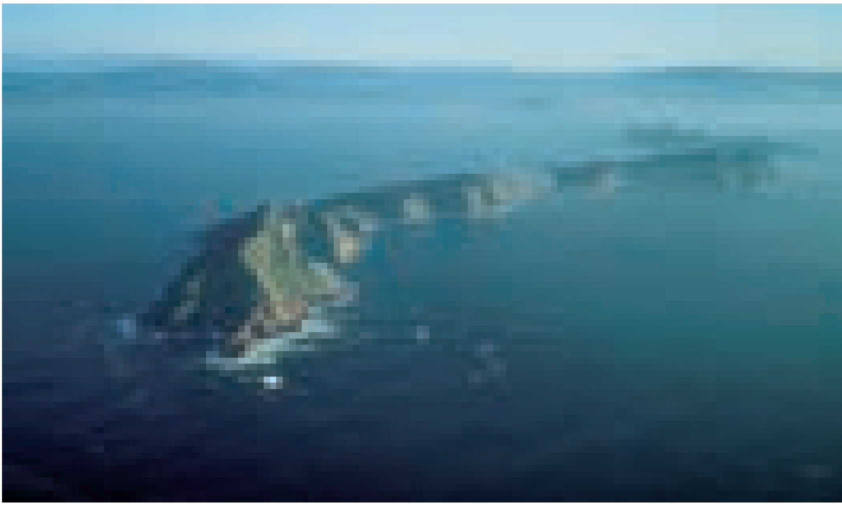
Physical setting



THE ORIGIN OF THE ISLANDS

Both the islands and the surrounding Rías Baixas have a common origin. Ancient movements of the Earth's crust caused the coast to sink, which was chiefly responsible for shaping these estuaries and islands. The subsequent rise in sea level caused the flooding of the coastal river valleys and the coastal ranges thus became the capes that separate the estuaries, while the peaks that were completely isolated became the islands that we know today.

Some of the rocks in this region were formed 400 million years ago and others 300 million years ago, crystallizing inside the Earth's crust under extreme temperatures and pressures. Tectonic processes and erosion over many millions of years thrust these rocks to the surface, where we can see them today.

Different geological events shaped the current landscape and can be divided into the following stages:

540 million years ago

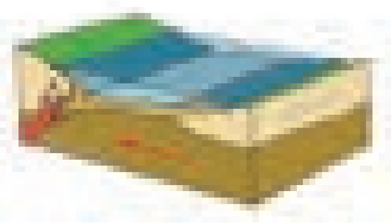
The Iberian Peninsula as we know it today did not exist. The zone it now occupies (highlighted on the map) was underwater. Marine sediments accumulated on the sea floor.

From 380 to 280 million years ago (Variscan orogeny)

Period of movement of crustal plates that caused the union of the continents into one super-continent: Pangaea.

The seabed between the ancient continents were put under pressure and lifted to form the large Variscan belt, which was part of the Iberian Massif (in the area highlighted on the map).

Below them, under extreme temperatures and pressure, the molten sediments together with magma intrusions crystalized to form granite rocks.

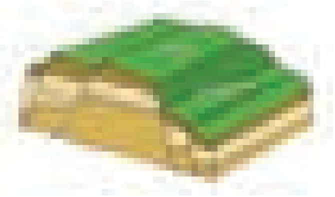


245 million years ago.

- Pangaea fractures and slowly forms the continents. The Iberian Massif fractures, giving it its recent coastline lapped by the nascent Atlantic Ocean.
- The split of Pangaea causes the appearance of faults along the coast of what is today Galicia, predominantly in NE-SW and NS directions.
- The rivers that flow into the Atlantic along the NE-SW faults erode and greatly widening the river valleys.
- The granite and metamorphic rocks are brought to the surface after the material deposited on top erodes.

60 million years ago (Alpine orogeny)

New movements of the Earth's crust begin. The African plate collides with the European plate, forming mountain ranges including the Pyrenees and the Betic range. The Galician coast adapts by giving rise to vertical movements of the various blocks created by the faults. The coastal blocks generally sink under the inland ones, forming tiered plains with the lowest points in the coastal river valleys.



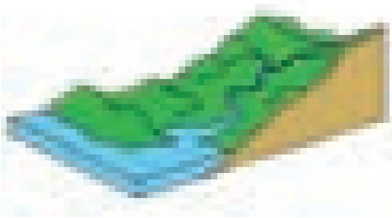
2.5 million years ago

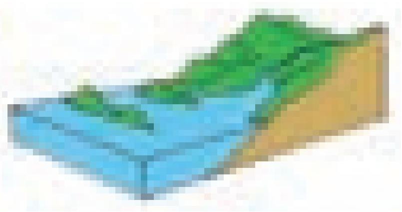
Successive ice ages cause the polar ice caps to expand and sea level to consequently fall. The melting of the ice caps in interglacial periods make the sea level rise.

A rise in sea level about 120,000 years ago flooded the coastal river valleys for the first time and the region's estuaries and islands appeared. Subsequent drops in sea level expanded the coast line and the river valleys reappeared.

The last ice age occurred 18,000 years ago and the sea level fell to 120 m below its current level. The sea gradually rose and the estuaries and islands we know today were formed 6,000 years ago.

.

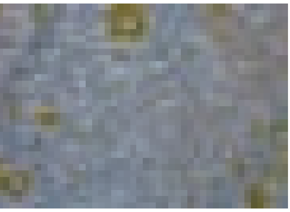




Source: Costas, 2008.

ROCKS THAT TELL THEIR HISTORY

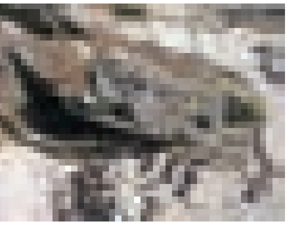
The Variscan orogeny transformed the sediments into metamorphic rocks and caused the magma to repeatedly rise. It gradually solidified within the crust, forming granite rock. When the latter's formation coincided with the beginning of the orogeny there was a greater orientation of minerals than in the final periods.



In the **two-mica granite** predominant on Cíes and Ons, where the granite formed during the second phase of the Variscan orogeny over 300 million years ago, the minerals are oriented in planes. Subsequent erosion by water and wind acted on the planes, creating fissures in the rock and angular blocks.

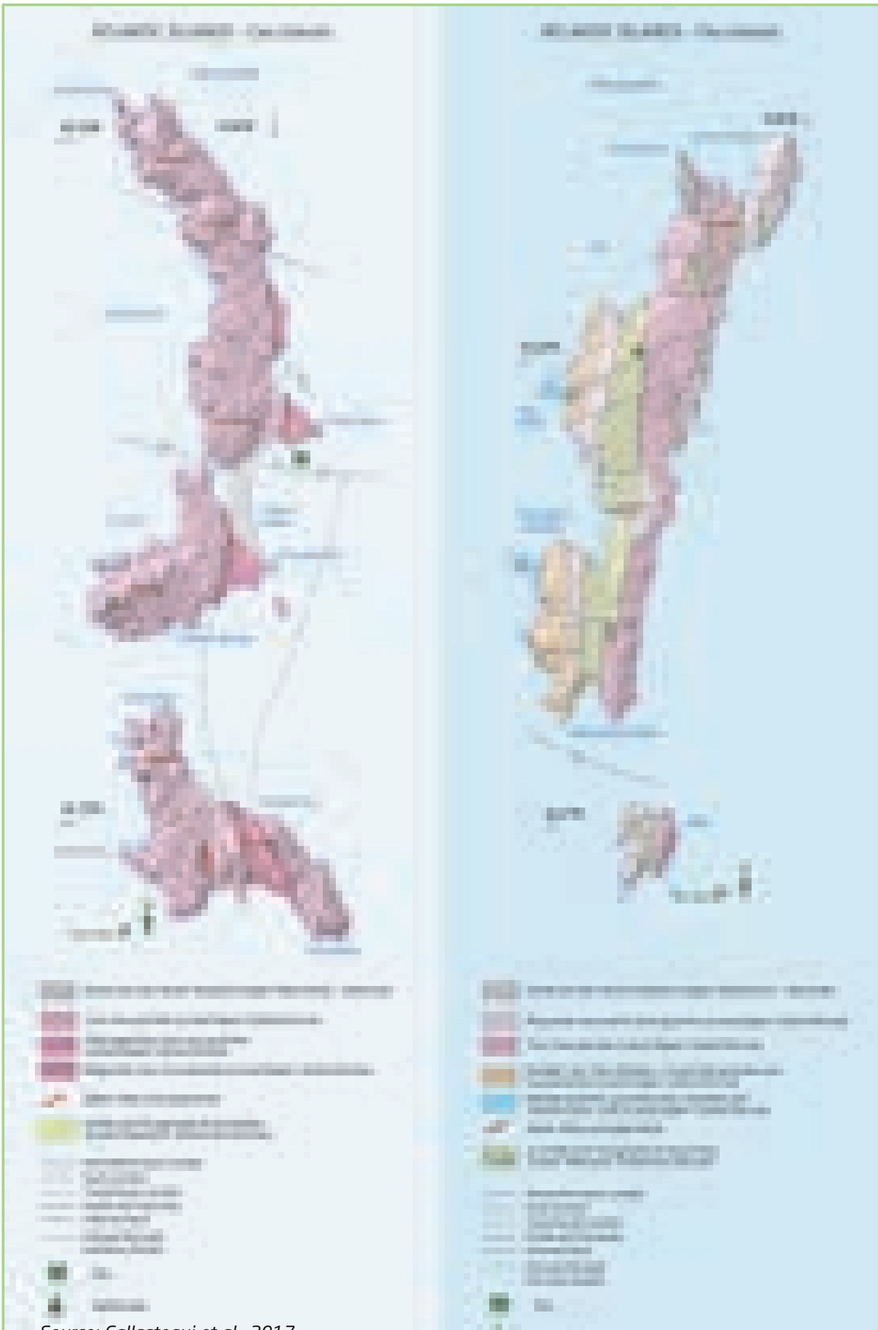
Granodiorites and tonalities are formed prior to the Variscan orogeny's second phase of folding. These somewhat older igneous rocks are also often deformed and appear in different areas of the western coast of the island of Ons: Punta Xubenco, Cabo Liñeiro and around the islet of As Freitosas.

Sálvora's **late-Variscan biotite granites**, pink from oxidation or because its minerals were enriched with iron, formed when magma solidified and reached into the interior of the Variscan massif right at the end of the orogeny and thus do not have mineral orientations like the rocks on Ons and Cíes.



The **granite** on Cortegada is welded to the metamorphic rock predominant on the island: **schists and gneisses**, formed by thin, overlapping layers of rock. These metamorphic rocks were formed from pelite (clayey) sediments due to the rise in pressure and temperature during the Variscan orogeny.

The oldest rocks in the park are the schists and gneisses on Cortegada, while the youngest are Sálvora's late-Variscan granites.



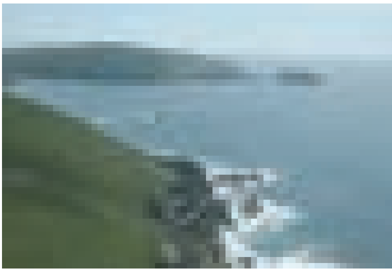
Source: *Gallastegui et al., 2017 & González Menéndez et al., 2013.*

Source: Gallastegui et al., 2017 & González Menéndez et al., 2013

FOUR VARIOUSLY-SHAPED ARCHIPELAGOS

Cíes and Ons are elongated islands featuring very different morphology on the western and eastern sides. To the west, cliffs are exposed to the ocean, whereas the eastern side, facing the estuaries, slopes down to sea level, where there are rocks and stretches of sand. The spray from the waves breaking on the cliffs puts visitors in mind of high walls defending the calm sea of the rías from the force of the Atlantic waves.

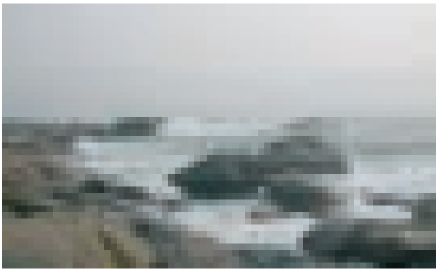
The prominent reliefs on the Cíes Islands.



The cliffs on Ons have a softer slope.

Sálvora eschews the elongated sloping forms of the neighbouring islands in favour of a more rounded flatter outline, high angular cliffs being replaced by a series of large spherical rocks. These "bolos" are made smooth and slippery by the pounding waves.

Sheltered in the ría, Cortegada avoids the ocean waves. Its low relief features stretches of sand and flat rock.



Granite blocks smoothed by the sea, on Sálvora.

Cortegada has an estuarine coastline, sheltered and with gentle relief.

The rocky coastline fending of the sea is the islands' most rugged facet

In the exposed parts of the islands of Ons and Cíes, cliffs are continually lashed by the ocean waves.

A **cliff** is a coastal formation which varies from sloping to sheer. It typically involves emerged rock affected by wave erosion. Granite adds hardness and stability to the cliff.

View of Onza from inside sandy - bottomed Fedorentos Cave (Ons).

The ***furnas*** or caves are a result of erosion at certain points in the cliff which degrade more quickly than the nearby rocks. On these islands they are associated with fractures in the rock. The morphology of the 55 caves in the park (33 on Ons and 22 on Cíes) depends on the kind of rock, fracture orientation, and the degree of erosion. The roof of O "Buraco do Inferno" on Ons has collapsed, creating a well with a height difference of 43 metres between the surface and the cave bottom.

Pebble/boulder ramp on Sálvora, partially covered in sand.

Pebble ramps are horizontal coastal areas consisting of rock fragments that have been rounded by wave action (pebbles/boulders). They were once under the sea. Cantareira Beach on Cíes is a good example. Ramps are very typical features on the island of Sálvora.

Erosion creates mysterious shapes in the rock

Bolos: large blocks rounded and smoothed by water and wind

Large round granite boulders are very typical of Sálvora. Erosion by water and wind among the horizontal fractures in the rock leaves them smooth and rounded.

Honeycombing and pías: wedthered rock

They are shaped by erosion of the chemical kind (mineral transformation, salt crystal formation) rather than mechanical (wind) or biological (moss and lichens). Rainwater loaded with sea salt accumulates in small hollows in the granite or in areas more prone to erosion. The hollows get larger as the water gradually breaks up the minerals in the rock. In the case of honeycombing and *taffoni* there are theories that claim that these are created when the granite is still underground.

Pías occur on horizontal and vertical surfaces, respectively. *Taffoni* are cavities in rock which appear when honeycombs develop and perforate the rock.

Examples of honeycombing and taffoni on the road to O Alto da Campá on Cíes. Right, a pía in O Alto do Príncipe on Cíes.

Sandy Coast: beaches and dunes moulded under the sea's influence

Beaches are areas where sand or gravel is deposited. Marine currents along the coast and wave action are weaker on the coasts protected from Atlantic winds (interior of estuaries, eastern side of islands, etc.). The drop in the speed of the sea reduces its ability to carry sediment, resulting in deposition on beaches.

The sand on Cortegada's beaches chiefly comes from rivers, whereas the sand of the other islands are granite sands deposited by ancient rivers that flowed into the sea near the islands in periods when the sea level was lower. Thus, the current beach of Rodas, on Cíes, is reusing sands that, due to successive fluctuations in sea level, were shifted in different periods to form different beaches over time. This shifting explains the sand's fineness and colour (darker minerals erode more quickly).

Quartz, feldspar, remains of shells and sea urchin spines are hidden from view in the sand.

Dunes are deposits of sand that the prevailing wind blowing in from the sea carries inland from the upper part of the beach. When there is some kind of obstacle in its way (vegetation or rocks), the wind slows down and deposits the sand.

The dunes at Muxieiro on Cíes and those at Melide on Ons are remarkable for their size and botanical importance.

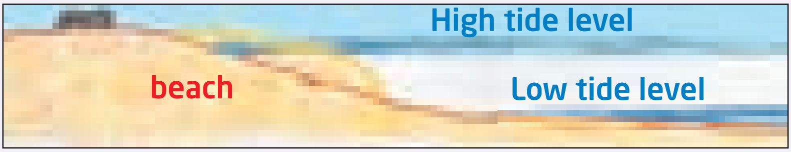
The beach-dune ecosystem is characterised by unstable morphology involving constant changes and dynamics influenced by wind, currents and waves. This explains why it is so fragile and vulnerable to any action on the coast that alters costal dynamics (quays, quarrying, etc.).

Dunes of Rodas and Muxieiro on Cíes.
The old cement walk was replaced by an elevated wooden walkway, which has less of an impact on dune dynamics.

Dune formation and dynamics

Sand accumulating on the upper part of the beach and the subsequent influence of the wind form dune ridges parallel to the beach.

The wind causes sand to accumulate on the upper part of the beach.

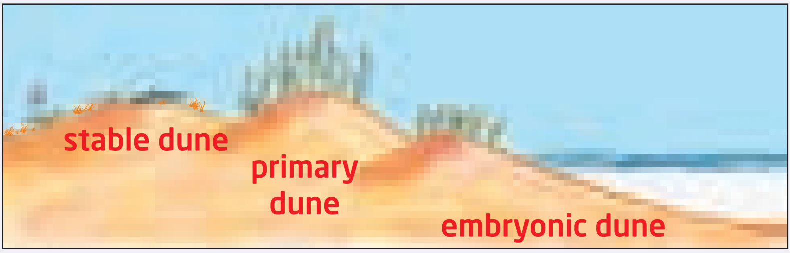


The first dune slack forms a little higher than the beach, but enough to be colonised by plants, which help to stabilise the sand.

As the sand accumulates, the shifting dune forms behind the initial dune. The latter is by then higher and further from the sea and therefore hosts a greater variety and density of plant life.

In winter, when the waves are stronger and the prevailing winds blow toward the sea, the dune supplies the beach with sand as currents and waves sweep sand out to sea. In summer, the beach recovers its sand and the winds blowing off the sea deposit it again on the dunes. It is a very fragile equilibrium.

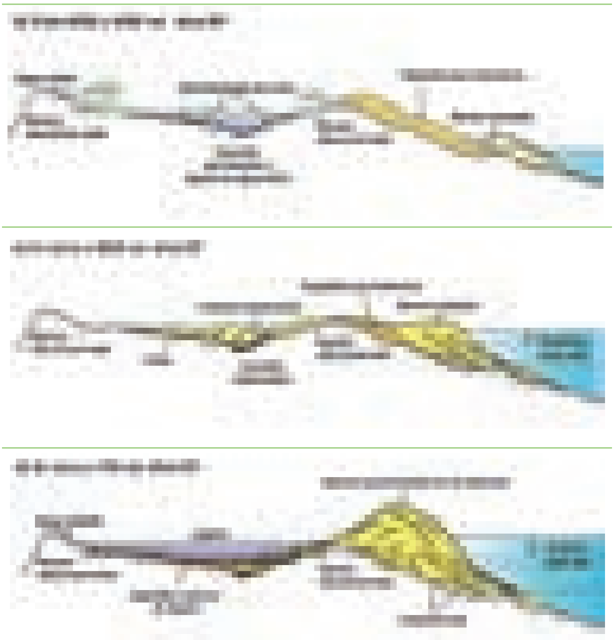
The ongoing accumulation of sand forms a complete dune system with three slacks. The shifting dune protects the stabilised dune from the wind and sea spray, providing more benign conditions for the many plants that grow on the latter. The carpet of vegetation immobilises the sand.



The fragility of Rodas beach and the lake.

A geomorphologic system as stunning as it is fragile is located in the Cíes Archipelago between the islands of Monteagudo and Faro. It consists of a sand bar (Rodas beach and dune) which acts as a natural bridge between the islands and protects a saltwater lagoon.

The formation of the present landscape began about 6,000 years after the last ice age and the subsequent rise in sea level. Waves and currents freed the sands from ancient fossilized beaches that existed in the area to gradually form the sand bar that exists today. A freshwater lagoon formed behind the sand bar as the result of a wetter climate and because sea level was a few meters lower than it is today. This wetland became silted over the years, a process which was accelerated 3,600 years ago due to a period of lower rainfall which, together with a slow but steady rise in sea level, pushed back the Rhodes beach and dune to create a large field of dunes



Graphics adapted from Costas, 2008

on the old wetland. It was not until 700 years ago that the sea reached such a level that the ocean flooded the western part of this dune field, thus forming the current salt-water lagoon behind the Rodas sand bar.

The decrease in the depth of the lake and erosion on some parts of the beach are red flags for the conservation of this landscape. In addition to the lagoon's natural silting and the current rise in sea level, some human activities have had their consequences: over-mining of sand from Rodas beach for constructive purposes over the twentieth century and the old concrete walk from the port to the interior of the islands on the dunes (now replaced by a wooden walkway) made a significant impact difficult to overcome for a system created with fossil sands and that rarely receives new sands to help replenish the system and heal these wounds.

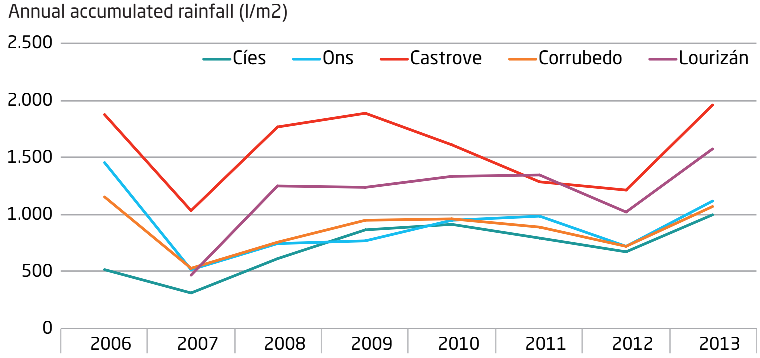
Detail of the fossil beach in Rodas. Beaches formed 120,000 years ago after being "left behind" when the sea level later lowered. Its sands were cemented between reddish iron and aluminum oxides.

Every year the bar that forms Rodas beach is broken by the force of the sea. The bar reforms in a matter of days.

DO THE ISLANDS HAVE AN ATLANTIC CLIMATE?

Galicia's Rías Baixas are part of a region with an oceanic climate involving high precipitation and moderate seasonality in terms of both temperatures and water.

However, on the archipelagos lying outside the *rías* (Cíes, Ons and Sálvora), less rain falls than nearer the coast due to the fact that the low altitudes of the islands barely represent an obstacle to cloud in contrast to the barrier of the coastal hills up to 700 metres high.



Clouds release more moisture when they come up against a geographical obstacle. The stations on Cíes and Corrubedo record less rainfall as they are somewhat further from the hills surrounding the rías.

The relative scarcity of rainfall, together with the shallow soil, means that there is a dry period in the summer months when less water is available in the ground for plants.

The islands' climate is far from Atlantic (despite their name) as the kind of dry period that they experience is typically Mediterranean.

Authors such as Allué describe the islands as a "Mediterranean type phytoclimatic subregion with Atlantic tendencies". Autumn and winter rains make up for the shortage in summer, yielding a positive overall annual balance (i.e. the amount of rainfall is greater than water lost through evaporation).

Plants typical of more Mediterranean climates, such as Mediterranean mezereon, can be found on the islands.

Cortegada's location on an estuary leads the same author to define its climate as a "European Atlantic subregion", casting off the Mediterranean character of the other islands.

Average annual temperature on the islands ranges between 13 and 15 ºC. There is a slight difference between average temperature in the hottest months (July and August: 18- 20ºC) and the coldest months (December and January: 10- 12ºC). Temperatures on the islands are milder than on the coast due to the fact that minimum temperatures on the islands are higher, mainly on cold days, and the maximum is somewhat lower, especially on hot days.

The prevailing winds in summer blow from the North-Northeast, while in winter they blow mainly from the South-Southwest.

The doors and windows of island houses face east, sheltered from the wet south-westerly winds.

SOILS FOR LIFE

Slope, bedrock, climate and living things are the ingredients of the various soils. Soil type, nutrients and depth determine the life any given soil can sustain.

Slope plays an important part in soil formation due to its relation with erosionability. Soils are deeper the less steep the slope.

The **rock type** on which soils develop determines the mineral and nutrient content, as well as its structure (proportion of sand and clay). Soils formed on metamorphic rock are better than granite soils (predominant in the park) for plant growth as they are more clayey, retain moisture better and supply more micronutrients (calcium, magnesium, potassium and sodium). The low amount of these cations means the park soils can be defined as acid.

Climate is another contributory factor in soil formation, especially rainfall, as rain causes rocks to break up faster and removes nutrients from the soil, making it more acid.

Micro-organisms, **soil fauna** and **vegetation** supply or alter nutrients and increase soil porosity (of galleries, etc.).

On the island of Malveira Grande there are two kinds of rock: quartz schist (metamorphic) with deeper soils containing more nutrients, and biotite granite (granitic) with very thin soils poor in nutrients. Pyrenean oaks grow on both islands, those on quartz schist being more developed as they are more sheltered from the wind.

On the islands of Cíes and Ons, which are granite and have a west-east orientation, the basic layout of soil types is as follows:

Cross-section of the island illustrating the relationship between slope and soil formation (FAO soil classification).

The four abovementioned soil types occur on Cortegada and Sálvora, but due to the gentle relief, cambisol or even flooded soil is more common. Cortegada's location at the mouth of the River Ulla means there are fluvisol soils with marine and river sediment which are regularly replenished with new matter (e.g. via tides).

Only the deepest and wettest soils have native tree vegetation (or agriculture). In the environs of the cliffs there is gorse scrub, while arenosols host highly fragile and botanically important dune plants.

Angelica grows on cliffs where gulls breed. Nitrogen and phosphate content increases thanks to the gull droppings. Sea spray provides calcium, magnesium, sodium and potassium-.

ROCK FISSURES CONTAIN WATER RESERVES

When defining the hydrological features of a site, weather and soil water storage capacity have to be taken into account.

The **climate** features a summer dry period, but the overall annual water balance is positive.

The **rock** (granite and metamorphic) is impermeable enough to create important aquifers.

This leads to the loss of most of the rainwater either via runoff to the sea or through evapotranspiration (water trapped by plant roots and via direct evaporation from the ground).

It is difficult to imagine how the towns and villages on the islands were supplied with water. It was possible thanks to the many fractures in the jointed granite along which water seeps, creating small shallow aquifers. The joints also allow the retained water to escape, forming springs. Losses were made up for naturally by autumn and winter rains.

Cortegada town, now deserted, was established in the environs of a spring and associated washing place located alongside the chapel; there was also a well in the island interior.

Although Sálvora has been less studied in terms of water, there are known to be four springs, which are put to a variety of uses: two old mills (one of which supplied a small tile factory), two fountains and a water outlet for the lighthouse.

The 11 springs on the island of Ons contrast with the absence of any on Onza. Many of the springs emerge in contact zones between granite and metamorphic rock.

In the Cíes archipelago, the island of Faro has six springs, the island of Saint Martin has four and the island of Monte Agudo has two.

On Cíes, past reforestation schemes for areas of scrub have led to an increase in evapotranspiration, leading some of the aquifers to dry out.

Making use of springs by building wells, wash troughs, fountains or irrigation channels has altered the breeding ecosystems of some amphibians (springs, flooded ground, etc.). Some overflows of fountains and wash troughs have become artificial substitutes.

There is no extensive permanent network of surface water. Any small streams and brooks that appear barely last through summer.

Sign along the little path leading to the monastery on Cíes.