

PRACTICAL TEST : ROCKS AS EVIDENCE IN THE FORMATION OF THE ALPS

實作測驗：見證阿爾卑斯山脈形成過程的岩石

Subduction of the oceanic lithosphere leads to the closure of ocean basin, the approach of two continental domains and their eventual collision. Subduction and collision produce mountain chains such as the Alps. This process of convergence results in modifications due to substantial changes in pressure and temperature.

Let us study these rocks in an attempt to understand past events.

海洋地殼的隱沒導致海盆的關閉，隨著兩端大陸地殼的靠攏與碰撞，隱沒與聚合形成如阿爾卑斯山一般之造山帶。此聚合過程導致岩石經過顯著溫度與壓力的改變，讓我們來研究這些岩石以瞭解過去的地質史吧。

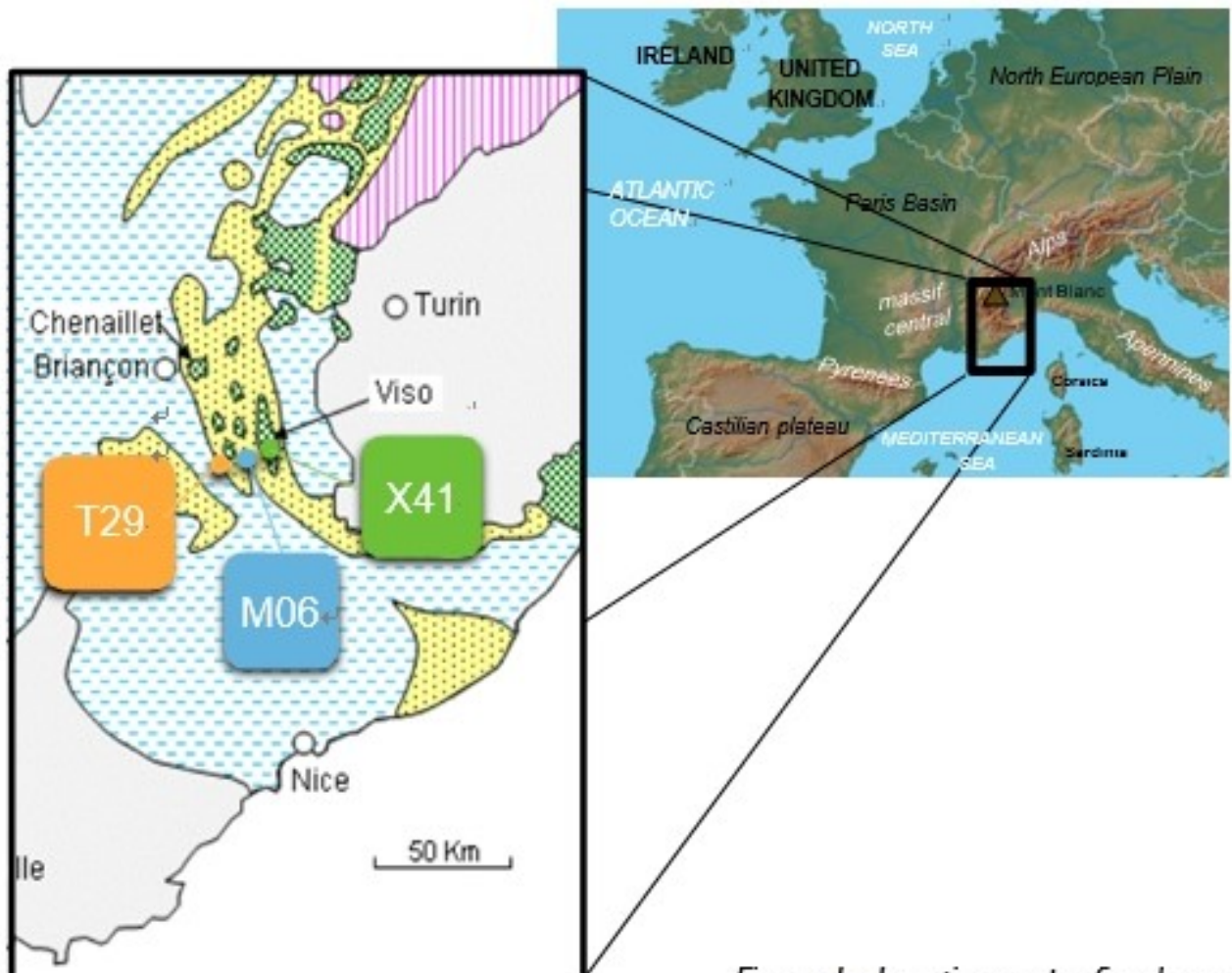


Figure 1: Location map of rock samples

圖 1: 岩石樣本的位置圖

PART I : Determining rock sample density.

單元一：找出岩石的密度

Instructions：操作步驟

- Familiarize yourself with the material provided.
 - 請熟悉所提供之儀器設備
- Design a method to calculate the density of rock samples.
 - 審慎設計一種測量計算岩石密度之方法
- Calculate the densities of samples T29 and X41.
 - 計算樣本 T29 與 X41 的密度
- Ask the judge for the density value of sample M06.
 - 向裁判詢問樣本 M06 的密度

Density T29 =	
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Density X41 =	
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Density M06 =	
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Question 1: The density of sample T29 is... (only one possible answer)

樣本 T29 的密度為：（單一選項）

- | | |
|-------------------------------|-------------------------------|
| 1- 1.9 g x cm^{-3} | 5- 2.4 g x cm^{-3} |
| 2- 3.9 g x cm^{-3} | 6- 78.4 g x cm^{-3} |
| 3- 15.7 g x cm^{-3} | 7- 5.7 g x cm^{-3} |
| 4- 3.0 g x cm^{-3} | 8- 0.8 g x cm^{-3} |

Question 2: The density of sample X41 is... (only one possible response)

樣本 X41 的密度為：（單一選項）

- | | |
|--------------------------------|---|
| 1- 3.8 g x cm^{-3} | 5- $2.0 \times 10^{-3} \text{ g x cm}^{-3}$ |
| 2- $124.7 \text{ g x cm}^{-3}$ | 6- 7.4 g x cm^{-3} |
| 3- 3.3 g x cm^{-3} | 7- 9.7 g x cm^{-3} |
| 4- 0.6 g x cm^{-3} | 8- 2.8 g x cm^{-3} |

Question 3 : In general, when a magmatic rock has a density that is higher than another (one answer possible)

一般狀況下，當一岩漿岩的密度高於其他岩石時，這表示：（單一選擇）

- 1- it is composed of more silicates.
其岩石矽酸成分較高
- 2- it has undergone a higher degree of diagenesis.
其岩石經過較高度的成岩作用
- 3- it contains a greater proportion of ferromagnesian minerals.
其岩石成分有較高的鐵鎂質
- 4- it has a higher proportion of water.
其岩石有較多的水含量
- 5- it is older.
其岩石較老

PART II : Determining rock water content 單元二：估計岩石之含水量

Instructions : 操作步驟

- Familiarize yourself with the material provided (annotated photos, graph paper).
- 請熟悉所提供之儀器設備(方格紙，描圖紙)
- Complete the table below to determine the percentage of water in the samples.
- 根據填寫下表來找出樣本的含水量
- Ask the judge for the water content value of sample M06.
跟裁判詢問樣本 M06 的含水量

Mineral 礦物	Group	M _{molar} of the mineral g/mol 礦物的 莫爾質 量(每 莫爾幾 克)	M _{water} contained in one mole of mineral (g) 每莫爾礦物 之含水量 (g)	T29			X41		
				% Observed mineral 其礦物於 岩石所佔 之百分比	% water in the mineral 水於其 礦物之 佔比	% in the rock 水於其 岩石之 佔比	% Observed mineral 其礦物於 岩石所佔 之百分比	% water in the mineral 水於其礦 物之佔比	% in the rock 水於其岩 石之佔比
Actinolite 陽起石	Amphibole 角閃石	488	18						
Augite 輝石	Pyroxene 輝石	281.7	0						
Chlorite 綠泥石	Mica 雲母	559	72						
Glaucophane 藍閃石	Amphibole 角閃石	796	18						
Grossularite 鈣石榴子石	Garnet 石榴子石	502.5	0						
Hornblende 角閃石	Amphibole 角閃石	572	18						
Jadeite 輝石玉	Pyroxene 輝石	140.5	0						
Phengite 矽白雲母	Mica 雲母	472	36						
Plagioclase 斜長石	Feldspar 長石	341	0						

Total percentage of water in the samples 水在樣本所佔的總百分比

T29	X41	M06

Question 4 : The water content of sample T29 is approximately :

樣本 T29 的含水量約為 :

- | | |
|----------|----------|
| 1- 1.6% | 5- 56.9% |
| 2- 4.8% | 6- 3.7% |
| 3- 32.0% | 7- 2.8 % |
| 4- 0% | 8- 0.6 % |

Question 5 : The water content of sample X41 is approximately :

樣本 X41 的含水量約為 :

- | | |
|----------|----------|
| 1- 0% | 5- 6.7% |
| 2- 4.7% | 6- 48.9% |
| 3- 7.5% | 7- 1.6% |
| 4- 44.0% | 8- 0.9% |

Question 6 : If we assume T29 became X41. The differences in the water content of the rocks are explained by... (one answer possible)

若樣本 T29 會轉變成樣本 X41，其水含量的差異可由下列何種機制解釋 (單一選項)

- 1- longer exposure to meteoric water.
長時暴露於天水
- 2- an increase in pressure and a decrease in temperature.
壓力增加，溫度減少
- 3- an increase in temperature and a decrease in pressure.
溫度增加，壓力減少
- 4- an increase in pressure and temperature.
增溫增壓
- 5- a decrease in pressure and temperature.
減溫減壓
- 6- longer contact with microorganisms that have used the water in rocks.
與微生物的長時接觸將岩石中的水消耗掉

Question 7 : Based on your knowledge and the results of your calculations, sample X41 corresponds to... (only one answer possible)

根據你的計算結果與知識判斷，樣本 X41 應是：(單一選項)

- | | |
|--|---|
| 1. a blueschist facies metagabbro.
藍片岩相的變質輝長岩 | 5. an eclogite facies metagabbro.
榴輝岩相的變質輝長岩 |
| 2. a basalt.
玄武岩 | 6. a peridotite.
橄欖岩 |
| 3. a blueschist facies granite.
藍片岩相的花崗岩 | 7. a diorite.
閃長岩 |
| 4. an andesite
安山岩 | 8. a blueschist facies limestone.
藍片岩相的大理岩 |

Question 8 : Based on your knowledge and the results of your calculations, sample M06 corresponds to... (only one answer possible)

根據你的計算結果與知識判斷，樣本 M06 應是：(單一選項)

- | | |
|--|---|
| 1. a blueschist facies metagabbro.
藍片岩相的變質輝長岩 | 5. an eclogite facies metagabbro.
榴輝岩相的變質輝長岩 |
| 2. a basalt.
玄武岩 | 6. a peridotite.
橄欖岩 |
| 3. a blueschist facies granite.
藍片岩相的花崗岩 | 7. a diorite.
閃長岩 |
| 4. an andesite
安山岩 | 8. a blueschist facies limestone.
藍片岩相的大理岩 |

PART III: Reconstructing a partial geological history of the Alps.

單元三：阿爾卑斯山區域地質史之重建

The three rocks T29, M06, and X41 are connected in the same geodynamic context: the subduction of the Alpine Ocean (the Tethys).

During this process, these three rocks have undergone transformations leading to changes in their density and their water content.

T29, M06, 和 X41 這三個岩石樣本在於同樣的地質動態架構下所形成，也就是特提司洋的隱沒。在此過程中，此三個樣本經過改變，導致其岩石密度與水含量有所改變。

Question 9 : The physical and mineralogical transformations observed in the three samples may be referred to as : (only one answer)

導致此三個樣本的物理性質與礦物組成會改變的是：（單一選項）

1- **Crustal anatexis.**

地殼重熔

5- **Diagenesis**

成岩作用

2- **Fractional crystallization**

分液結晶作用

6- **Magmatism**

岩漿作用

3- **Metamorphism**

變質作用

7- **Tectonism**

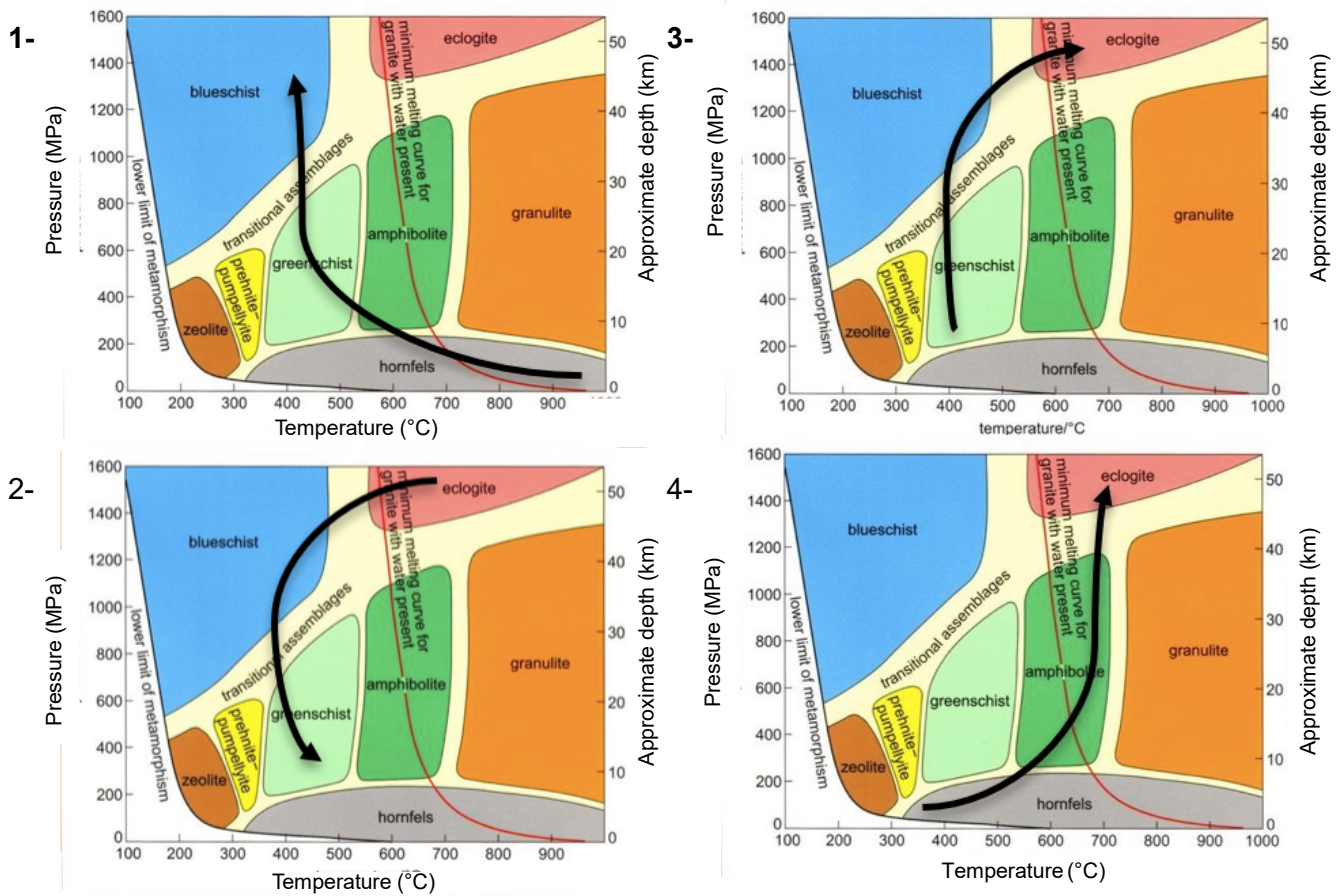
板塊運動

4- **Volcanism**

火山作用

Question 10 : Four possible routes of rock development are given below. Which one best corresponds to your calculations and conclusions ?

下列四個可能形成這些樣本的路徑（有箭頭的黑線）何者最符合你的計算結果與結論？



Question 11 : Considering the figures below, which of the following figure best illustrate ?

下列圖中，何圖最符合你的計算結果與結論？

