To test a slightly different hypothesis of subduction, Claudio Faccenna proposed an analog model, which is rather unique. With this model, he wanted to determine:
- if subduction could occur without convergence, and
- if such a phenomenon (subduction without convergence) could be compatible with the subduction of the western Mediterranean.
For this, he poured two liquids of different densities (as a function of their glucose concentration) and then placed a slab of silicone with elastic viscosity on the surface.
He took successive photos (I to V in figure 18) of the behavior of the silicone layer.

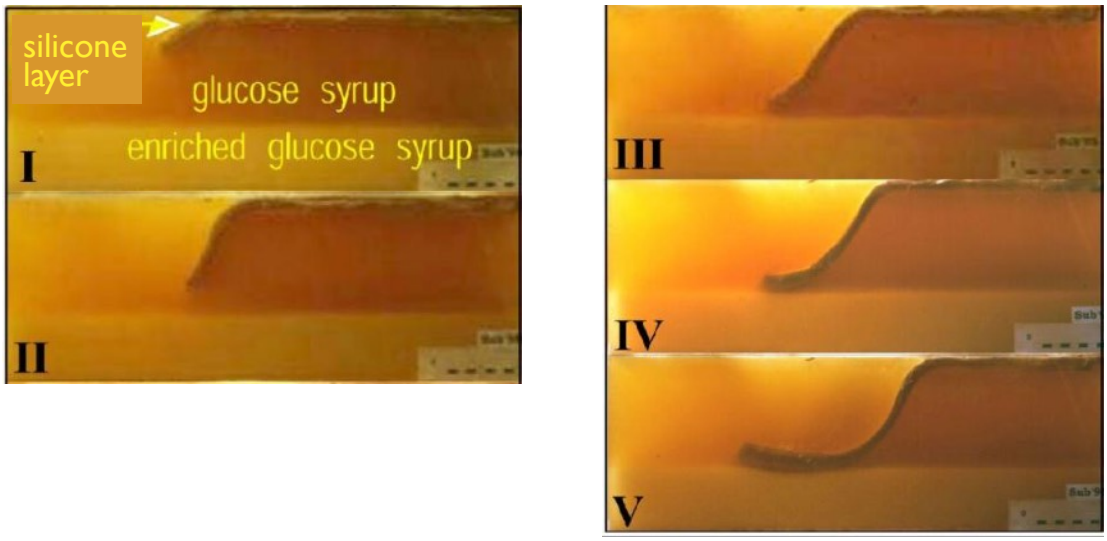


FIGURE 18 : Results of Claudio Faccenna's (University of Rome, 2003) experiments modeling subduction without convergence. I to V are sequential photographs taken during the experiments.

Question 37 : Refer to figure 18. Considering silicone layer (x), glucose syrup (y) and enriched glucose syrup (z); match x, y, z with one of the following:

1- The continental lithosphere.
2- The oceanic lithosphere.
3- The continental crust.
4- The asthenospheric mantle.
5- The lower mantle.
6- The core-mantle boundary
7- The lithospheric mantle.

Question 38 : In modeling, one must control the essential parameters of the modeled process. Indicate the parameters below that the researcher can control: (several answers possible)

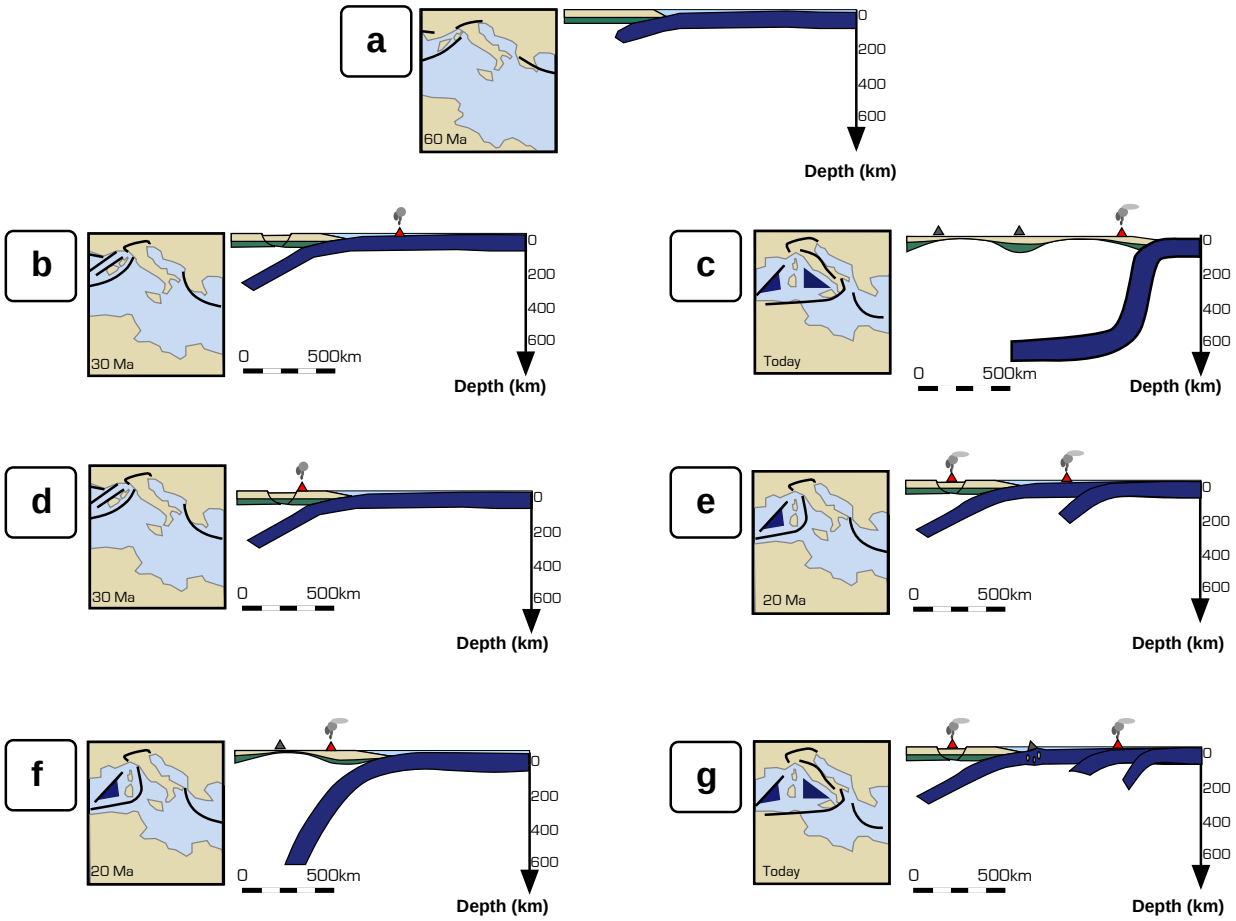
1- The density contrasts between the subducting plate and the underlying strata.
2- The viscosity of the strata.
3- The increasing temperature of successive strata.
4- The speed of convergence of the plates.
5- The convection currents in the upper mantle.

Question 39 : Subduction in the Mediterranean Sea resembles that shown in the analog model (figure 18). Choose the observations that demonstrate the similarity : (only one answer)

1- The slab (silicon layer) presses against an interface marked by a change in density, which is an observation specific to this subduction.
2- The front migrates in the model, which fits with the observed location of volcanism.
3- The slope of the subducting slab (silicon layer) is identical both in the model and the tomogram; such a slope is thus due to the absence of convergence.

Question 40 : From the information available and your knowledge, choose the correct chronological order of the events leading to the formation of the western Mediterranean.

1- a / d / e /g
2- a / b / e / c
3- a / d / f / c
4- a / b / e / g



Question 41 : In conclusion, one may say that the regions of Nice and the Var plain are currently subject to (only one answer.) (Please answer the question although It carries no point.)

1- A high volcanic risk.
2- A moderate volcanic risk.
3- A low volcanic risk.
4- No volcanic risk.

INSTRUCTIONS FOR THE WRITTEN TEST

WRITTEN TEST 2 : 2 HOURS

PLEASE ANSWER ON THE ANSWER SHEET

MARKING THE QUESTIONS :

If only one answer is required (only one answer) :
- Correct answer chosen : +1 point
- Wrong answer or several answers chosen : 0 point

If several possible answers :
- For each correct answer : + 1 point
- For each wrong answer : -0,5 point

No question can be marked under 0 (zero). If number of negative points exceeds the positive points, the question will be marked zero : +1-1,5 = 0

IESO 2017 - WRITTEN TEST NUMBER 2

SECTION 1: UNDERSTAND THE INTERACTIONS BETWEEN ATMOSPHERE AND HYDROSPHERE : A SPORTING CHALLENGE !

The “Vendée Globe” is a solo yacht race without assistance, which sets off from Vendée in France and whose objective is to circle the world as fast as possible. Both the start and finish are in Sables d’Olonnes (visible on figure 1A and marked as A in figure 1B. The race began on 6 november, 2016. Armel Le Cleac’h was the winner with a new record of 74 days of non-stop sailing.
The difficulty, especially on a solo voyage, is to find the route where the wind is always favorable, namely at the rear of the boat.



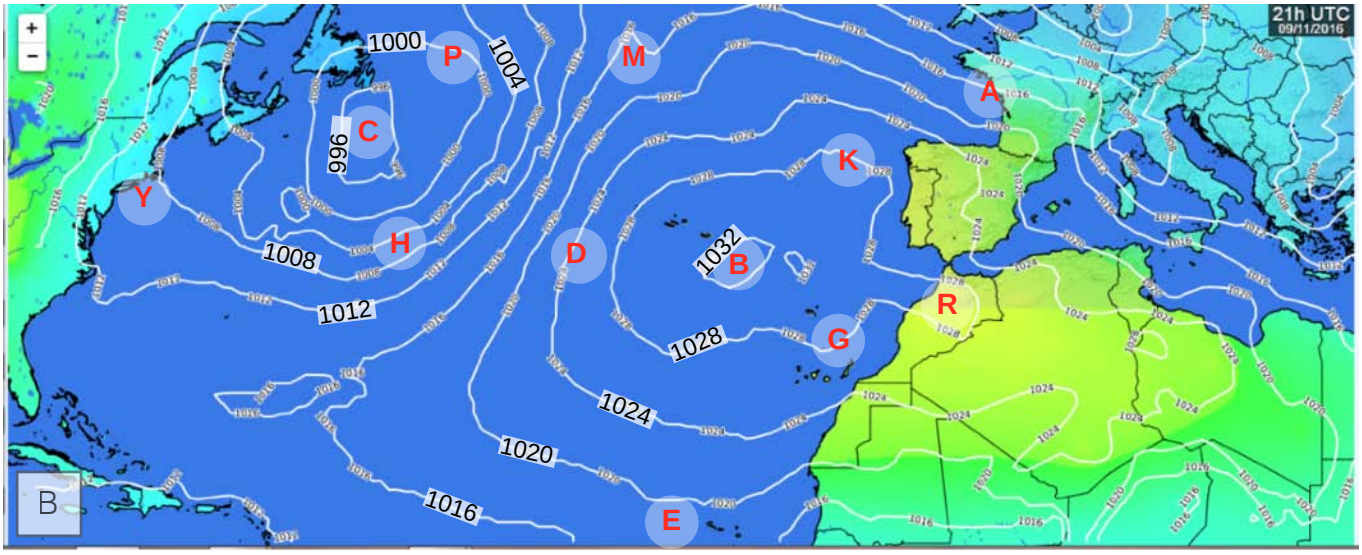


FIGURE 1: (A) Map showing the « Vendée Globe » route. (B) Barometric map of the North Atlantic Ocean and noted points (see question).

Question 1: Yachts make the best use of the dominant winds. According to your knowledge of the direction of winds produced by different air masses, indicate which is the fastest route the competitors should take to reach the Cape Verde islands (E). The barometric conditions shown on the map above remain the same for one week: (only one answer possible)

1- Trajectory AKGE
2- Trajectory AKBE
3- Trajectory AKDE
4- Trajectory AMPCHE

Question 2: Refer to figure 1. At the same time, a sailor decides to take the route Rabat (R)–New York (Y). Which itinerary will be the quickest? (only one answer possible)

1- RGDHY
2- RBDCY
3- RGDPY
4- RKDHY

The figure below shows the competitors' positions after 10 days of racing. A group of yachts (circled) seems to have lagged and is traveling at a slow speed of 2.5 knots (for information, 1 knot (kn) is equivalent to a little less than 2 km/h).

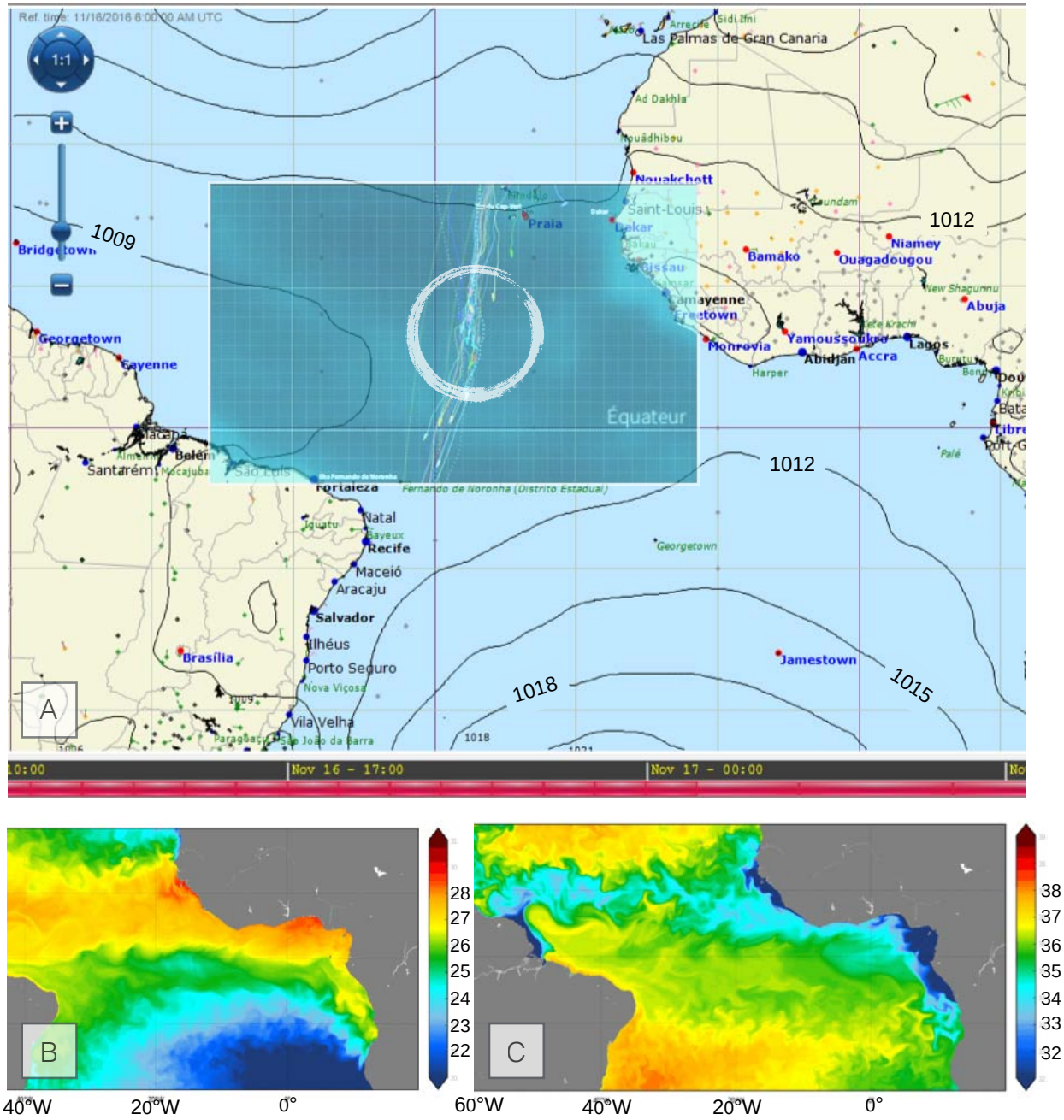


FIGURE 2: Racing zone in the Atlantic Ocean. (A) Barometric chart contour interval is 3 hPa. (B) Map of water temperature in °C. (C) Chart of water salinity in g/l.

Question 3: Which of the choices given below best explains the situation of sailors compelled to travel at a slow speed ? (only one answer possible)
1- The high water temperature prevents the formation of wind.
2- The sailors cross a zone where there are headwinds.
3- The water is very salty and its viscosity slows the sailors.
4- The sailors are trapped in a zone with very weak winds.

Question 4: Refer to figure 2C. The intertropical zone has a salinity which is different from the average (green zones). Choose the most evident cause: (only one answer possible)
1- The water from the big rivers brings down the salinity of the ocean water.
2- In the tropical anticyclonal zones, the air temperature is lower, and thus evaporation weaker.
3- Rainfall is more important in the intertropical convergence zone and it brings down the salinity.
4- The characteristic strong winds in the intertropical convergence zone produce upwelling, which brings less saline water to the surface.

Avoiding areas sheltered from the wind was a preoccupation of all the participants. Kito de Pavant, our sailor for the IESO 2017, remained stuck for several days in the area described in the figures below.

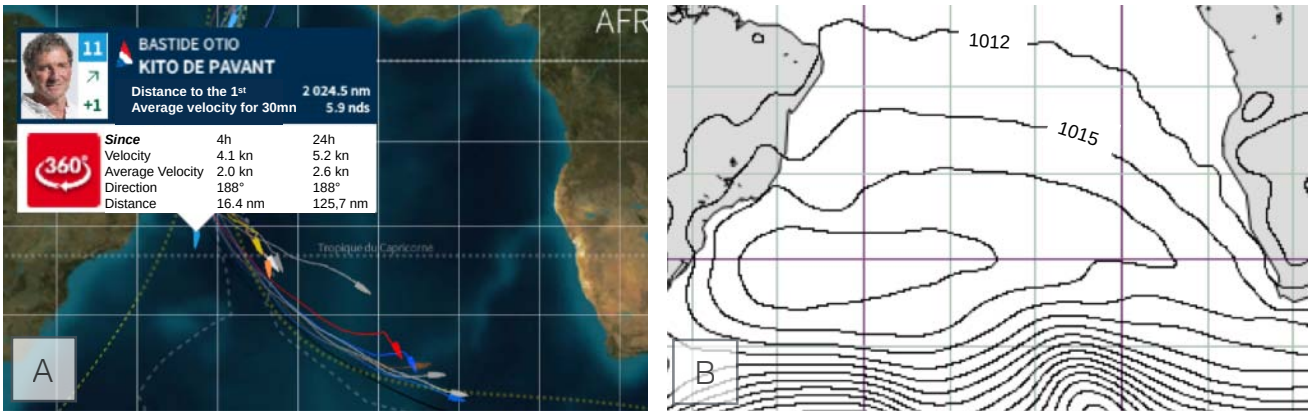


FIGURE 3: Map of the competitor Kito de Pavant's position (blue arrow) and other sailors on 2 December 2016. (A) Position map indicating, among other things, the change of his speed (knot) in the last 24 hours. Distances are indicated in nautical miles (nm), 1nm = 1.85 km. (B) Barometric map of the race area on 12 December, 2016. Contour interval is 3 hPa.

Question 5: Describe the problem Kito de Pavant encountered in this area of the race: (only one answer possible)
1- His yacht was located in the center of a depression characterized by a lack of wind.
2- His yacht was in the center of an anticyclone characterized by a lack of wind.
3- His yacht was in the center of a depression characterized by a shallow trough on the ocean surface which hinders the boat's movement.

Question 6: The winds which circulate around an anticyclone located in the Southern Hemisphere … (several answers possible)
1- rotate clockwise.
2- rotate counterclockwise.
3- are stronger when they approach the center of the anticyclone.
4- are weaker when they approach the center of the anticyclone.

While traversing the Drake Passage south of Cape Horn (southern tip of South America) on 26 December 2016, the oceanographic service recorded the water temperature and salinity as a function of depth along a transect between the southern tip of South America and the northernmost point of the Antarctic Peninsula.

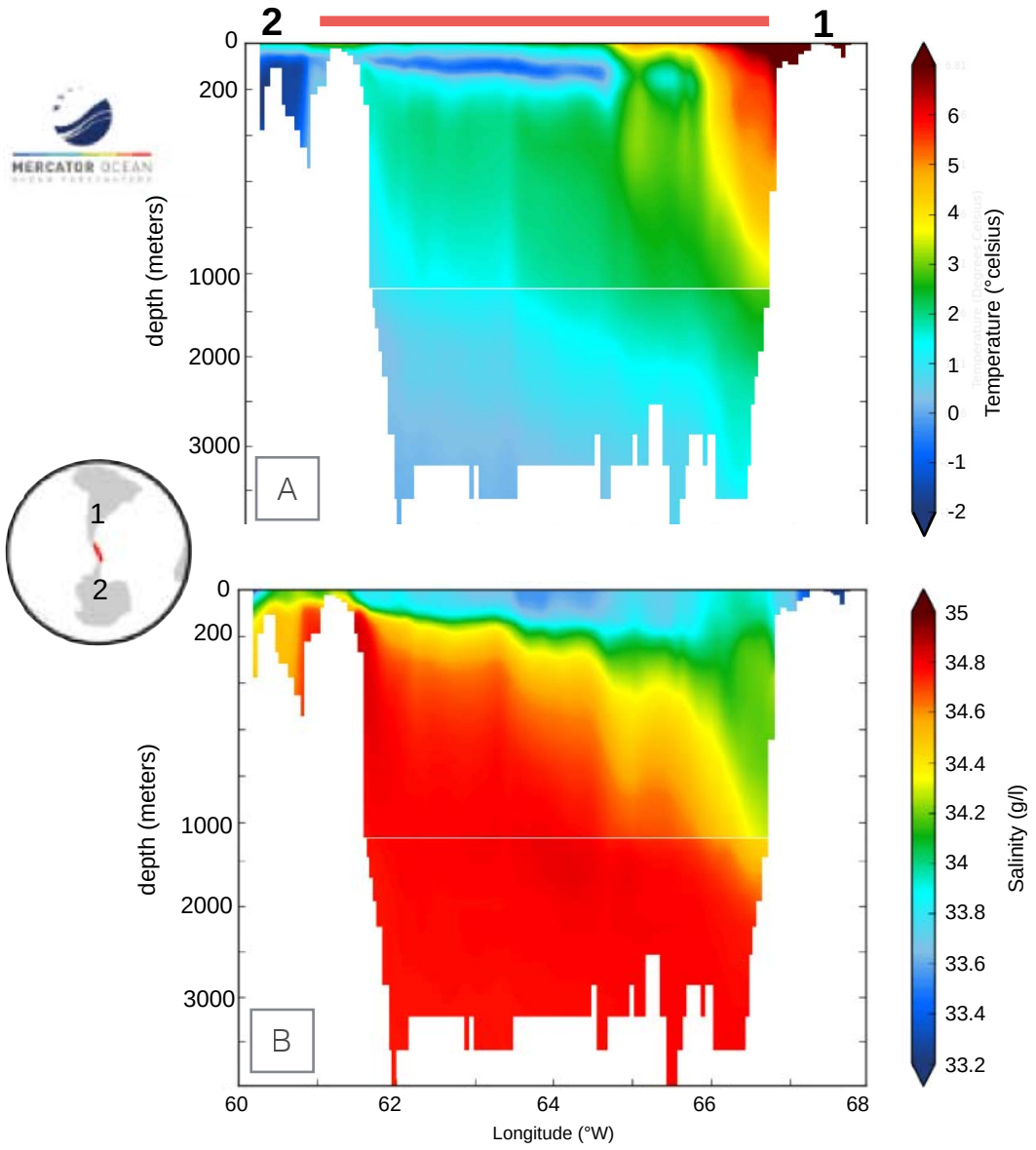


FIGURE 4: Profiles of the change in temperature (A) and salinity (B) of the ocean water on a line along the Drake Passage (visible in the inset showing the planet viewed from the South Pole).

Question 7: Refer to Figure 4. One can say that, at longitude 62.5°W, … (only one answer possible).

1- both the temperature and salinity gradients are normal over the whole depth.
2- only the temperature gradient is abnormal in at least one area.
3- only the salinity gradient is abnormal in at least one area.
4- both gradients are abnormal.

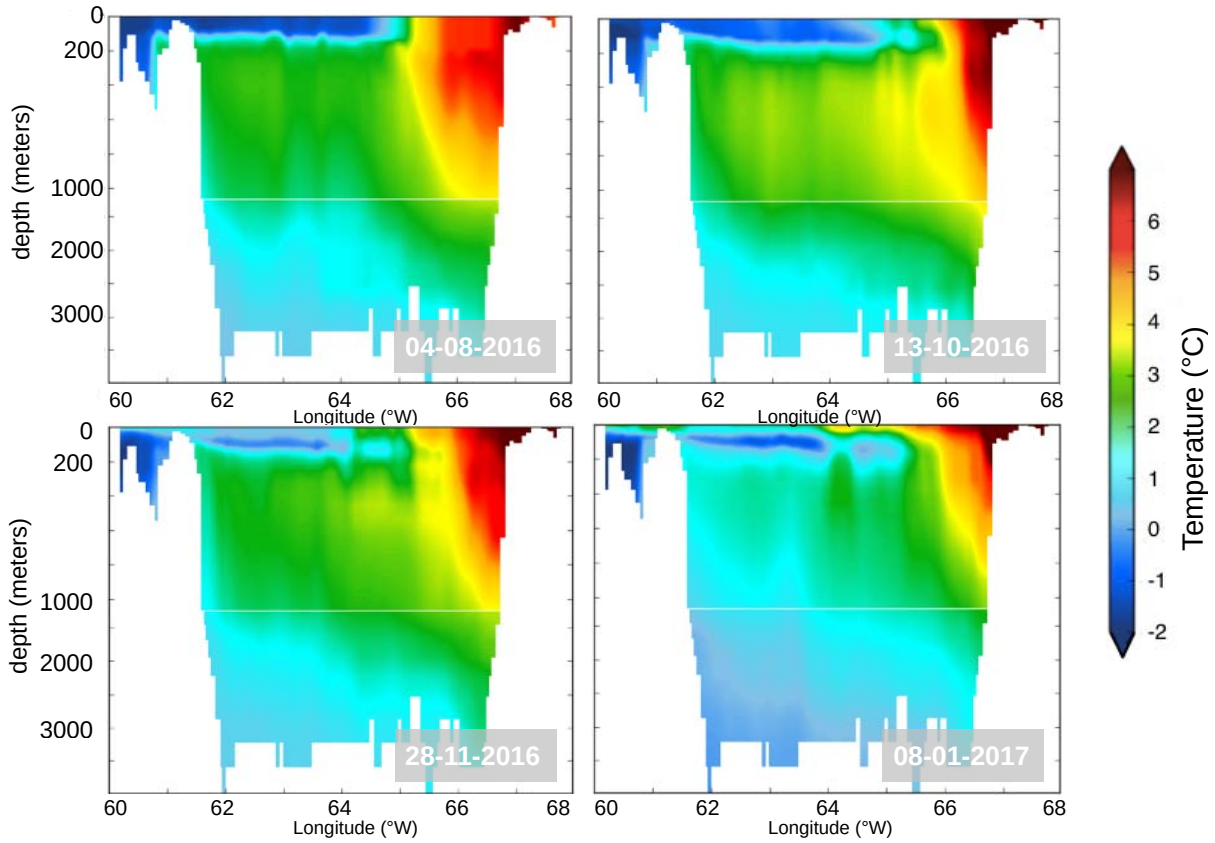


FIGURE 5: Temperature profiles on different dates during August 2016 - January 2017 along transects shown in figure 4.

Question 8: Refer to figures 4 and 5. Which of the following statements are correct ? (several answers possible)

1- The water was colder at 3000m depth compared to the surface during August.
2- The pack ice (floating ice) was located off the Antarctic coast and reached a longitude of 64.5 °W along the transect during August 2016.
3- During January 2017, the pack ice (floating ice) was denser and hence sank.
4- The lower layers of the hydrosphere are composed of colder and more saline water because it is denser.

Passing by the coast of Namibia, the sailors encountered numerous fishing boats heading for the African coast. There are indeed shoals (of fish) in this region.

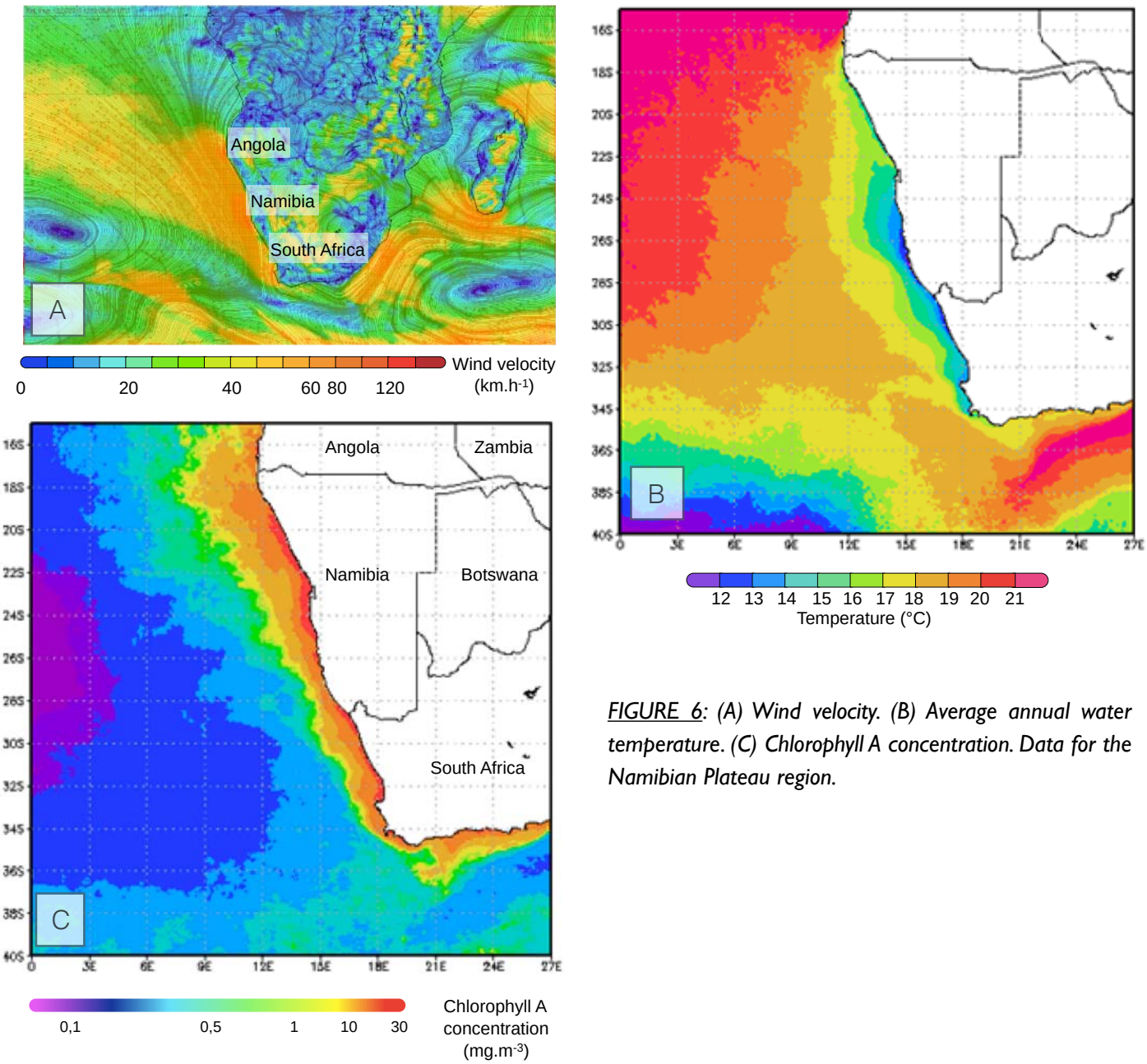


FIGURE 6: (A) Wind velocity. (B) Average annual water temperature. (C) Chlorophyll A concentration. Data for the Namibian Plateau region.

Question 9: Refer to figure 6. Choose all the correct statements below: (several answers possible).

1- The ocean water closer to the coast of Namibia is warmer than that farther away.`
2- This temperature anomaly along the Namibian coast is due to water rising from the depths.
3- The driving force of this rising water is the difference in temperature between deep and shallow waters.
4- The driving force of this rising water is the force of the wind on the surface.
5- The warm water induces high primary productivity, leading to a richness of the food chain (trophic chain) and thus an abundance of fish.
6- The high primary productivity is linked to an increase in nutrients concentration, which sustains a rich food chain (trophic chain).

Question 10 : The Namibian and Angolan continental plateau is known for its abundance of fossil fuels (oil, gas hydrates). The geography and meteorological and climatic conditions have remained approximately the same for several hundred thousand years. The southwest coast of Africa has remained a desert. Which of the following statements are correct ? (several answers possible)

1- The abundance of plankton and the richness of the food chain are necessary elements for the formation of hydrocarbons.
2- Oil is formed at the bottom of the Atlantic Ocean and rises due to the upwelling of water.
3- The organic matter from the continent (dead animals and vegetative matter) is sedimented on the continental plateau and is the main source of hydrocarbons.
4- The organic matter of plankton which is sedimented on the continental plateau must be in anoxic conditions to be transformed into hydrocarbons.

The sailor Kito de Pavant dropped a GPS beacon named IESO2017 into the water upon crossing the Equator on 17 November 2016. This floating beacon drifted solely due to the marine currents and transmitted its latitude and longitude position every hour.

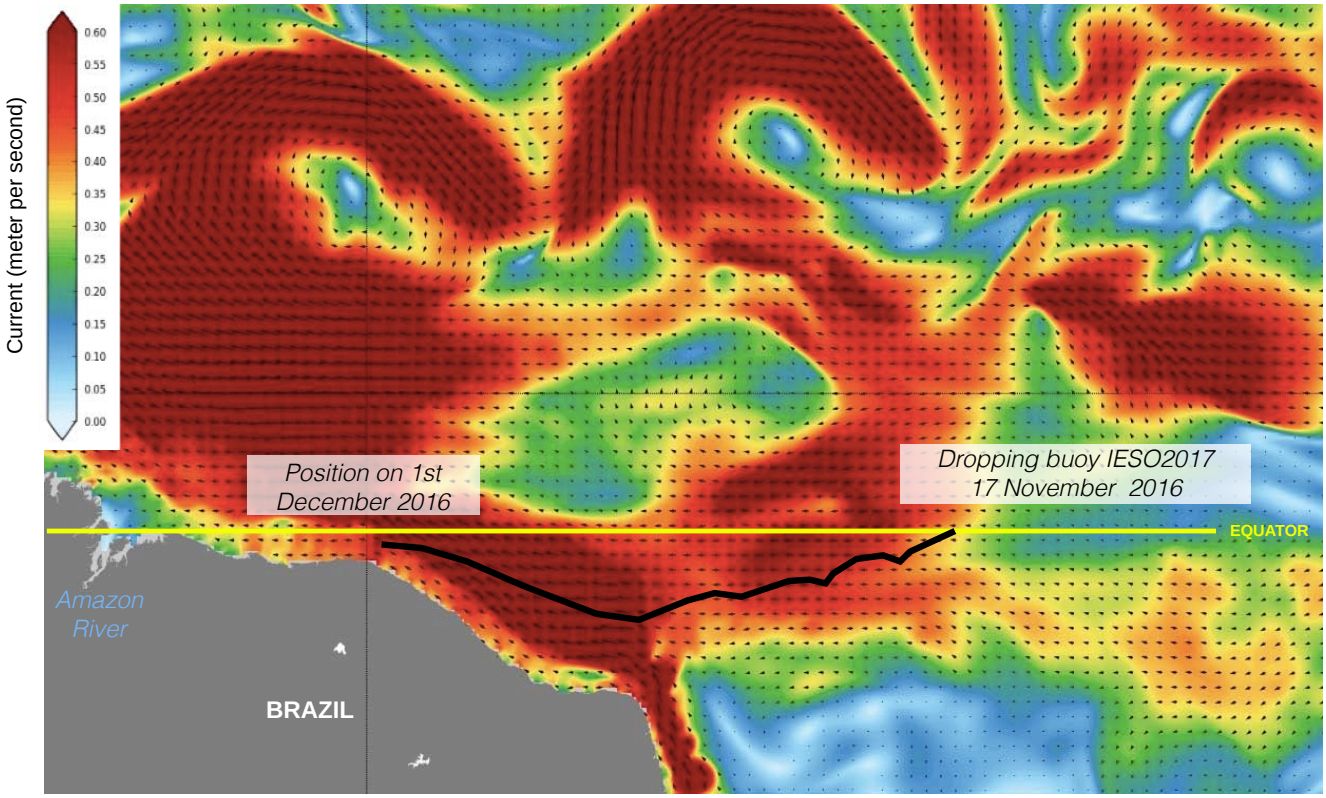


FIGURE 7 : Map of the equatorial Atlantic Ocean. The black line traces the movement of the IESO2017 beacon during 17 November - 1 December 2016. The beacon was placed while crossing the Equator by the skipper Kito de Pavant. The colors indicate the force of the currents, and the arrows specify the direction. The current appearing on this map is called the "Equatorial current".

Question 11: Refer to figure 7. Which of the following statements are correct ? (several answers possible)

1- The current carrying the beacon is caused by the trade winds of the Southern Hemisphere.
2- The current carrying the beacon is caused by the difference in temperature between the east and western parts of the Atlantic.
3- The current carrying the beacon is caused by the difference in salinity between the eastern and western parts of the Atlantic.
4- The current carrying the beacon is caused by the difference in height of the ocean between the east and western parts of the Atlantic.
5- The direction of the current carrying the beacon is influenced by the Coriolis force.

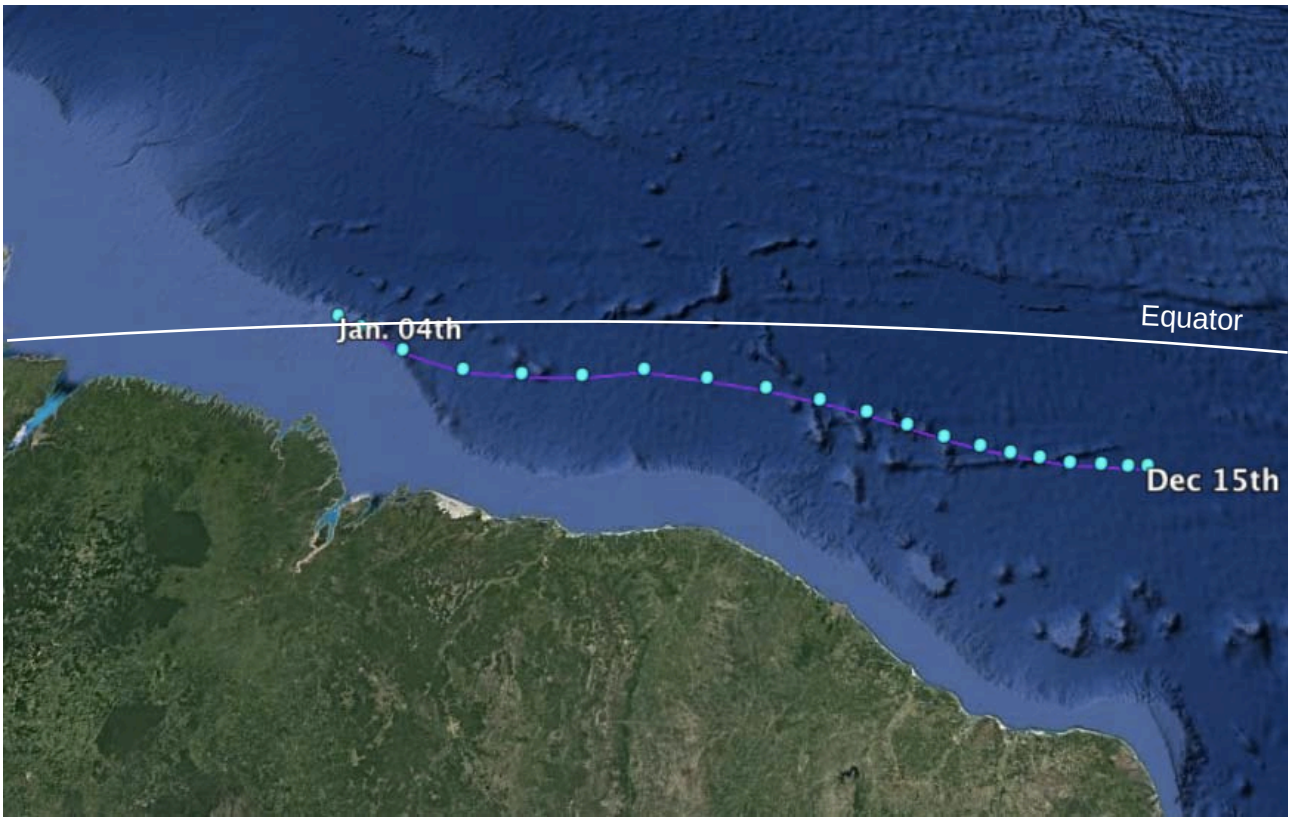


FIGURE 8: Map showing the end stage of the beacon's journey between 15 December 2016 and 4 January 2017. Each symbol corresponds to a daily position at a fixed time (midnight).

Question 12: Analyzing the path of the beacon close to the South American coast (figure 8), choose the correct statement: (only one answer possible)

1- The speed is constant, and the trajectory becomes parallel to the coast.
2- The speed is constant, and the trajectory is not influenced by the approach to the coast.
3- The speed decreases as the beacon approaches the coast due to fresh water current opposing the oceanic current.
4- The speed decreases as the beacon approaches the coast due to a decrease in water depth.
5- The speed increases as the beacon approaches the coast due to fresh water current opposing the oceanic current.
6- The speed increases as the beacon approaches the coast due to a decrease in water depth.

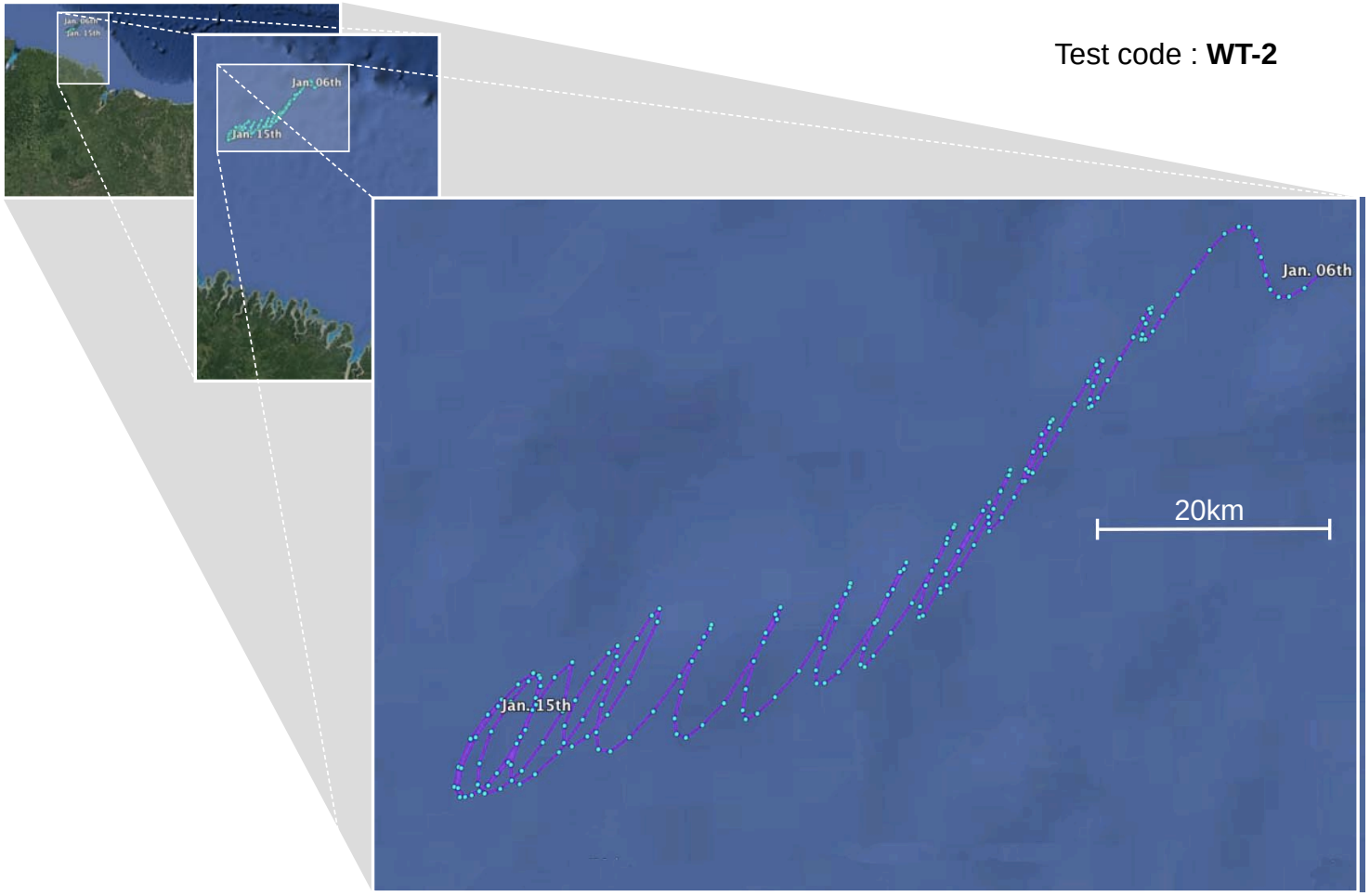


FIGURE 9 :Trajectory of the beacon near the South American coast. Geolocation was measured every hour.

Question 13 : Refer to figure 9 and choose the statement which best describes the beacon's behavior. The observed phenomenon seems to be periodic with an average period of… (only one answer possible)
1- 6 hours.
2- 12 hours.
3- 24 hours.

Question 14 : Among the possible causes listed below, choose the most probable one. This particular pattern of trajectory is due to… (only one answer possible)
1- the turbulent currents caused by the difference in salinity between the inland and offshore waters.
2- the turbulent currents caused by the difference in temperature between the inland and offshore waters.
3- tidal currents.

SECTION 2: STANDING ON THE EARTH, GAZING AT THE PLANETS

During the race, the sailor Kito de Pavant had the opportunity to observe different phases of the Moon. How can we understand what he was able to see?

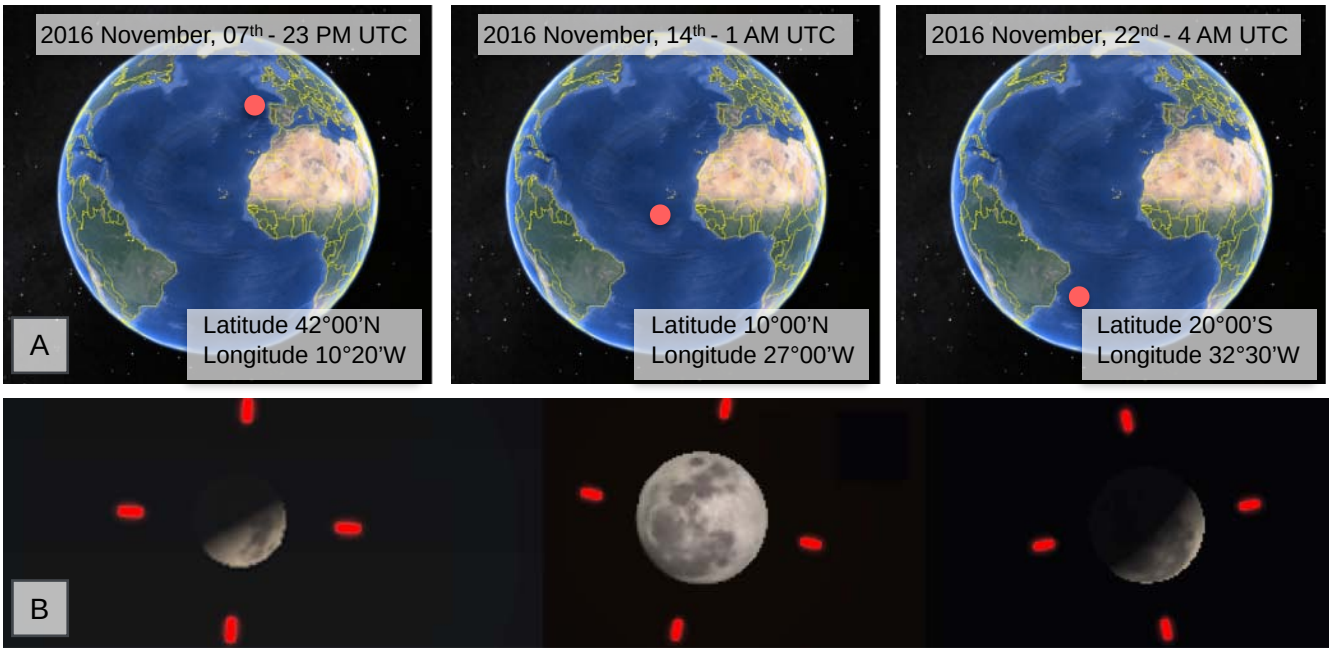


FIGURE 10: (A) Position of the sailor Kito de Pavant during November 2016. (B) The images of the moon that the skipper could see from the corresponding positions.

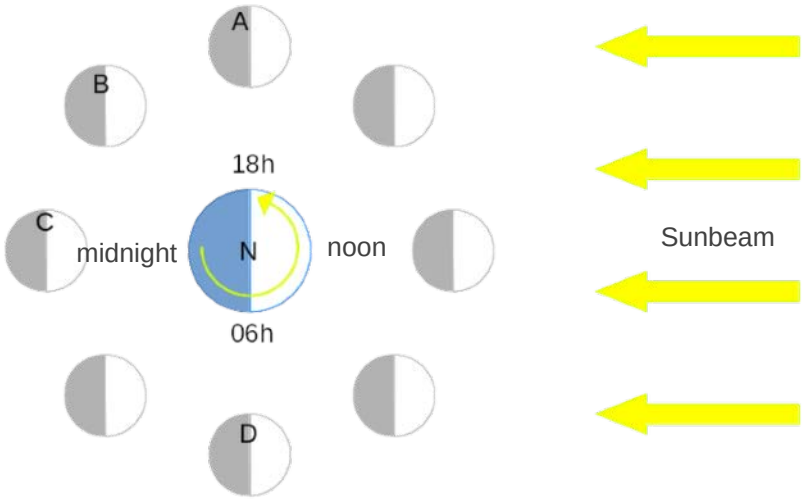


FIGURE 11: Phases of the Moon as a function of the three bodies (the Sun, the Earth, and the Moon).

Question 15: Refer to figure 11. During the night from 7 to 8 November, the position of the Moon relative to the Earth–Sun reference system is… (only one answer possible)

1- A
2- B
3- C
4- D

Question 16: During the night of 14 to 15 November, the Moon reached 90°. This situation… (several answers possible)
1- can be witnessed only when one is located between the tropics.
2- is only possible when the Moon is full.
3- is possible anywhere on the Earth each time the Moon is full.
4- is extremely rare and occurs at most twice a year for a given location.

Question 17: The Moon seen by the sailor on the nights of 7 and 22 November was very similar. This is because… (Only one answer)
1- The Moon's synodic period of revolution is on the order of 14 days.
2- The Moon's sidereal period of revolution is on the order of 28 days. Therefore, one finds the same phase at the halfway point of 14 days.
3- The first and last quarters appear identical because they are not observed in the same hemisphere.
4- The first and last quarters appear identical because they are not observed during the same time of the night.

Question 18: The full moon of 14 November was observable between 18:00 and 6:00 hours. Choose the correct statement: (only one answer possible)
1- This is always the case with a full moon.
2- This is extremely rare. Most of the time, it can be seen starting at noon.
3- This is solely because one is located close to the Equator.

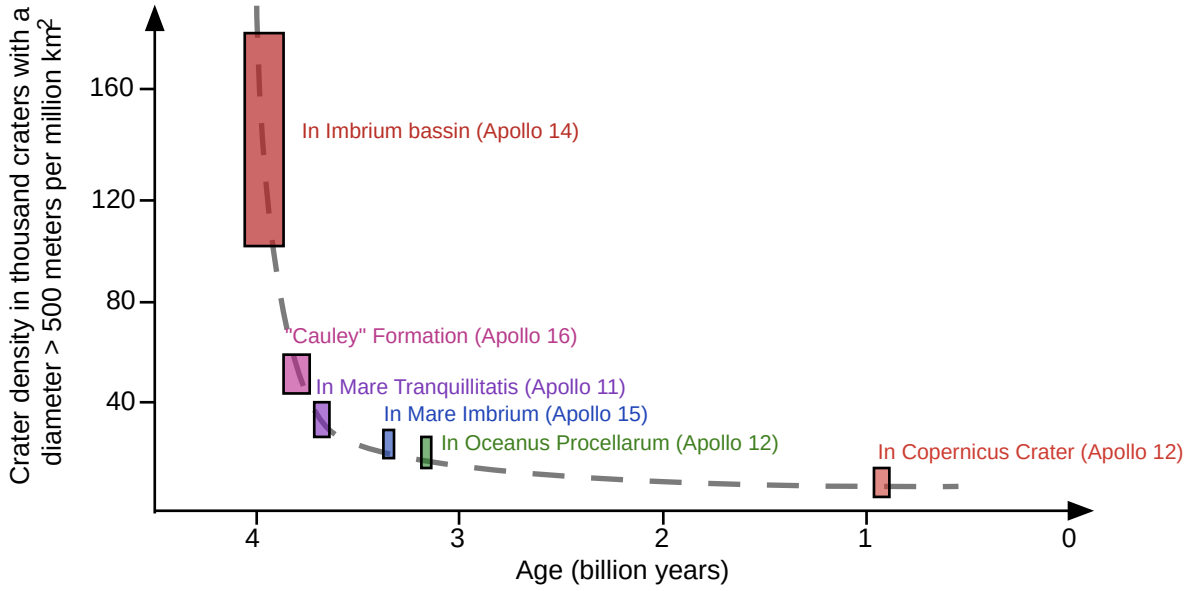


FIGURE 12: Number of craters on the lunar surface and the age of the surface. The dashed curve is the best fit for the observational data (rectangles).

Question 19: Figure 12 indicates a hyperbolic relationship between the lunar crater density and the age of the impacted surface. Which of the following variables effect the exact profile of this inverse relationship ? (several answers possible)

1- the decreasing number of impacting objects since the origin of the Solar System.
2- tectonics, which regenerates the planetary surface.
3- the distance from the planet to the asteroid belt and the Kuiper belt.
4- the period of revolution and the period of rotation of the planet under consideration.
5- the temperature of the impacted surface.
6- the size of the impacted planet.

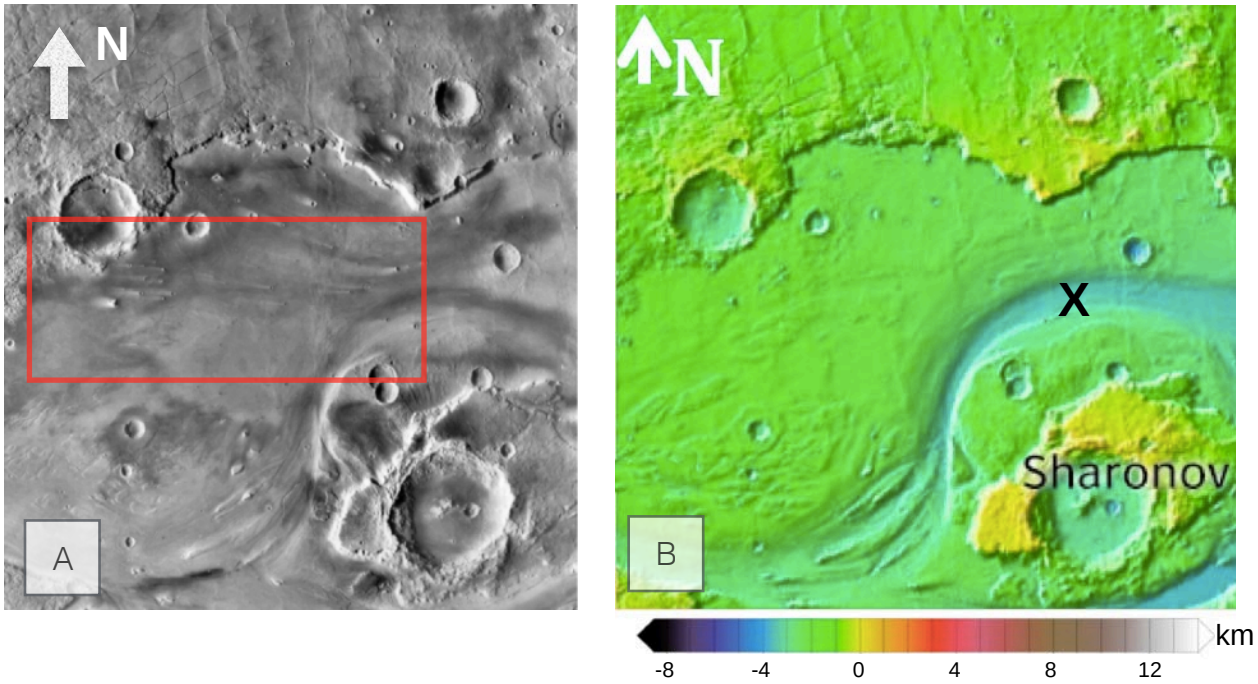


FIGURE 13: Position of the Kasei Valles on the planet Mars. (A) Satellite imagery of the region. The Sharonov crater has a diameter of 100 km. (B) Topographic image of the same region.

Question 20: The river that formed the Kasei Valles at point X flows towards: (only one answer possible)

1- the south
2- the north
3- the east
4- the west
5- the southeast
6- the northwest
7- the southwest

Question 21: There are small streaks linked to the small craters bounded by the red box in figure13A. The accepted explanation is the presence of winds. What are their directions? (only one answer possible)

1- towards the west and northwest.
2- towards the west and southwest.
3- towards the east and northeast.
4- towards the east and southeast.

Question 22: Refer to figure 13. The following geological events can be identified as:
A– Flow of the river **B– Small craters** **C– Large craters in the northwest**
D – Fracture in the north **E– Wind streak.**
Among the relative chronologies (oldest to the youngest) of these events, choose the correct order: (only one answer possible)
1- A / B / C / D / E
2- A / C / D / E / B
3- D / C / A / B / E
4- C / D / B / E / A

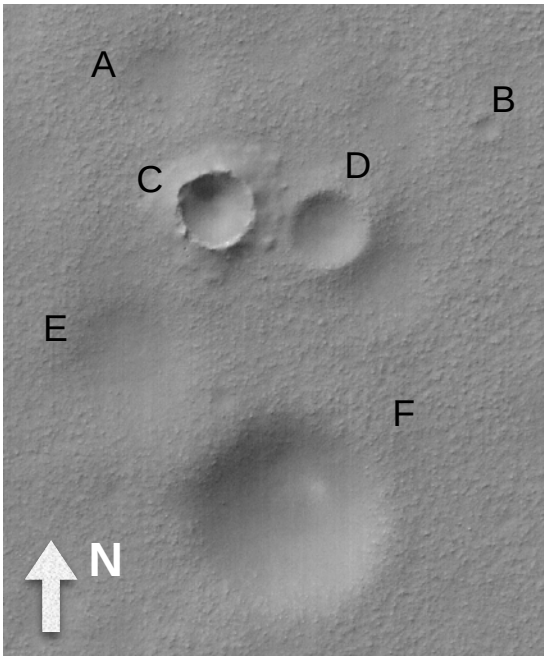


FIGURE 14: Satellite imagery of the Martian region named Sonia Planum. Imagery acquired by the Mars Orbiter Camera (MOC) of the Mars Surveyor (MGS) mission.

Question 23: Refer to figure 14. Which is the correct sequence of the relative ages (oldest to the youngest) of the craters ? (only one answer possible)
1- A / B / C / D / E / F
2- E / F / D / C / B / A
3- C / D / B / A / E / F
4- F / E / A / B / D / C
5- A / E / F / B / D / C
6- C / D / B / F / E / A
7- D / A / E / C / B / F
8- B / D / E / F / A / C

Question 24: There are fewer craters on Venus, Earth, and Mars, compared to the Moon or Mercury… (only one answer)
1- because fewer meteorites struck these planets.
2- due to volcanism that has regenerated the surfaces.
3- because the Earth has been protected by the Moon.
4- due to erosion.

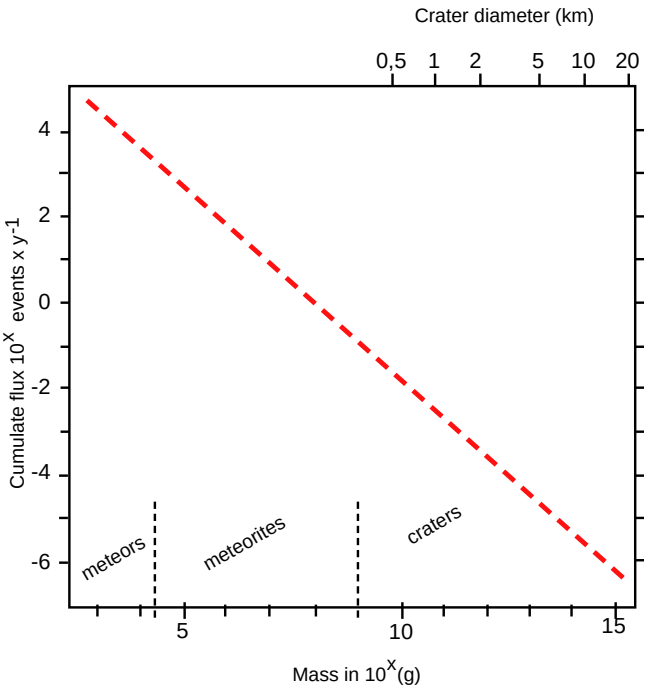


FIGURE 15: Diagram presenting the Hughes scale. The mass of the bodies, crater diameter, and the recurrence of impacts are correlated therein. The values indicated refer to the bodies approaching the Earth at approximately 15.4 km/s speed. Source: Hughes (1992) Space Science Reviews.

Question 25: According to the Hughes scale (figure 15), a body that creates a crater of 5 km diameter on Earth, corresponds at a mass of… (only one answer)
1- 100 Kilotons
2- 0.1 Megaton
3- 10 Megatons
4- 1 Gigaton

Question 26: One such body impacts the Earth at a frequency of… (only one answer)
1- once every century.
2- once every 10,000 years.
3- once every million years.

Question 27: Choose the factors that determine the size of an impact crater on the Earth : (several answers possible)
1- the shape of the body.
2- the mass of the body.
3- the amount of ice on the body.
4- the speed of the body.
5- the density of forest at the site of impact.
6- the weather

Question 28: Refer to figure 15. An impact of magnitude M=5.5, less than 100 km from the seismological station, induced vibrations of an amplitude that was too large to be precisely recorded (saturation phenomenon). The annual frequency of impacts of magnitude "M" on Mars is expressed as $R(M) = 100 \times 10^{(3.5-M)}$; the radius of Mars is 3376 km. Calculate the annual probability that such an event will occur: (only one answer)
1- 2.9%
2- 100%
3- 33%
4- 0.02%

SECTION 2 : A SURPRISING SATELLITE AROUND SATURN

Enceladus is one of the seven major satellites of Saturn. Table 1 shows some remarkable characteristics of this body. Note that its extremely clear surface has facilitated the observation of complex topography, reflecting geology that is difficult to explain for an object of this size. The aim is to study a possible geological current geological activity.

Characteristics of Enceladus					
Physical parameters				**Chemical parameters**	
Diameter (km)	Density ($g \times cm^{-3}$)	Gravity ($m \times s^{-2}$)	Temperature of the surface (K)	Composition in volume	Atmosphere
500	1.2	0.06	73	10% silicates 90% water	Trace (H_2O)

TABLE 1: Physical and chemical parameters of Enceladus.

Question 29: Considering that Enceladus has experienced differentiation, calculate the radius of the silicate core of this satellite: (only one answer)
1- 85 km.
2- 100 km.
3- 115 km.
4- 140 km.

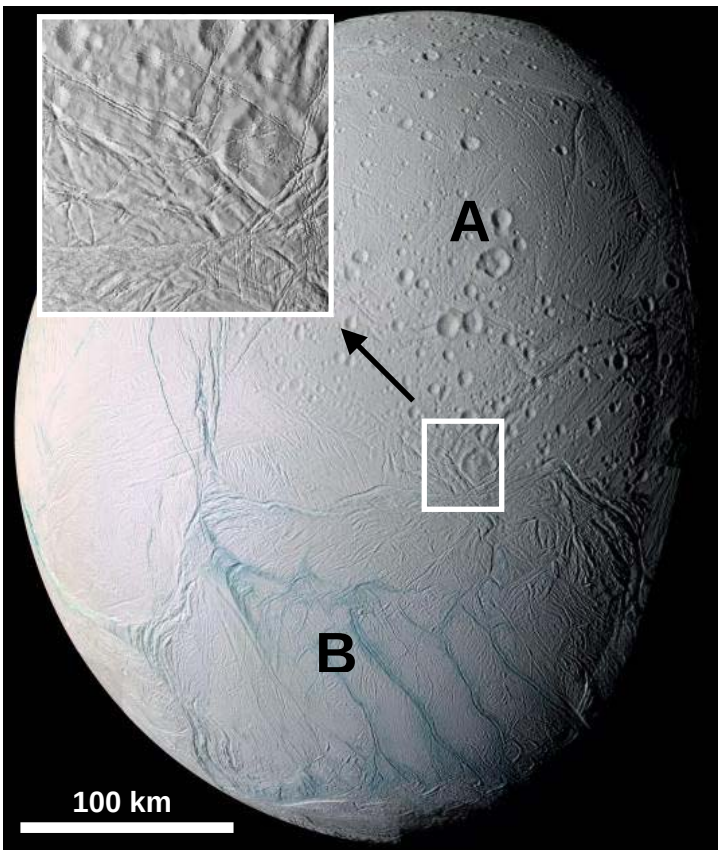


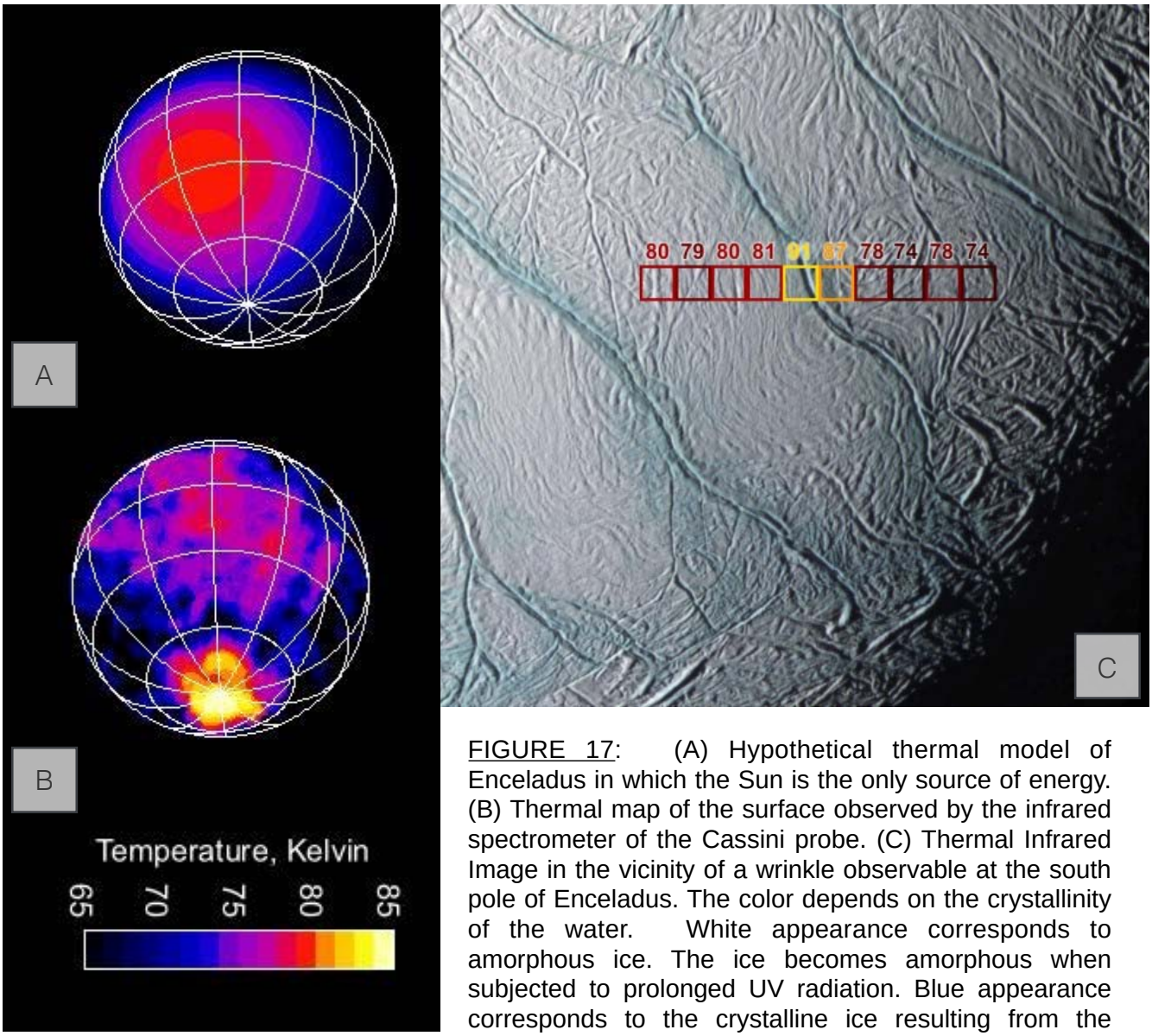
FIGURE 16 : Satellite Imaging of Enceladus obtained by the Cassini probe flying at 1000 km altitude on 14 July 2005 (source: planet-terre.ens-lyon). ***Zone A*** *refers to a major part of the planet, marked by numerous impact craters.* ***Zone B*** *corresponds to the south pole of the satellite, where topographic relief and numerous wrinkles may be seen.*

© 2005 NASA/JPL/Space Science Institute

The zoom presented as inset in figure 16 indicates that the structures of zone B intersect with the craters. Zone B is therefore more recent as suggested by the total absence of craters. Scientists hypothesize that there must be internal activity regularly renewing part of the surface of Enceladus.

Question 30: Using the Earth as an analogy, identify the parameters required to determine <u>the present</u> internal activity of Enceladus: (several answers possible)
1- Atmospheric pressure at the surface of Enceladus from the probe.
2- Surface temperature from the probe.
3- Surface chemistry to detect possible volcanic rocks.
4- Magnetic field.

In terms of the characteristics of Enceladus, the only energy that can maintain tectonics seems to be solar energy. The documents below give some specificities on its thermal state.



<u>FIGURE 17</u>: (A) Hypothetical thermal model of Enceladus in which the Sun is the only source of energy. (B) Thermal map of the surface observed by the infrared spectrometer of the Cassini probe. (C) Thermal Infrared Image in the vicinity of a wrinkle observable at the south pole of Enceladus. The color depends on the crystallinity of the water. White appearance corresponds to amorphous ice. The ice becomes amorphous when subjected to prolonged UV radiation. Blue appearance corresponds to the crystalline ice resulting from the solidification of water.

© 2005 NASA/JPL/Space Science Institute

Question 31: Refer to figure 17. A comparison between the hypothetical and spectrometer data models suggests that… (only one answer possible)
1- The only source of heat for the satellite is the Sun.
2- The Sun is too far away and has no influence on the temperature of Enceladus.
3- There is a significant heat source at the equator of the satellite.
4- The solar source impacts the surface temperature of Enceladus but there is another heat source located at the South Pole.

Question 32: The numerous wrinkles on the surface at the South Pole are correlated with detectable thermal anomalies. This observation makes it possible to deduce that the wrinkles are… (only one answer)

1- recent tectonic structures made visible by the presence of recently formed ice.
2- recent tectonic structures whose thermal anomaly does not allow for water to exist.
3- very old structures and are an evidence of the erosion caused by a past flow of water on the surface of the satellite.
4- current waterways on the surface of the satellite.

The Cassini probe flew over the mysterious south pole of Enceladus to perform chemical measurements. For this purpose, it activated its Ion and Neutral Mass Spectrometer (INMS) to detect water in its gaseous phase as well as its Cosmic Dust Analyzer (CDA) particle detector to detect particles of water ice.

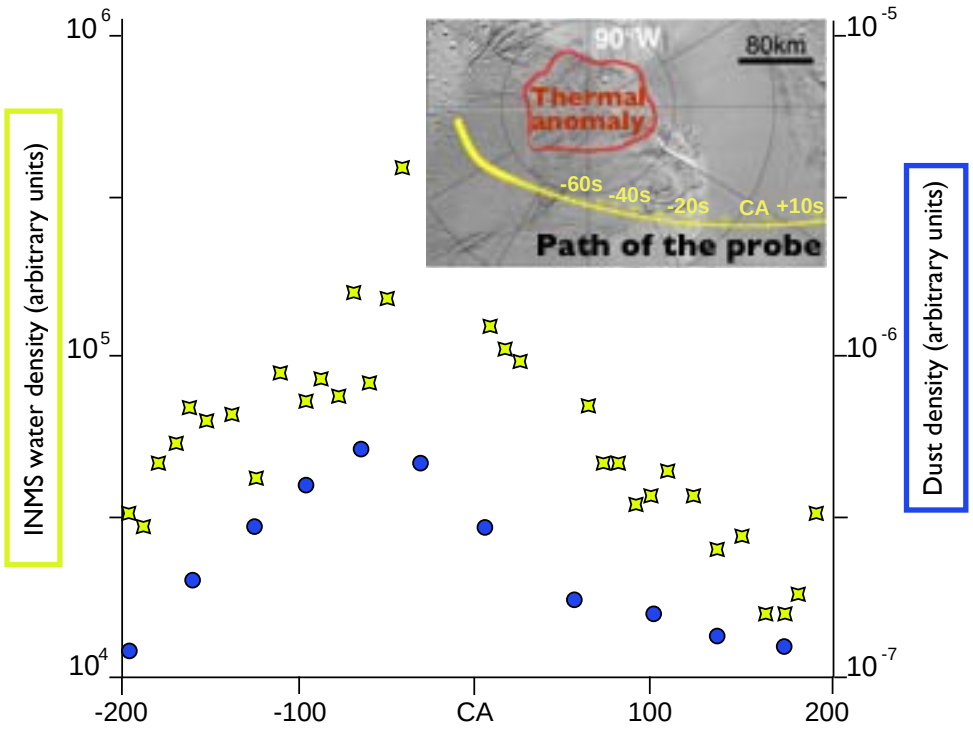


FIGURE 18 : Graph showing the measurements made by the instruments onboard the Cassini spacecraft. The thumbnail picture indicates the probe's flight path near the South Pole. Point closest approach (CA) is the probe's point of passage closest to the ground. Yellow plots correspond to INMS water density and the blue ones to the dust density. Modified from NASA/JPL/University of Michigan/Max Planck Institut 2005 ©

Question 33: Refer to figure 18. The measurements from the Cassini probe indicate that: (several answers possible)

1- The probe recorded the homogeneous presence of particles and water vapor along its path.
2- The probe recorded a diffuse zone (of over 100 km) where particles and water vapor were detected in high concentrations. The zone corresponds to the lowest position of the probe.
3- The probe recorded a constricted zone where water vapor and dust are highly concentrated. The zone corresponds to an area near the thermal anomaly of the South Pole.
4- Outside the zone of high concentration, there is always a small amount of water vapor and particles. Enceladus has a thin atmosphere.

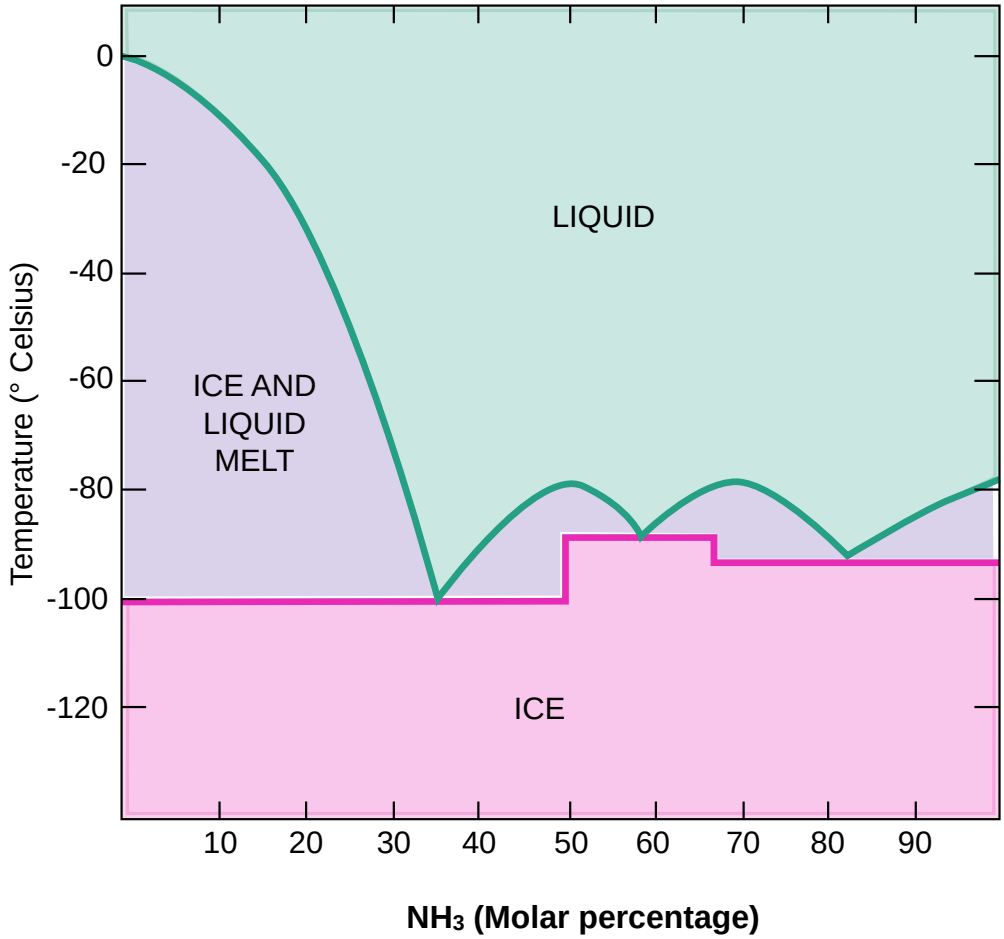


FIGURE 19: Diagram showing the phase changes of an H_2O-NH_3 mixture. The mixture is eutectic, in that it is a mixture of two pure compounds behaving like a single pure compound with respect to its changes of state. The experimental pressure corresponds to that at the surface of the satellite.

© 2005 NASA/JPL/Univ. Michigan/Max Planck Institute.

Question 34: Refer to the figure 19. Select the mixture that would allow for the minimum melting temperature:
1- A mixture containing 90% ammonia and 10% water.
2- A mixture containing 35% ammonia and 65% water.
3- A mixture containing 65% ammonia and 35% water.
4- A mixture containing 80% ammonia and 20% water.

Question 35: Is the minimum melting temperature, inferred from figure 19, compatible with the conditions of Enceladus ? (several answers possible)
1- The average temperature measured on the surface of Enceladus allows for the melting of the water-ammonia mixture.
2- The temperature measured very locally at the level of the South Pole anomalies allows for the rapid appearance of liquid.
3- No surface condition on Enceladus allows for the appearance of a liquid containing water.
4- The presence of water projected into the atmosphere indicates that internal conditions must allow for its appearance in liquid or gaseous phase.



FIGURE 20 : Photograph of a cryo-volcanic (cryo means ice) eruption on the surface of Enceladus. Analyses indicate that water vapor and ice are ejected. NASA/JPL/Space Science Institute

Question 36: Refer to figure 20. Which of the concluding sentences below are justified ? (several possible answers)

1- The northern part is marked by ancient volcanism and the southern part is an ancient ocean.
2- The surface of Enceladus is heterogeneous. It shows that solar radiation erases the craters by causing a change of state in the ice which reforms a smooth surface.
3- The surface of Enceladus indicates that only one part of the southern hemisphere is recent. It is now frozen and will gradually accumulate impact craters.
4- The surface of Enceladus indicates a very peculiar form of volcanism at the South Pole. Water vapor is ejected into the atmosphere and liquid water spreads over the surface to solidify.
5- The southern part of the satellite is marked by active tectonics maintained by an unexplained source of internal energy.
6- Despite its size Enceladus has an atmosphere, which is maintained by cryo-volcanism.