A GEOLOGICAL FIELD GUIDE TO ACI CASTELLO AND ACI TREZZA

INGV

OSSERVATORIO ETNEO
SEZIONE DI CATANIA

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INTRODUCTION

Unknown to many visitors, the popular villages of Aci Castello and Aci Trezza on the east coast of Sicily are home to sites of significant geological interest. These take the form of the distinctive rock formations found at the castle rock in Aci Castello and off the coast from Aci Trezza - the Cyclopean Islands. This field guide invites you to explore these unusual looking rocks and explains the geological processes that formed them. As you will discover, these rocks were formed from magmas and are related to those that make up the volcano of Mt Etna, which dominates the geology of eastern Sicily.

THE GEOLOGICAL EVOLUTION OF MT ETNA

The present day Etna volcano has been built up by many stages of volcanic eruptions over the last 500,000 years. A geological map of the volcano is shown in **Figure 1** – the different colours on the map refer to rocks formed at different stages of the volcano's history. The dominant colour on the map is red – this corresponds to the products of eruptions (mostly lava flows) from the last 15,000 years, which now cover most of the volcano. However, this guide focuses on the rocks formed by the earliest volcanic eruptions in this part of Sicily, before the Mt Etna edifice was built.

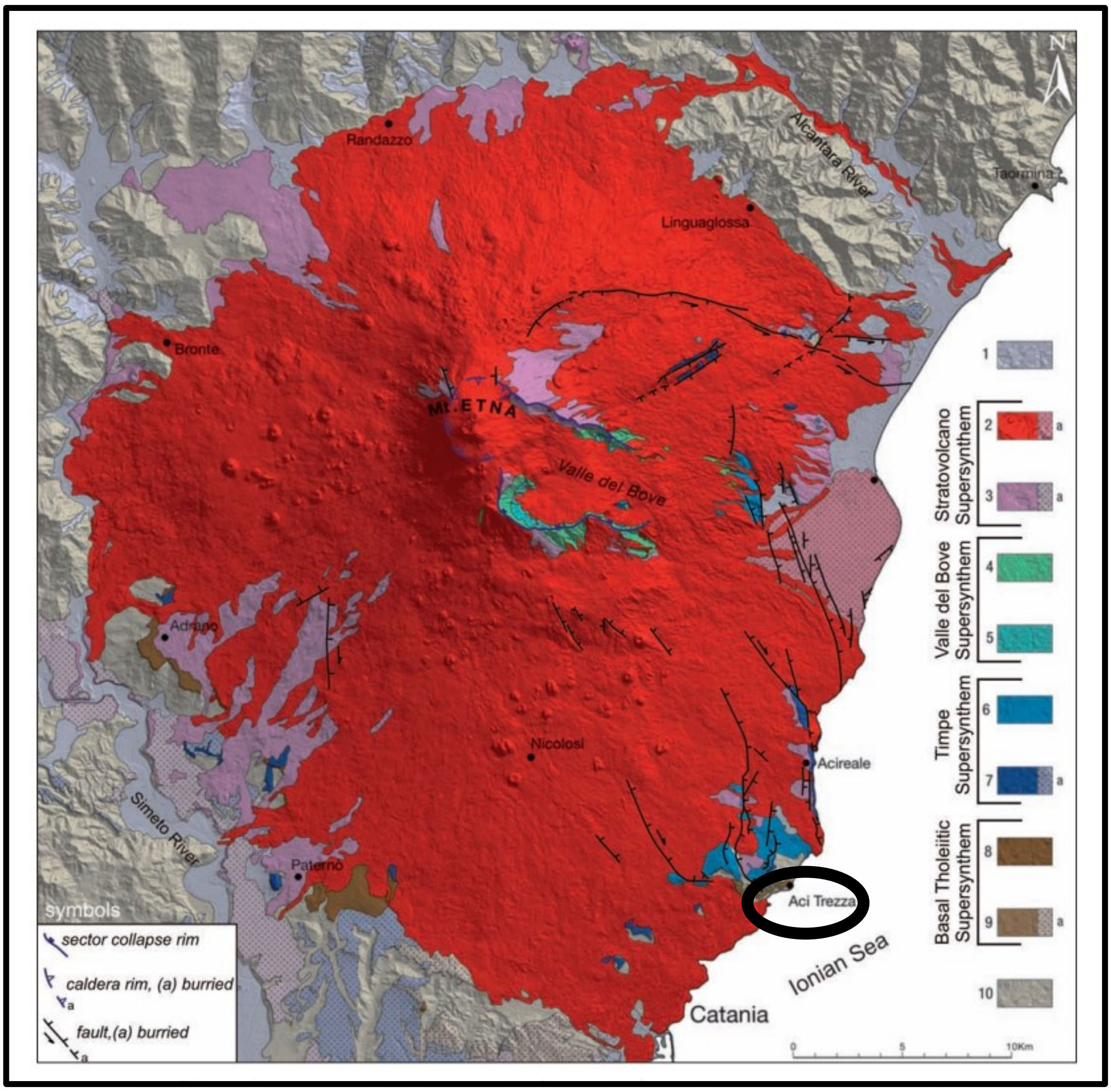


Figure 1 *– Geological map of Etna volcano, from Branca et al., 2011a. The area of Aci Trezza and Aci Castello, the focus of this field guide, is shown by the black circle.*

Around 500,000 years ago, the coastline of Sicily was located further west than it is today and the area presently occupied by Aci Castello and Aci Trezza (circled in **Figure 1**) was underwater (brown circle in **Figure 2**).

In this area, the seafloor was formed of soft clay-rich sediments. At this time, magmas rising from deep within the Earth cooled beneath the surface and erupted on the seafloor to create the rock formations at Aci Castello and Aci Trezza. These rocks therefore record the very first stages of the volcanic evolution of Mt Etna.

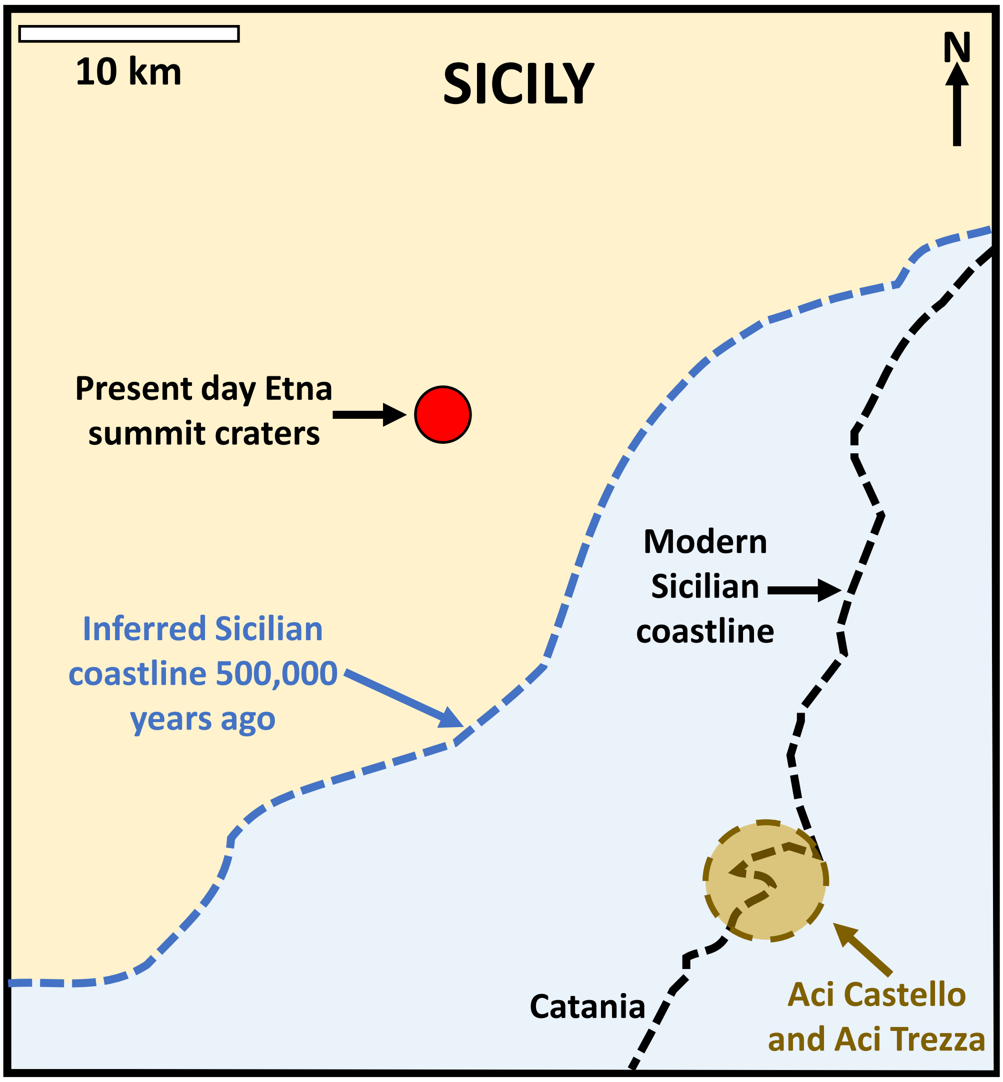


Figure 2 *– Schematic map of the Etna region, modified from Branca et al., 2011b. The map shows the inferred position of the Sicilian coastline 500,000 years ago. At this time, the area now occupied by Aci Castello and Aci Trezza (brown circle) was underwater and the Etna volcano did not yet exist.*

The following pages of this field guide explain the geological features of and processes recorded by the rock formations at Aci Castello and Aci Trezza. For each location, a map and labelled photographs are provided to help you to find the geological features discussed.

LOCALITY MAP *– Screenshot from Google Maps showing the Aci Castello castle rock from above. The yellow stars mark the three localities described in this field guide.*

The castle at Aci Castello is built on a large body of rock, which lies on top of a rocky platform extending out into the sea. These rocks were formed from magmas that were erupted on the bottom of the sea, around 500,000 years ago. Over time, regional tectonic movements have lifted these rocks above sea level. Many years of erosion have created the distinctive shape of the outcrop that we see today.

The “LOCALITY MAP” above is designed to help you find the locations described on the following pages. **Locality 1** is located on the promenade – go to the edge and view the castle rock from the south. **Locality 2** is on the east of the rocky platform – the geological features described in the photos can be found in this area, though you may need to look around a bit to find the exact locations! **Locality 3** is on the north side of the rocky platform.

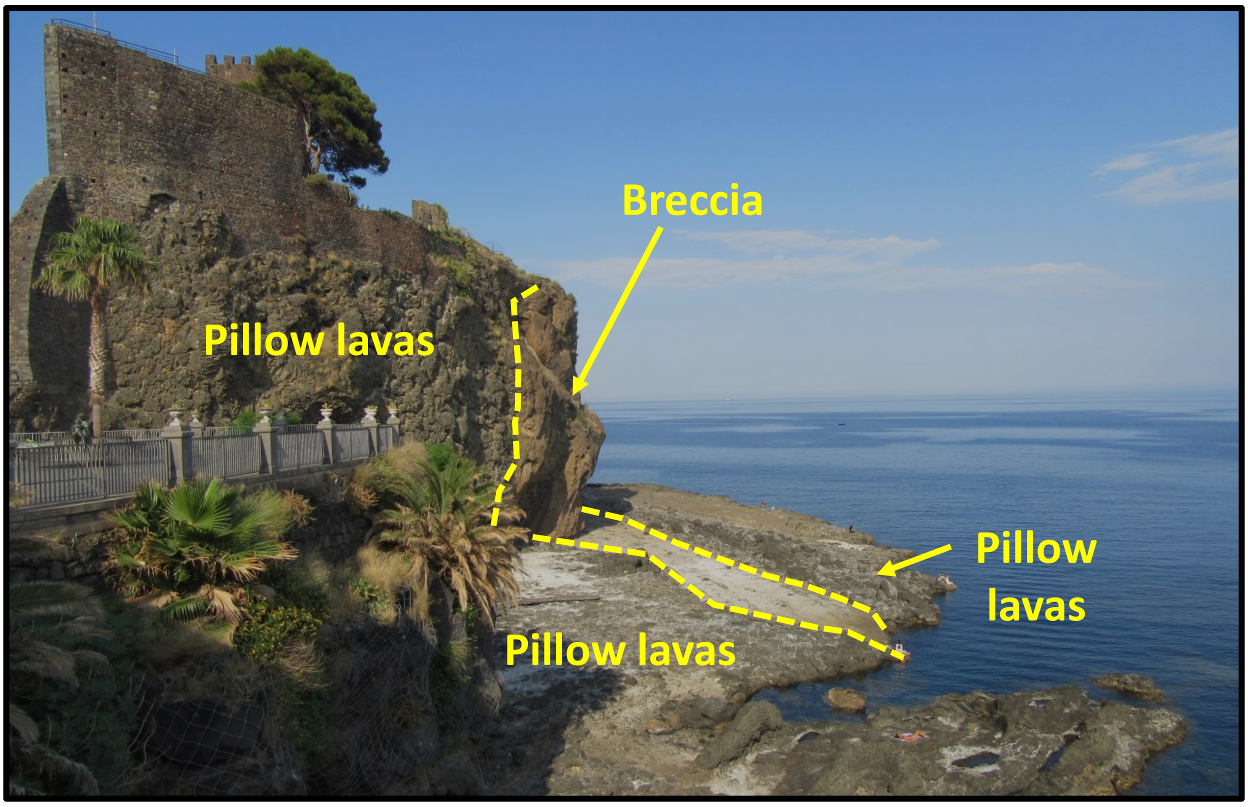
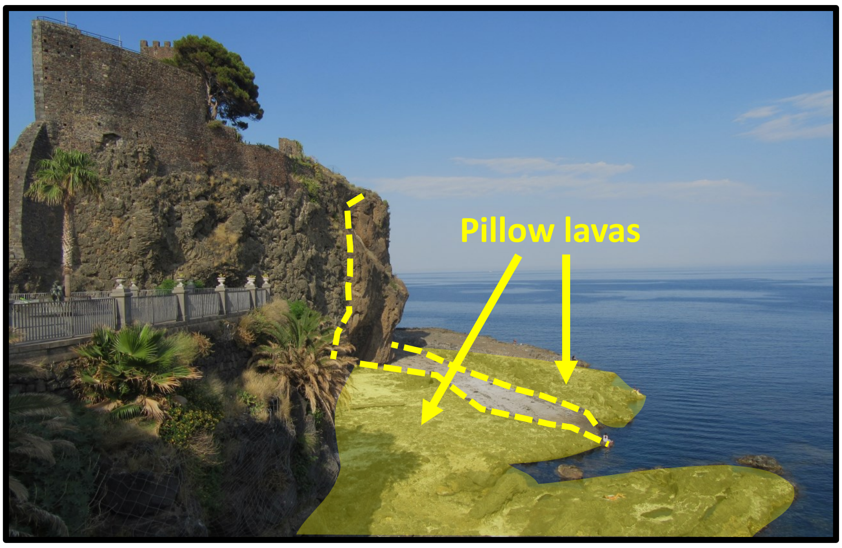
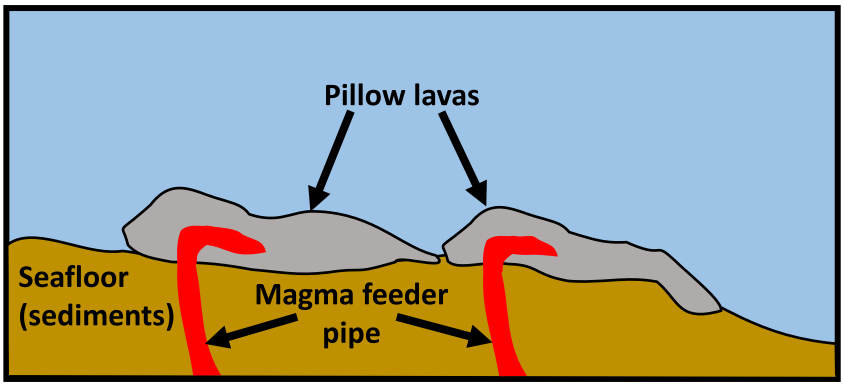


__Figure 1__ – Labelled photo highlighting the different rock units at Aci Castello, viewed looking north towards the castle from Locality 1.

Standing at Locality 1 on the map, on the path along the seafront, you can see the castle rock from the viewpoint shown in the photo in **Figure 1**. Two different types of rock, labelled on the photo, are present in the outcrop – **pillow lavas** and **breccia**. The breccia (a mixture of broken up volcanic material) can be distinguished by its pale brown colour. The following cartoons describe the sequence of processes that formed the outcrop you can see today.

Stage A

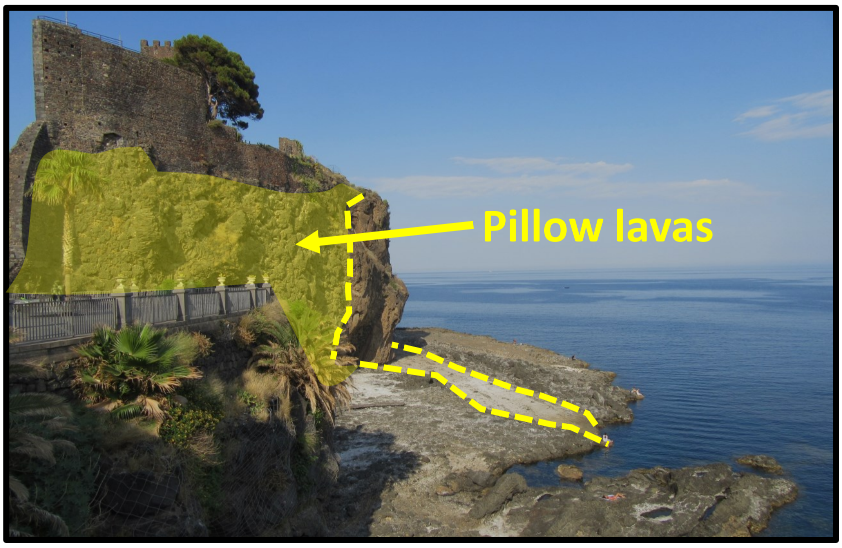


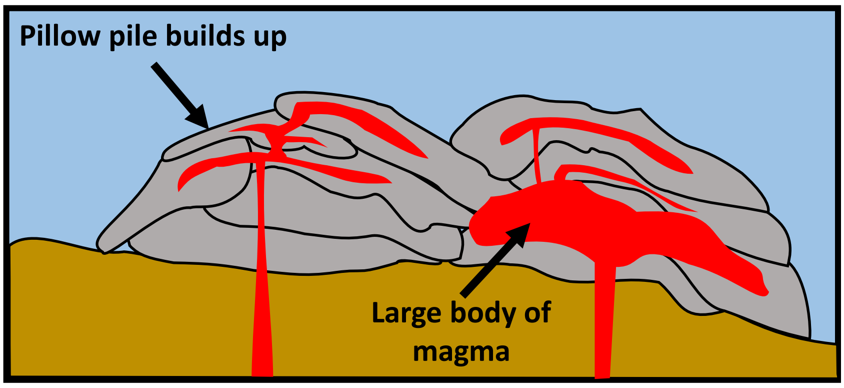


Small batches of magma rise through the sediments and reach the seafloor, where they erupt forming pillow lavas. These initial pillow lavas can be observed at the rocky platform, as highlighted in yellow in the photo on the left.

In the cartoon, the red represents the molten (hot) magma feeding the eruptions, while the grey represents the solid lava rock formed once the magma cools.

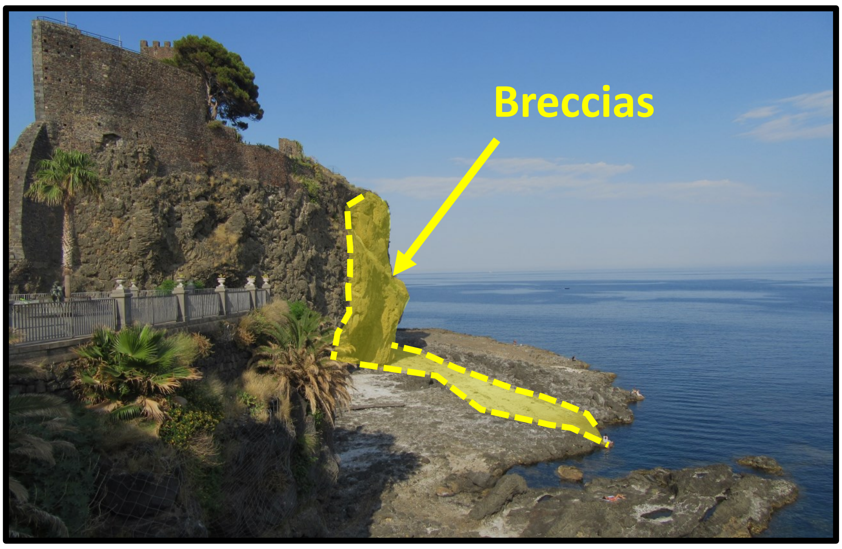
Stage B

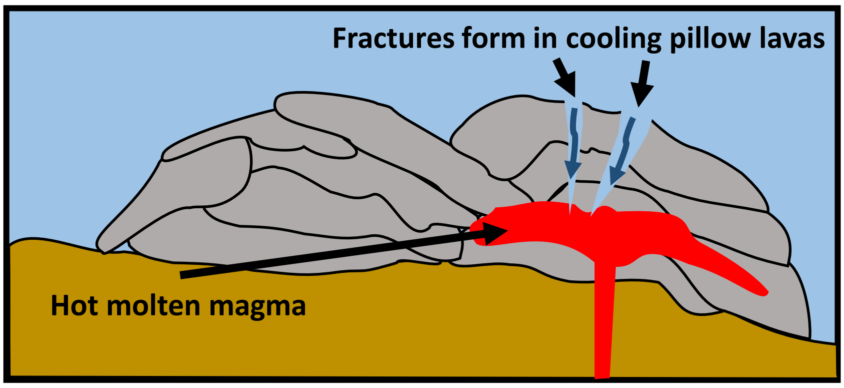


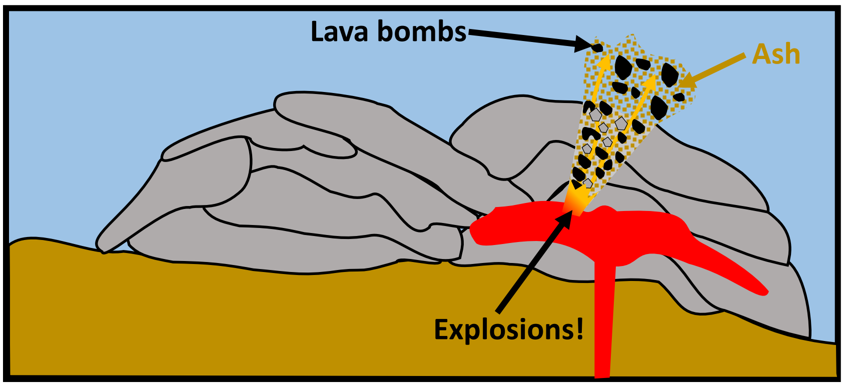


More magma reaches the seafloor and erupts, building up the pile of pillow lavas. Part of this pile is now preserved as the castle rock, highlighted in the photo on the left.

Stage C







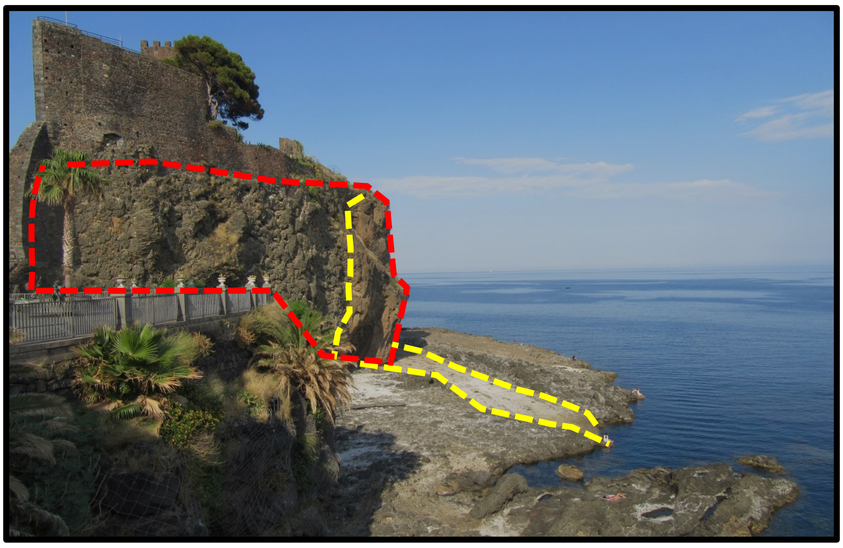
As the pile of pillow lavas cools, it contracts and fractures form at the surface.

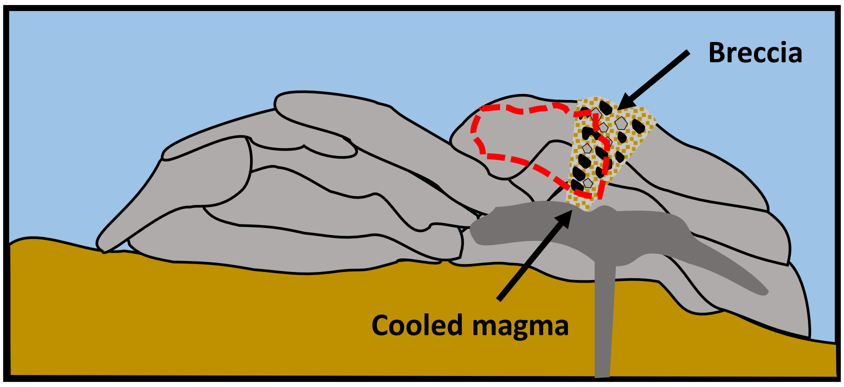
However, some of the magma near the base of the pillow lava pile remains hot and molten.

Seawater enters the fractures (blue arrows on cartoon) and eventually reaches the hot magma. This vaporizes the water and triggers violent explosions!

The interaction between hot magma and cold seawater produces lava bombs, lapilli and ash, due to quenching (very fast cooling) of the magma. The force of the explosions also breaks off fragments of cooled pillow lavas. These materials fill the fracture, forming the coarse breccia preserved on the edge of the castle rock.

Stage D





The eruption stops and the inner part of the volcanic pile eventually cools.

Over many thousands of years, the pillow lavas are uplifted above sea level by regional tectonic movements. A long period of erosion of the area means only a small portion of the pillow lavas and breccia, shown by the dashed red line, are preserved at the castle rock today.

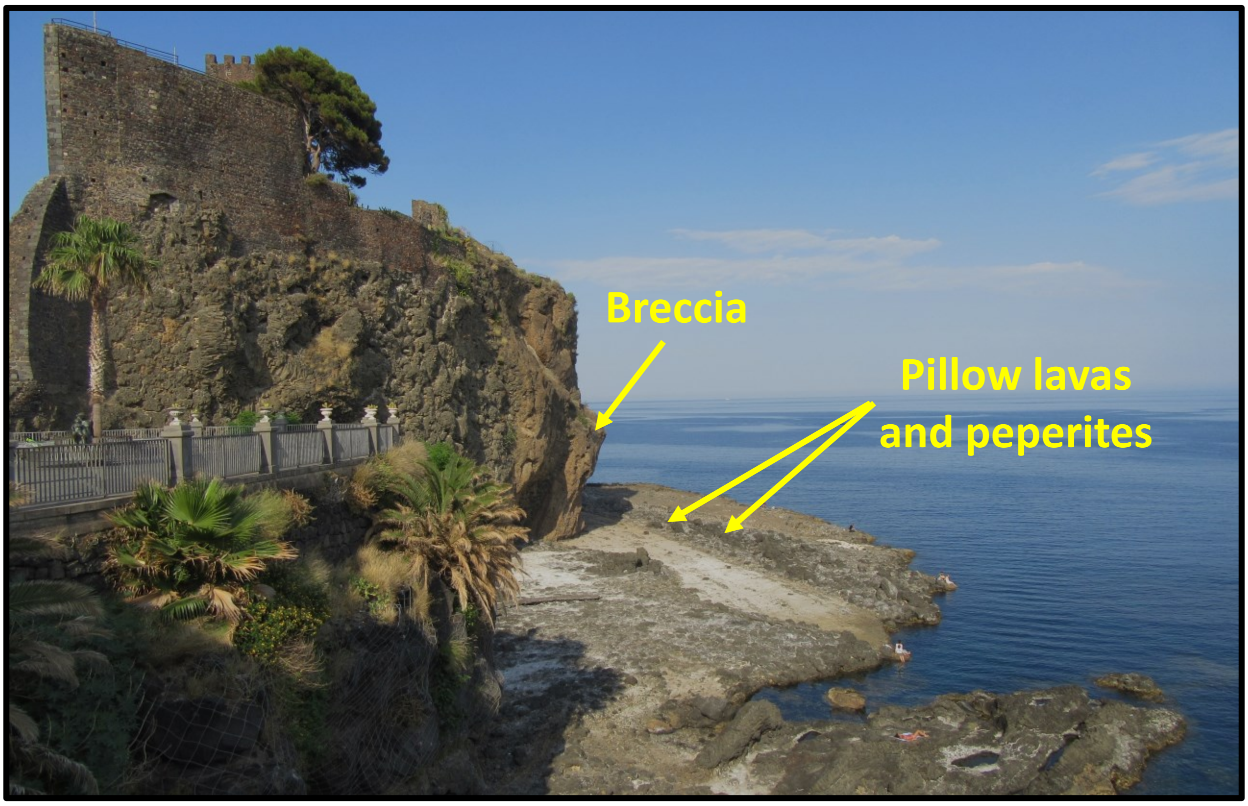
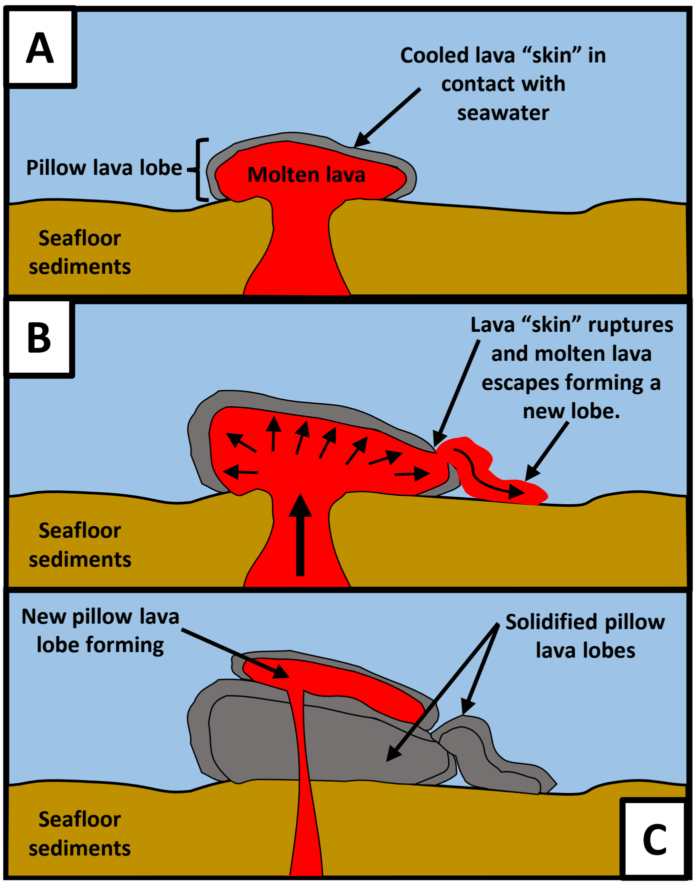


Figure 2 *– labelled photograph showing locations of geological features described on the following pages.*

By walking down the steps on the south side of the castle rock, you can access the rocky platform. Here you can examine close up some of the geological features in the outcrop. The labelled photograph (**Figure 2**) shows you roughly where to find the features shown in **Figures 3-7**, though you may have to look around a bit to find the exact locations!

Pillow lavas

Pillow lavas are named for their shape - their rounded lobes look a bit like pillows! These rocks form when lava is erupted underwater and immediately comes into contact with water upon reaching the surface. The cartoons below illustrate the process by which pillow lavas form.



Stage A - When molten lavas are erupted on the seafloor, they are cooled very quickly by the surrounding seawater. This forms a glassy rind or "skin" of solidified lava around a molten core. These bodies of lava occur as rounded or "lobe" shapes, which look like pillows.

Stage B - As more lava is erupted, the lobe inflates from the inside. Eventually, the pressure causes the "skin" to break open and some molten lava can escape to form a new lobe.

Stage C - Over time, the lobes fully solidify. More molten lava erupts through the top of the pile of cooled lava, forming a stack of pillow lava lobes over time.

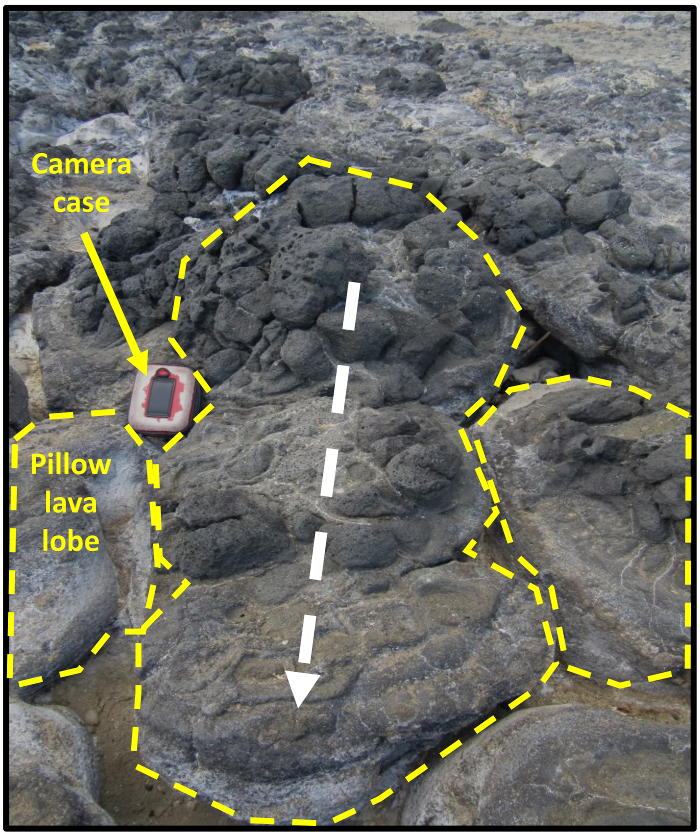


Figure 3 *- Close up photo of pillow lava lobes found on the rocky platform below the castle (see* ***Figure 2*** *for the location). The rounded shape of the lobes is marked by the dashed yellow outlines. The dashed white arrow shows the direction of movement of the biggest lobe. For scale, the camera case is 12 cm long! Pillow lava lobes can also be viewed all around the rocky platform – see how many you can spot!*

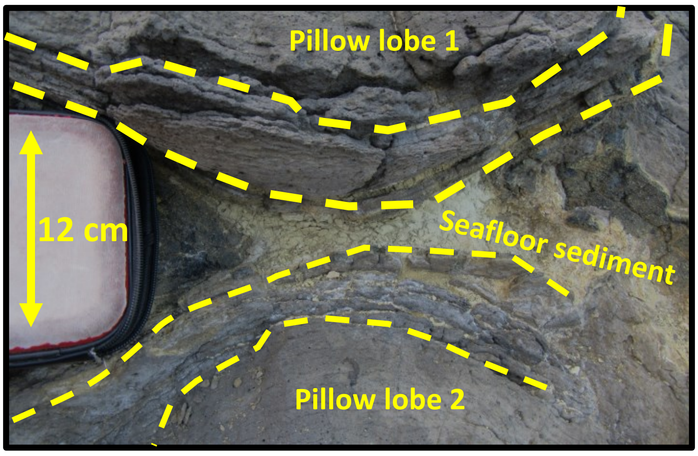


Figure 4 *- Close up photo of the edges of two pillow lobes on the castle rock platform (see* ***Figure 2*** *for the location). The area of the pillow lobe between the dashed lines is the dark and shiny "skin" of volcanic glass formed by rapid cooling. Look around the platform and see if you can find similar examples! The pale brown material between the pillows is clay-rich sediment from the seafloor on which they were erupted.*

Peperites

Towards the eastern edge of the platform, some particularly unusual pillow lava lobes, with thin lenses of sediment inside, can be found **(Figure 5).** These strange features are known as “peperites”. The cartoons below illustrate how these lenses of sediment came to be trapped inside the pillow lavas.

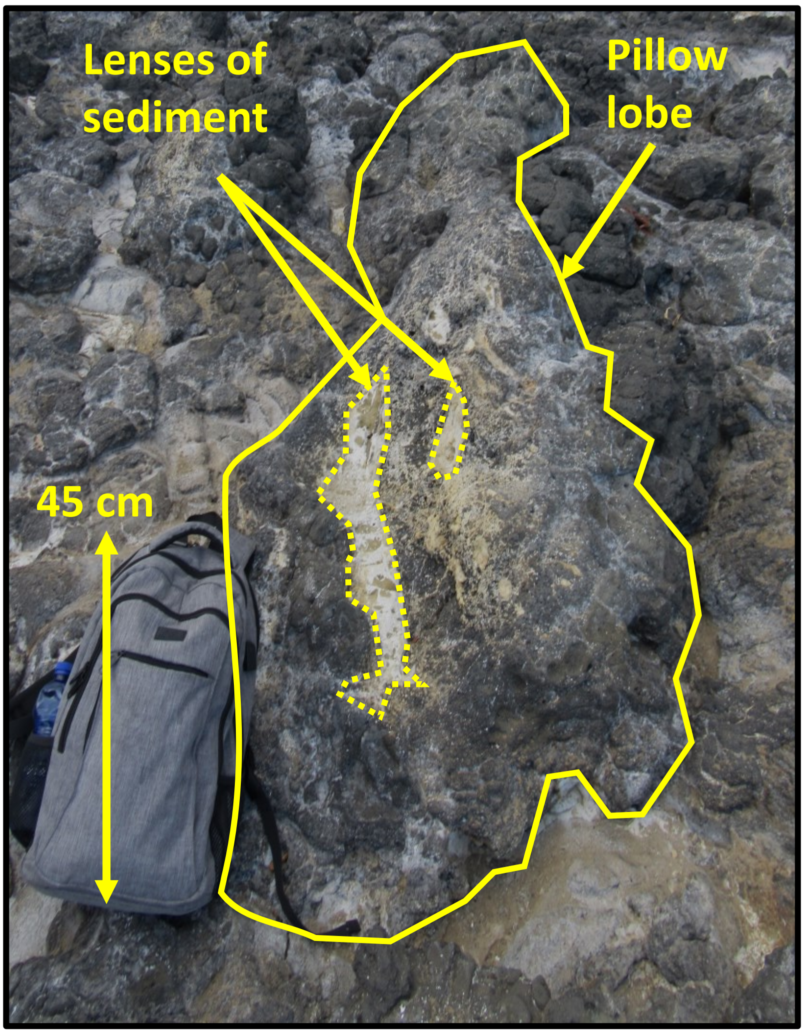
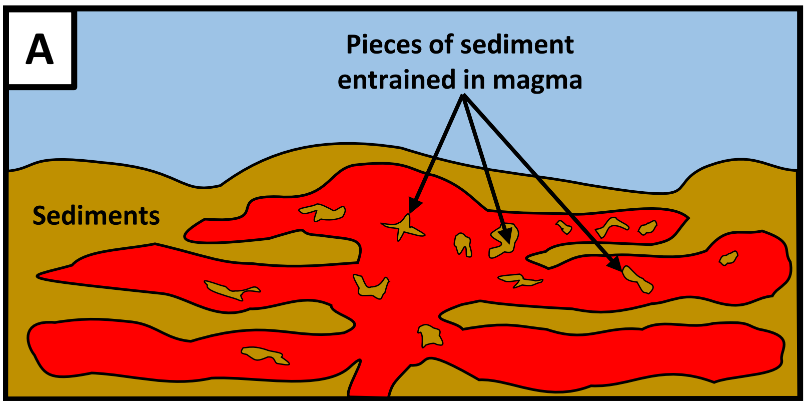
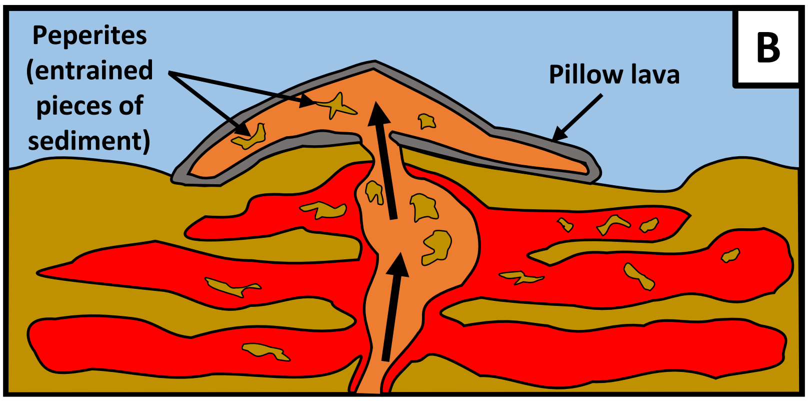


Figure 5 *– Labelled photo of peperites (lenses of sediment) inside pillow lava on eastern edge of rocky platform.*



Stage A: Magma intrudes into sediments on the seafloor – because the sediments are soft, they can mix with the liquid magma, causing pieces of sediment to become entrained.



Stage B: More magma later rises towards the seafloor - this magma captures some of the entrained pieces of sediment and transports them to the surface. Here the magma is erupted on the seafloor as pillow lavas, with the pieces of sediment trapped inside, forming the peperites.

Breccia

The breccia is made up of a mixture of broken up volcanic material, formed by explosions caused by seawater interacting with hot lava. The breccia can be viewed close up by going up to the rock face where it extends upwards from the rocky platform (see **Figure 2**). **Figures 6 and 7** show close up photos of the different types of volcanic material found in the breccia.

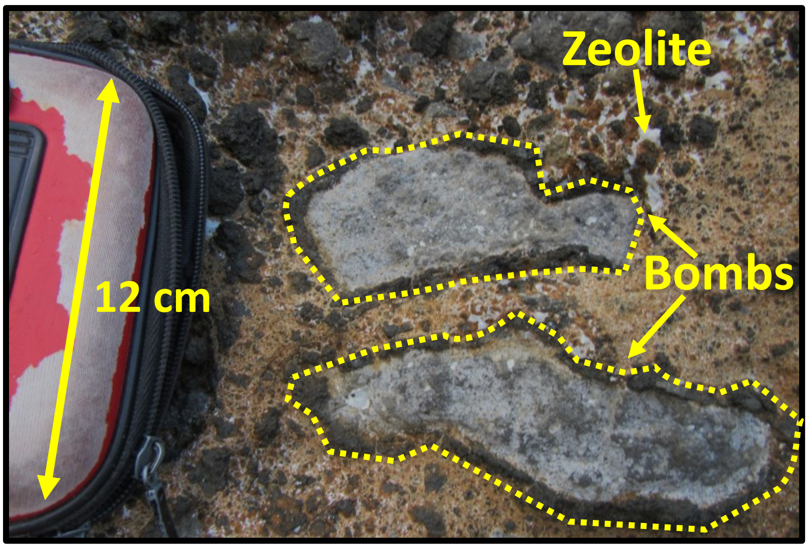


Figure 6 *– Close up photo of breccia. The dotted lines highlight rounded pieces of lava with dark glassy margins – these are volcanic bombs produced when the hot lava interacted with the seawater. After the explosive events, seawater was able to infiltrate the loose pile of lava pieces and ash filling the fracture. In the gaps between the volcanic material, the white mineral zeolite (labelled) was precipitated from the seawater.*

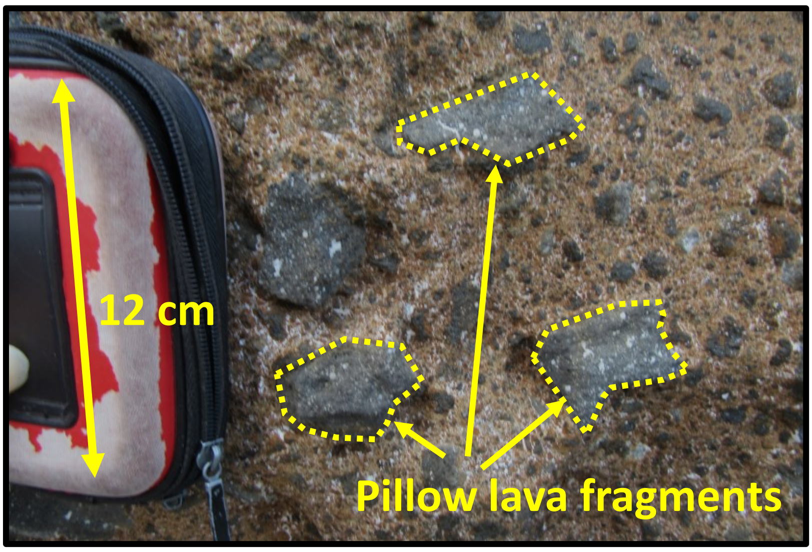


Figure 7 *– Close up photo of breccia. The dotted lines highlight angular fragments of solidified pillow lavas ripped off by the explosions that formed the breccia. The brown matrix between the lava pieces is made of fine volcanic ash produced in the explosions.*

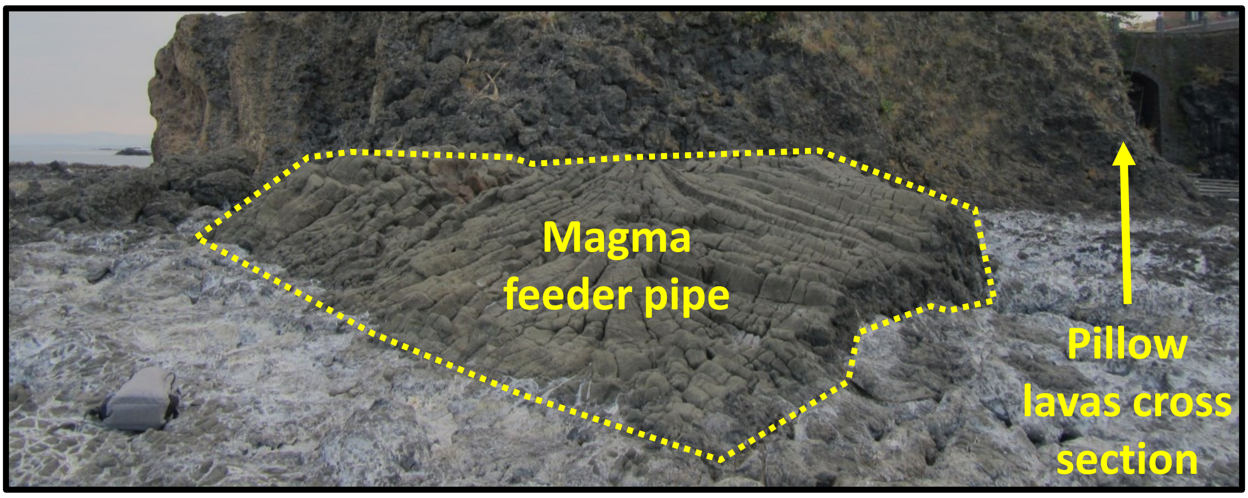


Figure 8 *– labelled photograph showing locations of geological features described below.*

Walking around the rocky platform and viewing the castle rock from the northern side, looking south, you can observe an exposure of a magma feeder pipe and a great example of a cross section through pillow lava lobes (**Figure 8**).

Magma Feeder Pipe

On the north side of the rocky platform, a large mass of cooled lava rock with unusual shapes can be found. This is thought to be one of the "magma feeder pipes" (**Figure 8**), like those in the cartoons on **page 5** that supplied magma to the surface to create the pillow lavas. Eventually the supply of fresh magma stopped and the magma in the pipe cooled slowly and solidified. Erosion of the surrounding pillow lavas has left this feature visible on the surface today.

Cross section of pillow lava pile

On the north-west side of the castle rock, you can find an exposure which provides a cross section through the pile of pillow lavas. The different pillow lobes, stacked on top of one another, are highlighted in **Figure 9**. This outcrop shows a great example of how the pillow pile built up over time.

Figure 9: *A stack of pillow lava lobes. Each individual lobe is marked by the yellow dashed lines.*

LOCALITY MAP *– Screenshot from Google Maps showing the port of Aci Trezza from above. Off the coast from the port are the Cyclopean islands – the main islands of Lachea and Santa Maria are labelled. The yellow stars mark the three localities described in this field guide.*

Looking out to sea from the port of Aci Trezza, you can view a series of unusually shaped rocks protruding from the water, known as the Cyclopean Islands. These islands represent the remnants of a geological feature known as a laccolith, formed when a large body of magma intruded into soft sediments beneath the seabed and cooled slowly. Uplift via regional tectonic movements combined with erosion has left the islands exposed as seen today.

It is thought that these rocks were created by magmatic activity that occurred before the formation of Etna volcano. However, the date at which the laccolith was intruded into the sediments remains unknown and is currently subject to scientific investigation.

The LOCALITY MAP is designed to help you find the locations described on the following pages. **Locality 1** is located on the promenade, next to some steps that lead down on to the rocks below. To reach **Locality 2** (split into 2.1 and 2.2) and **Locality 3**, the islands of Lachea and Santa Maria, you will need access to a boat. However, if this is not possible, some of the features discussed can still be observed by looking at the islands from Aci Trezza using a camera with a good zoom or some binoculars!

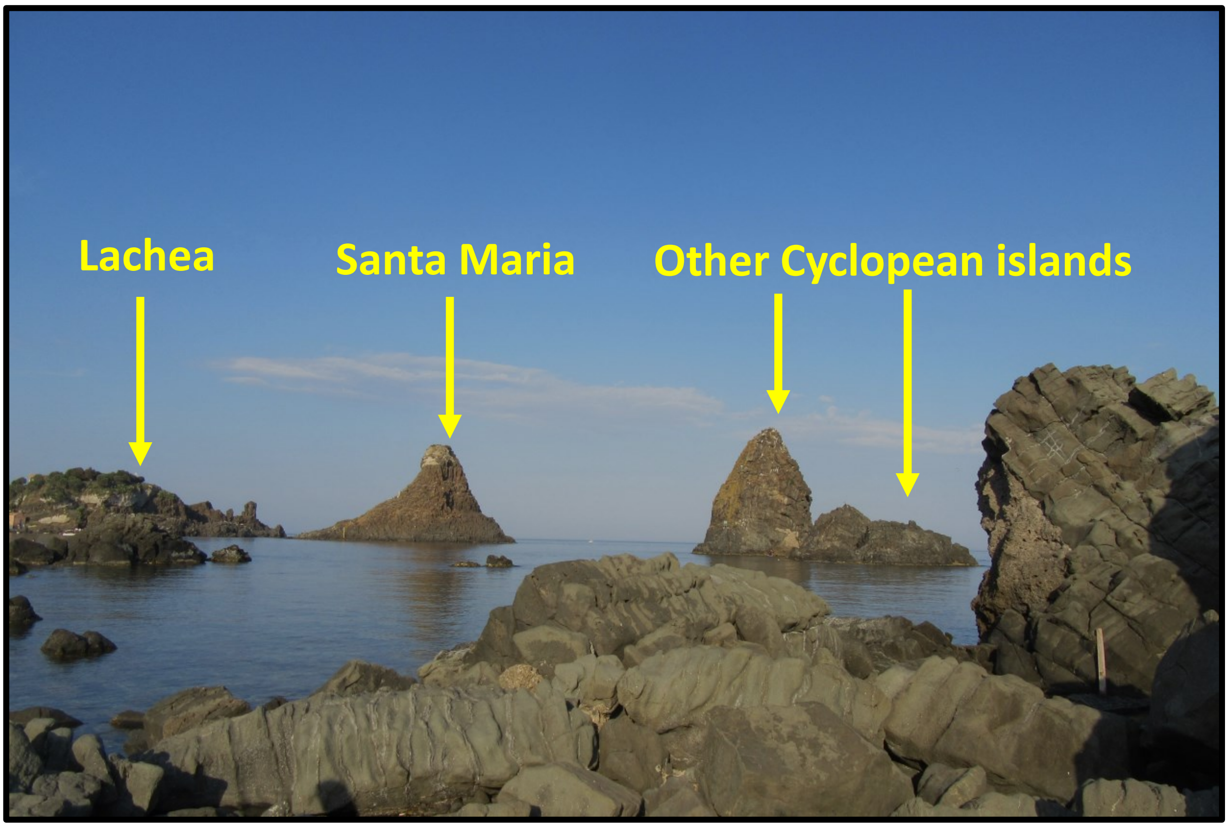
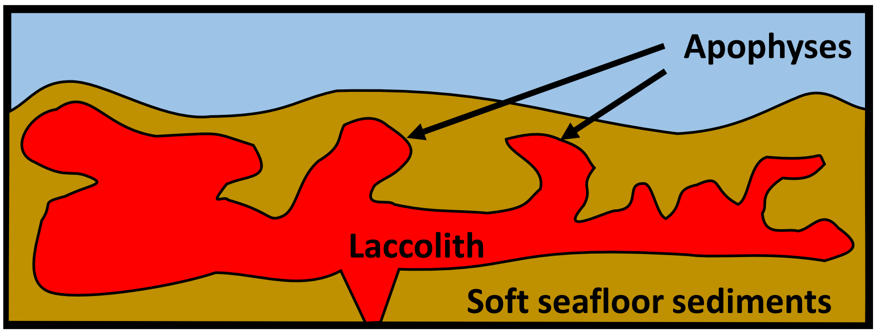


Figure 1 *– View of the Cyclopean Islands from the village of Aci Trezza. The largest islands of Lachea and Santa Maria are labelled.*

The photo in **Figure 1** shows the Cyclopean Islands as viewed from the edge of the promenade at Aci Trezza, marked as Locality 1 on the map. However, the islands that you see actually only represent a small part of the laccolith, which extends considerably below sea level!

The cartoons below illustrate how the Cyclopean Islands that you see today were formed. It is likely that the islands represent part of the laccolith or small bulb-like bodies of magma (called "apophyses") protruding from the main laccolith. The very rough, ragged shape of the laccolith in the cartoons is designed to be a realistic depiction – magma intrusions typically have irregular shapes!

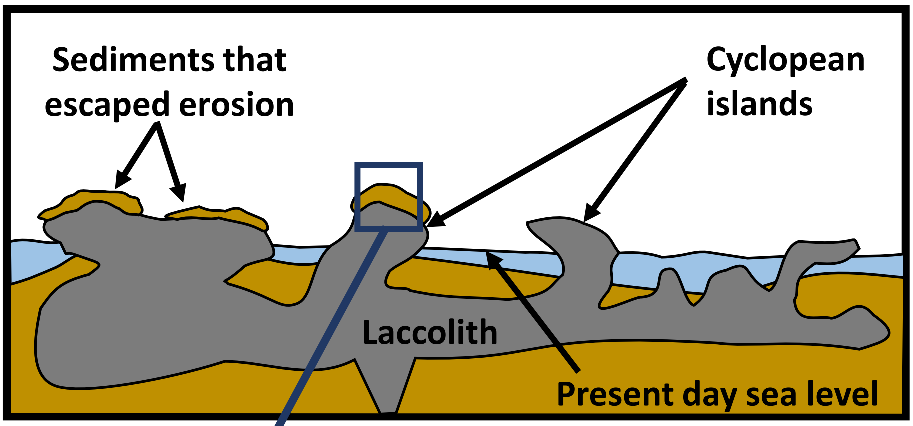
Stage A

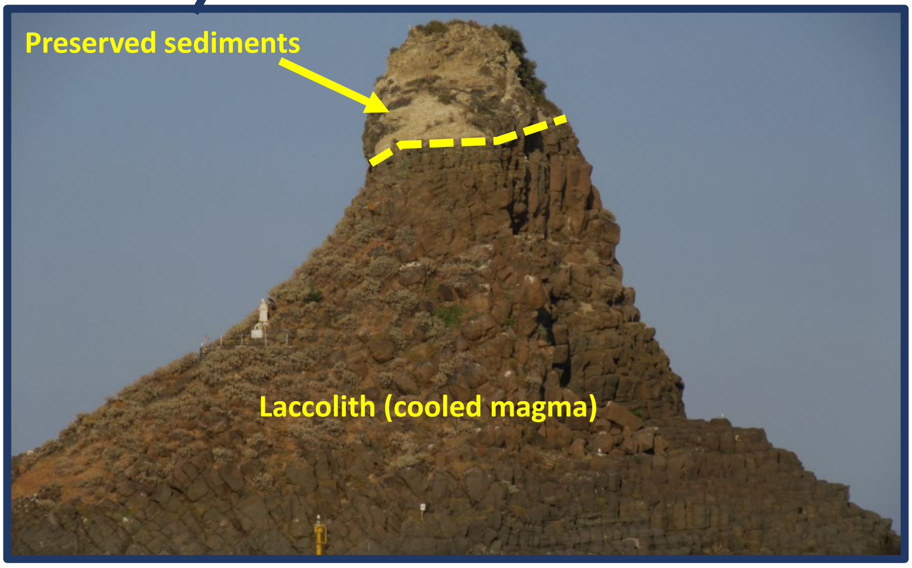


A large volume of hot, molten magma intrudes into soft sediments beneath the sea, forming a feature known as a laccolith with peripheral apophyses.

Most of the laccolith takes the form of a wide, near horizontal body of magma. In some areas, the molten magma is able to penetrate further into the sediments, forming the apophyses.

Stage B





Sediments preserved on the summit of the island of Santa Maria.

The magma cools and solidifies within the sediments and **does not erupt** at the surface. Over time, the whole area is uplifted, in parts above the sea surface, and subjected to erosion.

The cooled magma is much more resistant to erosion than surrounding sediments, so most of these are eroded away.

This process leads to parts of the laccolith sticking out above the surface of the sea, forming the Cyclopean islands.

On Lachea and the top of Santa Maria, small patches of sediment have escaped erosion, preserving the initial contact between the magma and the sediments.

Contact between laccolith and sediments

The photos in **Figure 2** show outcrops on Lachea, viewed from a boat, looking towards the north and east sides of the island (labelled as **Locality 2.1** on the map). Here the contact between the intruding magma of the laccolith and sediments is well exposed and sharp.

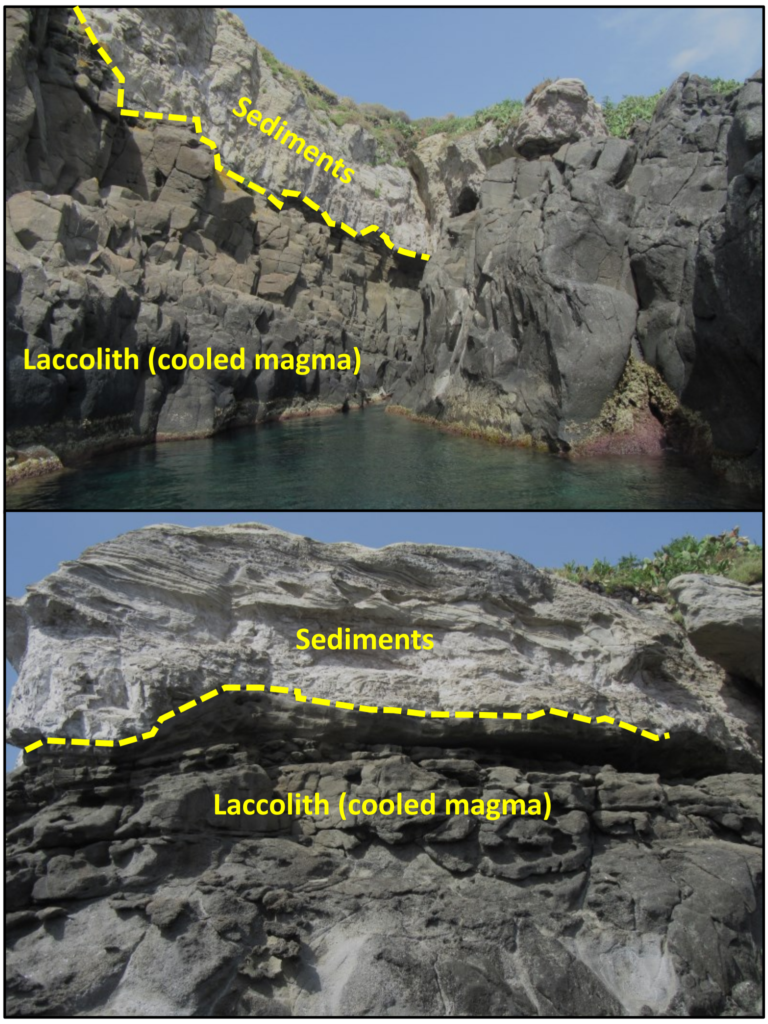


***Figure 2** – Labelled photos of outcrops from Lachea island, highlighting the magma-sediment contact (dashed line).*

The photos in **Figure 3** on the next page show outcrops on the west side of Lachea island (labelled as **Locality 2.2** on the map), next to the steps leading up from the boat drop off point. Here the contact between the magma (black/grey) and sediments (brown/white) is wavy and uneven, which suggests that the sediments were soft and able to deform around the intruding magma. In the lower photo, it is possible to see some small lenses of sediment that have been completely enclosed by the intruding magma.

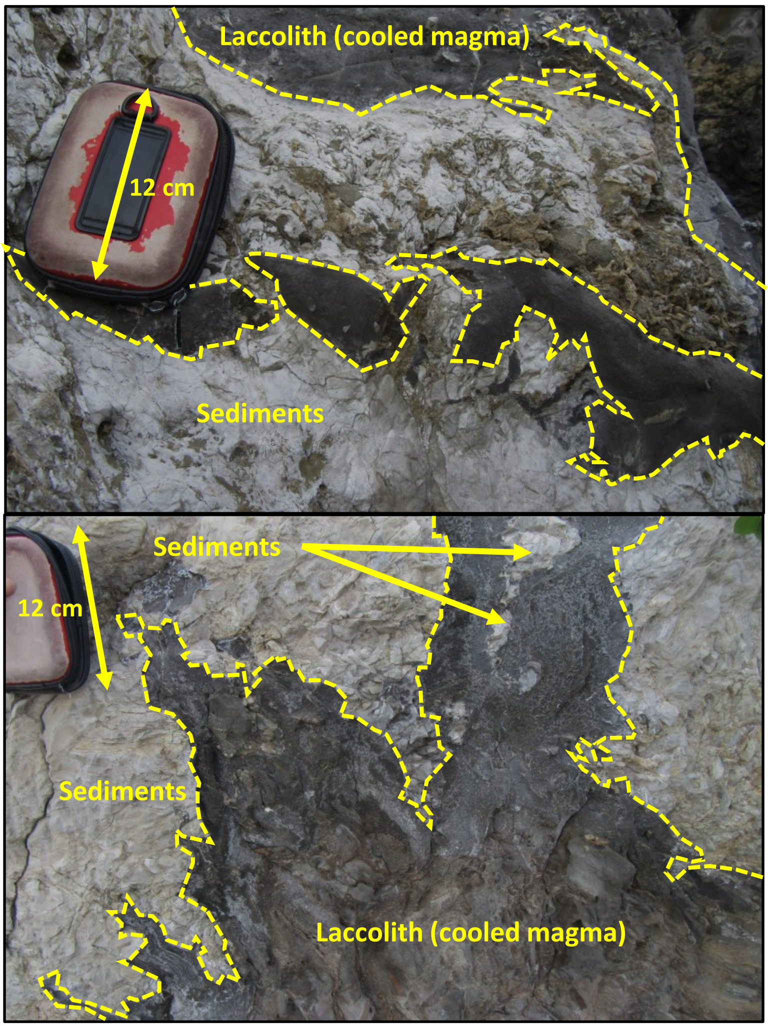


Figure 3 *– Labelled photos of outcrops from Lachea island, showing wavy, uneven magma-sediment contacts (highlighted by the dashed lines).*

The photos in **Figure 4** show views of the island of Santa Maria, both looking south from Lachea and close up from a boat.

An interesting geological feature found throughout the Cyclopean Islands is the presence of columnar jointing. This is particularly well preserved on the north side of Santa Maria.

The hexagonal columns were formed by the contraction of the intruding magma as it cooled. This process is illustrated in the cartoons on the following page.

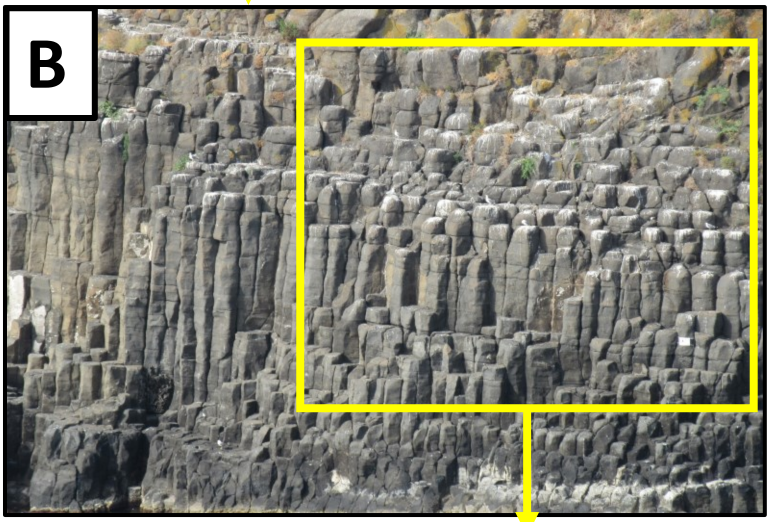


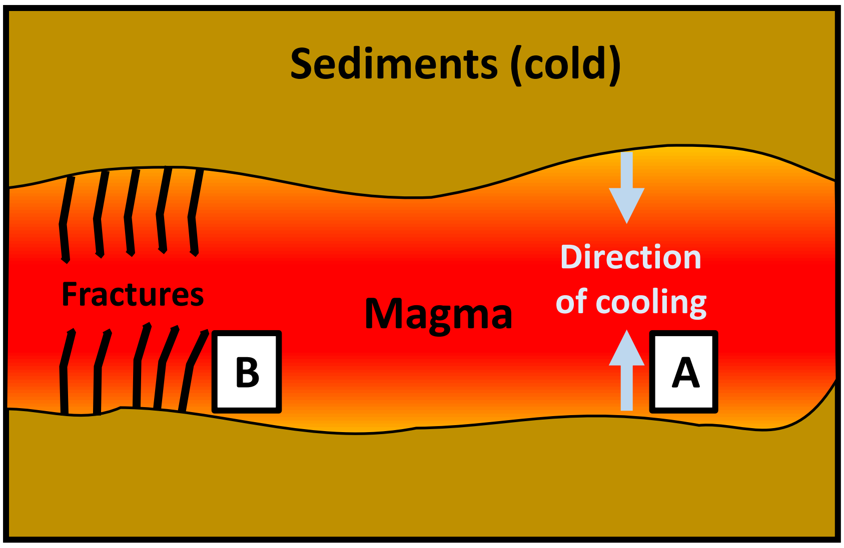
Figure 4:

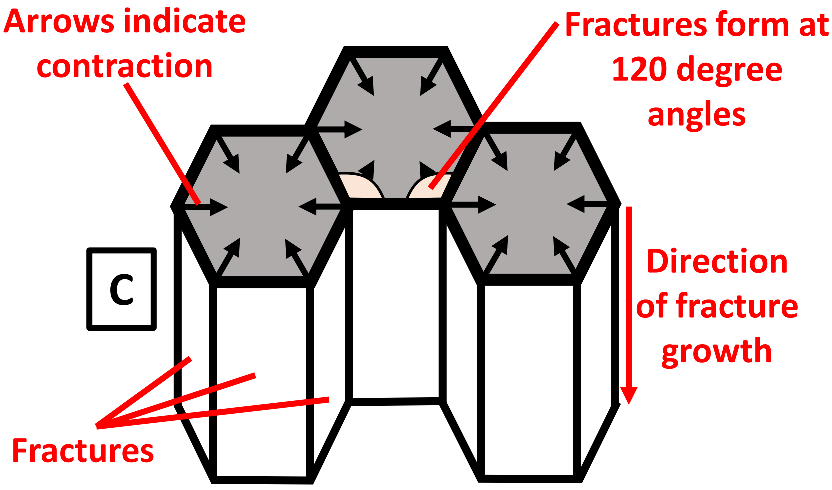
A) *Santa Maria and the other Cyclopean islands viewed from the south of Lachea.*

B) *Hexagonal columnar joints on the north side of Santa Maria.*

C) *Close up of the columnar joints on Santa Maria, viewed from a boat.*

How does columnar jointing form?





When the magma forming a laccolith cools, the parts of the magma body closest to the contact with the cold sediments cool first **(A)**.

As the magma cools, it contracts. This causes the rock to fracture. These fractures first form near to the contact with the sediments **(B)**, and extend into the magma body as the more central areas continue to cool.

The contraction of the rock naturally causes these fractures to form at 120 degree angles, creating hexagonal columns in the cooled and solidified magma **(C)**.

This is illustrated in the lower cartoon – the grey filled hexagons represent the top of the magma body at the contact with the sediments.

Acknowledgements:

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