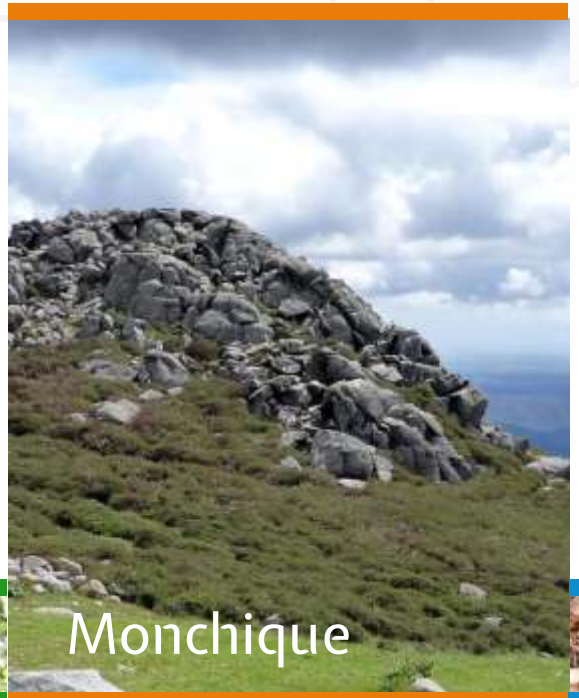
Rota da Geologia



Monchique

Rota das Árvores Monumentais



Rota da Água



Rota do Contrabandista



Preface

In order to increase the attractiveness of Via Algarviana (GR13) there were created new products and infrastructures to enrich this Long Distance Path! One of those products was the creation of a set of 4 thematic Routes distributed by 3 Municipalities partners:

- Rota do Contrabandista (Alcoutim)
- Rota da Água (Loulé)
- Rota das Árvores Monumentais (Monchique)
- Rota da Geologia (Monchique)

The themes and the municipalities in question were not randomly selectect, as they are full in harmony! This is a way to increase the diversity of Via Algarviana, allowing people with very specific interests or just plain curious to move to these places and travel the routes that we propose, some on foot, others on mountain bike or even by car. For each Route there is a Digital Guide, which can be downloaded for free, to help you and to find out more information along each Thematic Route!

Dare to discover the complementary offerings we have for you!
Enjoy all that the Inland Algarve has at your disposal!

Signalling



Colour / Symbolic element

Logo /Name of the Route

Logo of Via Algarviana

Rota das Árvores Monumentais

Rota da Geologia

Rota da Água

Rota do Contrabandista






Foreword

The distinct landscape, marked valleys, abundant streams, typical flora and fauna and geologic diversity of the Monchique Range, sporting rocks of relative rarity, make it an original and unique place in the Algarve.

Geography

Located in the northwestern sector of the Algarve, the Monchique Range has an east-west elongated topography 16 km (10 miles) long and up to 6 km (3.7 miles) wide. It has three main units: Picota (773 m, 2536 feet high), located in the easternmost block; Fóia (902 m, 2959 feet high) and Picos (574 m, 1883 feet high), located in the westernmost block. Both blocks are separated from each other by a northeast-southwest oriented valley.

Rock types and structure of the Monchique Range

The Monchique Range has a wide variety of rocks of different ages, structures and origins.

Most of the Monchique Range is comprised of the Monchique Alkaline Complex, which occupies an area of about 80 km2 (30.9 miles2). This Complex is, in fact, an intrusive body of igneous (magmatic) origin that has a somewhat elliptical shape with an east-west orientation.

Also known as Monchique Alkaline Massif, the Monchique Alkaline Complex is part of the Iberian Alkaline Igneous Province, which encompasses two other Portuguese igneous massifs (one in Sines and the other in Sintra), the Lisbon Volcanic Complex, several outcrops of magmatic rocks that exist in the Portuguese mesozoic sedimentary basins (Algarve Basin and Lusitanian Basin), the Mount Ormonde Massif and several igneous bodies in the Pyrenees.

This igneous body was probably originated during the Upper Cretaceous, some 70 to 74 million years ago, by intruding the turbiditic sequences of the Brejeira Formation, formed by intercalated shale and greywacke strata that date back to the Upper Carboniferous (318 to 307 million years ago). The deposition of sediments (sand, silt and clay) transported to the bottom of an ancient ocean by turbidity currents (a mix of water and sediments that travel in underwater channels along the continental slope) formed the rocks of the Brejeira Formation. The coarser materials formed the greywacke strata while the finer ones (silt and clay) originated the shale strata. These rocks are intensely buckled, sporting folds and faults that were produced during the Hercynian or Variscan orogeny (period of the Earth's history marked by intense compressional movement of the tectonic plates, which originated a large mountain range, called Hercynian or Variscan, as part of the Pangaea supercontinent).

Due to the high temperatures of the magma, the emplacement of the Monchique massif caused a contact metamorphism aureole (heat-induced modification of the country rocks) on the rocks of the Brejeira Formation (country rocks). Such aureole is visible around the entire massif and has a constant width of about 200 m (656 feet), with exception of its northwestern part, where it is much wider. Present in this aureole are metamorphic rocks such as solid, quite hard and dark-toned hornfels, which bear no telltale signs of their original sedimentary nature. Less frequently, one can also find cordierite- and andalusite-bearing mottled shale originated from the more clayey strata of the Brejeira Formation.

About 90% of the Monchique Alkaline Massif is comprised of nepheline syenite rocks. In smaller amounts, one can also find several other rocks, such as ultramafic, mafic and intermediate rocks, breccia-like formations and igneous dykes. This varied array of igneous rocks is roughly arranged in a concentric, ring-like fashion.

The central part of the massif is occupied by the so-called Central Nepheline Syenite Unit (from here on referred to as the Central Unit), which is formed of a fairly homogeneous (relatively constant crystal size) and coarse-grained (large crystals) nepheline syenite. Mineral-wise, this syenite bears, as their prime constituents, alkaline feldspar, the feldspathoid nepheline (usually just over 20%; sometimes, as much as 40%), pyroxenes, biotite and sphene (titanite). This kind of syenite was historically associated with the term foiaite, which is inaccurate and so we do not recommend its use.

This Central Unit is surrounded by an irregular outer ring of other syenitic rocks that have heterogeneous mineral composition (the ratios of the different minerals vary) and texture (the size, shape and arrangement of the crystals vary). In mineral terms, the rocks that pertain to this unit (called the Border Heterogeneous Nepheline Syenite Unit – from here on referred to as the Border Unit) have a lower amount of nepheline (usually, under 10%; sometimes as much as 20%) but a higher amount of pyroxene, biotite, sphene (titanite) and opaque minerals (minerals that, when cut very thinly, light cannot pass through them – usually correlated with metallic minerals) when compared to the rocks of the Central Unit. This kind of syenite was historically associated with the term pulaskite, which is inaccurate and so we also don't recommend its use.

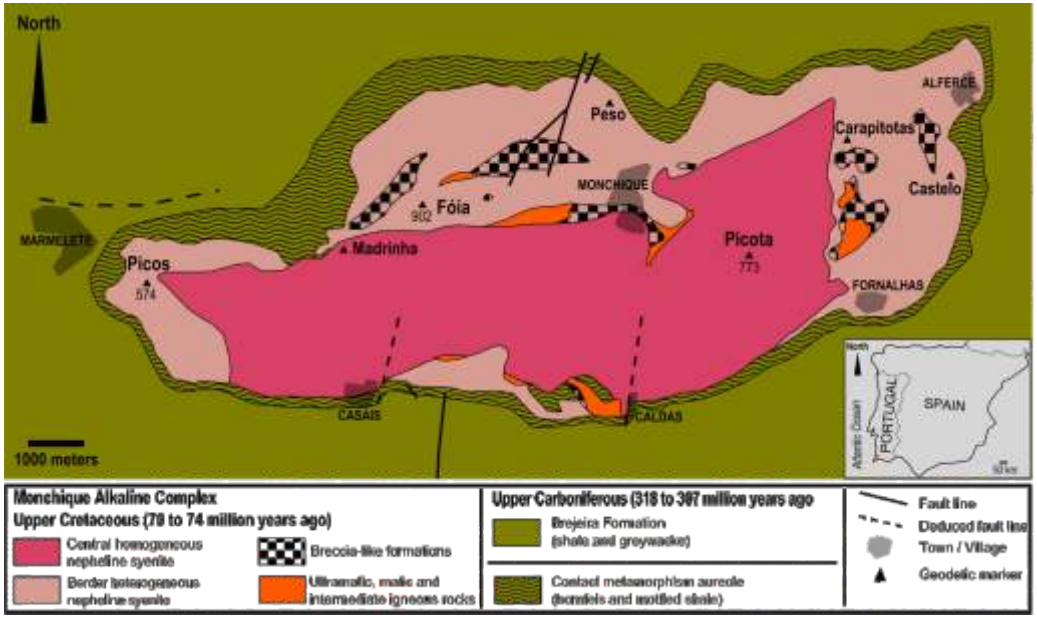
The ultramafic, mafic and intermediate igneous rocks that can be found in the Monchique massif are, generally, dark-colored and quite heterogeneous in terms of their mineralogy (ratios of the different minerals that comprise them) and texture (crystal size). Mineral-wise, these rocks bear alkaline feldspar, plagioclase feldspar, nepheline, pyroxenes, amphiboles, sphene (titanite), apatite, olivine (rare) and opaque minerals. The foid-bearing gabbro found in the Complex is included in this group of rocks.

The breccia-like formations present in the Monchique massif are composed of clasts (fragments) of various rocks (syenite, foid-bearing gabbro, mafic igneous rocks, hornfels) held together by either a ligh-toned syenitic groundmass or a dark-toned intrusive mafic groundmass.

The heterogeneity of these rocks is clearly visible both in the size and origin of the clasts and in the nature and texture of the supporting groundmass.

Both the ultramafic, mafic and intermediate rocks, as well as the breccia-like formations are scattered across the Border Unit and in the contact zone between this unit and the Central Unit.

In addition to the aforementioned rocks types, both the Monchique Alkaline Complex and the Paleozoic country rocks of the Brejeira Formation are peppered with numerous dykes of igneous rock, with variable mineral composition, thickness and orientation.



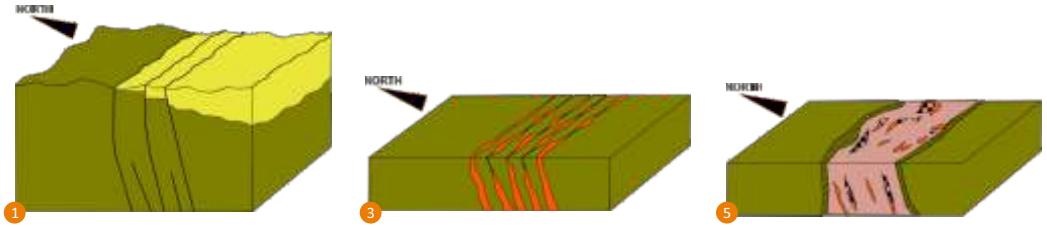
Map 1 – Geologic map of the Monchique Alkaline Complex and surrounding area (modified from González-Clavijo and Valadares, 2003).

Geologic history of the Monchique Range

According to González-Clavijo and Valadares (2003), there were a series of deep fault lines in the rocks of the Brejeira Formation, which were roughly oriented in an east-west direction. About 70 to 74 million years ago, in the Earth's deep upper crust, began the first pulses (upsurges) of mafic (with abundant iron-rich minerals) magma along those fault lines. This magma was originated in a magma chamber located in the Earth's upper mantle and formed the ultramafic, mafic and intermediate igneous rocks, the most ancient of all the rock units that make up the Monchique Alkaline Complex.

Other syenitic magma pulses followed, originating the Border Unit. The successive magma pulses also led to the formation of igneous rock dykes of variable composition (which cross-cut the rocks of the Monchique massif and those of the Brejeira Formation) and produced the breccia-like formations by incorporating the preexisting rocks within them.

Lastly, there's one final pulse and the remainder of the magma that was in the magma chamber rose and emplaced in a somewhat central position regarding the surrounding rocks. This last pulse originated the more homogeneous and nepheline-rich syenite that comprises the Central Unit, which cross-cuts every single rock unit mentioned before and masks (hides) the fault lines that served as pipes for the rise of the different magmas.Ita as falhas que serviram de condutas para os magmas.



The first pulses of magma caused ultramafic, mafic and intermediate igneous rocks to intrude the Brejeira Formation rocks along a series of fault lines that had a roughly east-west orientation.

Several other pulses of syenitic magma followed, originating the Border Heterogeneous Nepheline Syenite Unit. The successive upsurges of magma also produced the breccia-like formations.

A single pulse of magma caused a mass of fairly homogeneous and nepheline-rich syenite to intrude in a more or less central position, originating the Central Homogeneous Nepheline Syenite Unit.

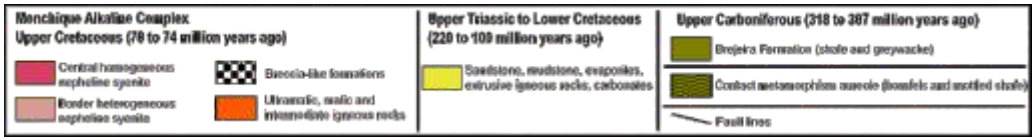
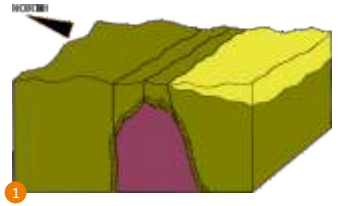
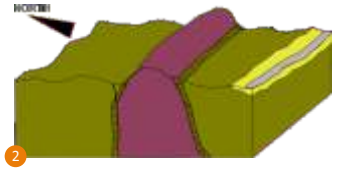


Diagram 1 – Geologic history of the Monchique Alkaline Complex's emplacement, some 70 to 74 million years ago (Upper Cretaceous).





Recent data shows that the Monchique Alkaline Complex's rocks experienced a relatively quick cooling, either because it was emplaced at a relatively shallow depth or it experienced a quick exhumation (uplift) right after the magma consolidated (turned to rock) in the depths.

Originated in the depths of the upper Earth's crust some 70 to 74 million years ago, the Monchique Alkaline Complex was quickly exposed to the elements.

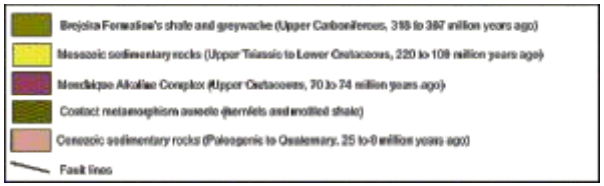
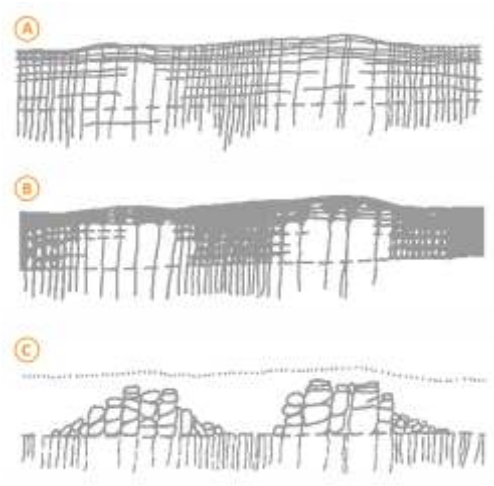


Diagram 2 – Exhumation (exposure) of the Monchique alkaline massif.

As soon as the Monchique massif reached the surface, physical and chemical weathering processes began altering its constituent rocks. In some places, the chemical alteration of the syenitic rocks, namely of the nepheline and alkaline feldspar crystals, is quite evident. These minerals can react with the rainwater, which is slightly acidic from the natural incorporation of the atmospheric carbon dioxide into it, and thus undergo a kind of very slow dissolution process. As an example, the orthoclase (an alkaline feldspar) present in the syenite partially dissolves when it's presented to acidic rainwater. This chemical reaction produces dissolved silica and a newly formed clay mineral (kaolinite). The chemical weathering of some minerals leads to the disintegration of the rocks, originating a kind of sand in a process called arenization.

In solid rocks, such as syenite, weathering plays a more important role along the planes formed by the network of interconnected fissures that divide them into blocks of every size, since runoff water tends to circulate through these fissures. Throughout this process, these roughly prismatic blocks slowly become more rounded and scattered as the arenized (weathered) rock loses its structural integrity and ends up being removed by the runoff water. Thus, these solid rock outcrops eventually form tors, marked topographic features constituted by heaps of the leftover smooth rounded blocks of unweathered rock.



A - Solid massive rocks like syenite, granite and other similar rocks typically have a network of joints (fractures) that divide them into rough prismatic blocks of every size.

B - Runoff rainwater tends to circulate through the network of fissures. Throughout this process, the rough prismatic blocks slowly become more rounded and scattered as the arenized (weathered) rock loses its structural integrity and ends up being removed by the runoff water.

C - Therefore, these solid massive outcrops of syenite eventually form tors, marked topographic features constituted by heaps of the leftover smooth rounded blocks of unweathered rock.

Diagram 3 – Onset and evolution of tors.

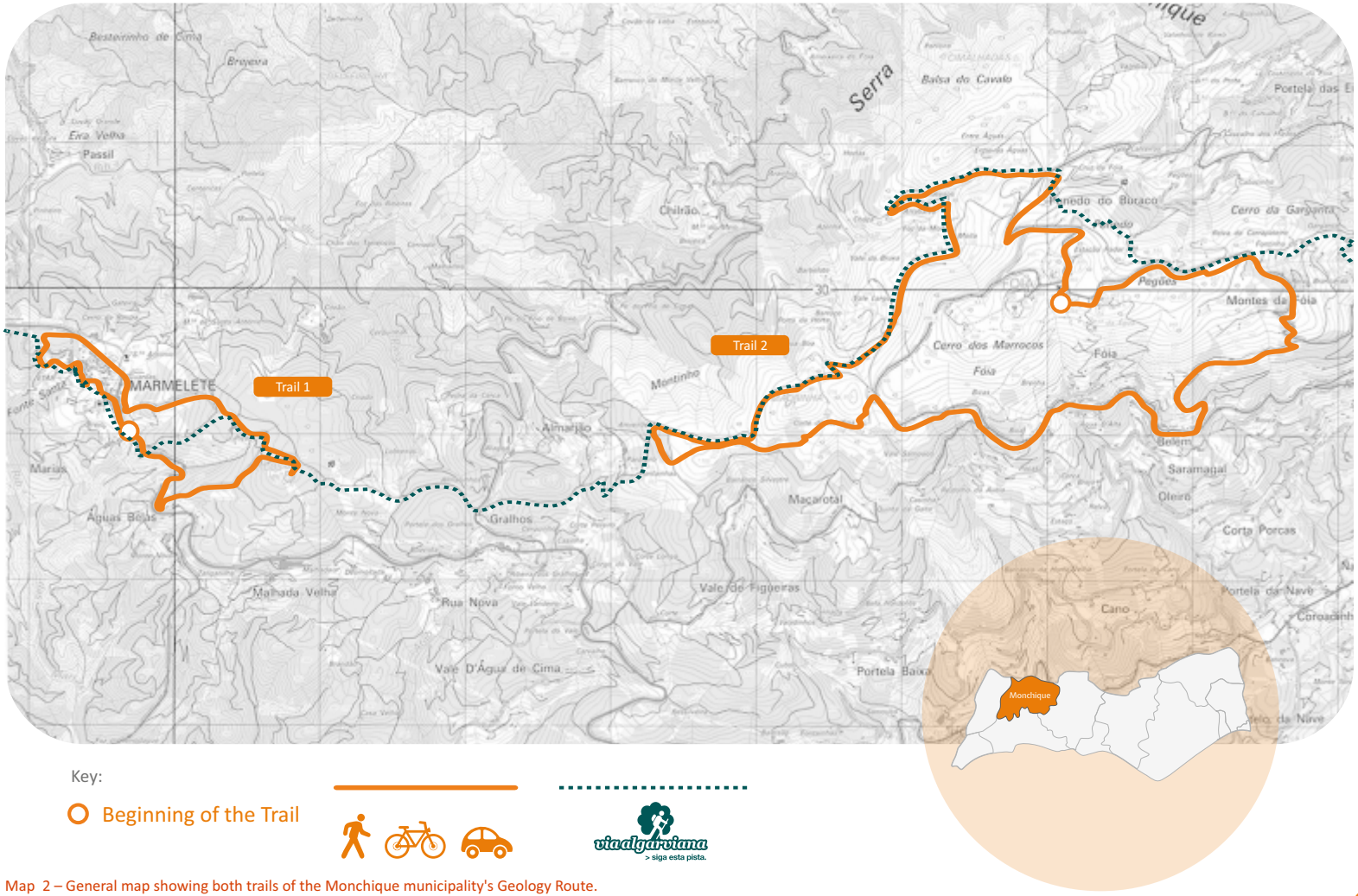
Trails of the Geology Route in the municipality of Monchique

Two trails were devised for the Geology Route in the municipality of Monchique:

Trail 1 - Marmelete;

Trail 2 - Foia and the surrounding area.

Several Places of Geologic Significance (PGS) have been identified throughout both trails, where some characteristic features of the municipality's geology can be appreciated. It should be noticed, though, that geologic features similar to those pointed out in the different PGS can be found throughout both trails and in other places of the municipality – all it takes is an attentive eye and you'll be able to spot them all by yourself!



Map 2 – General map showing both trails of the Monchique municipality's Geology Route.

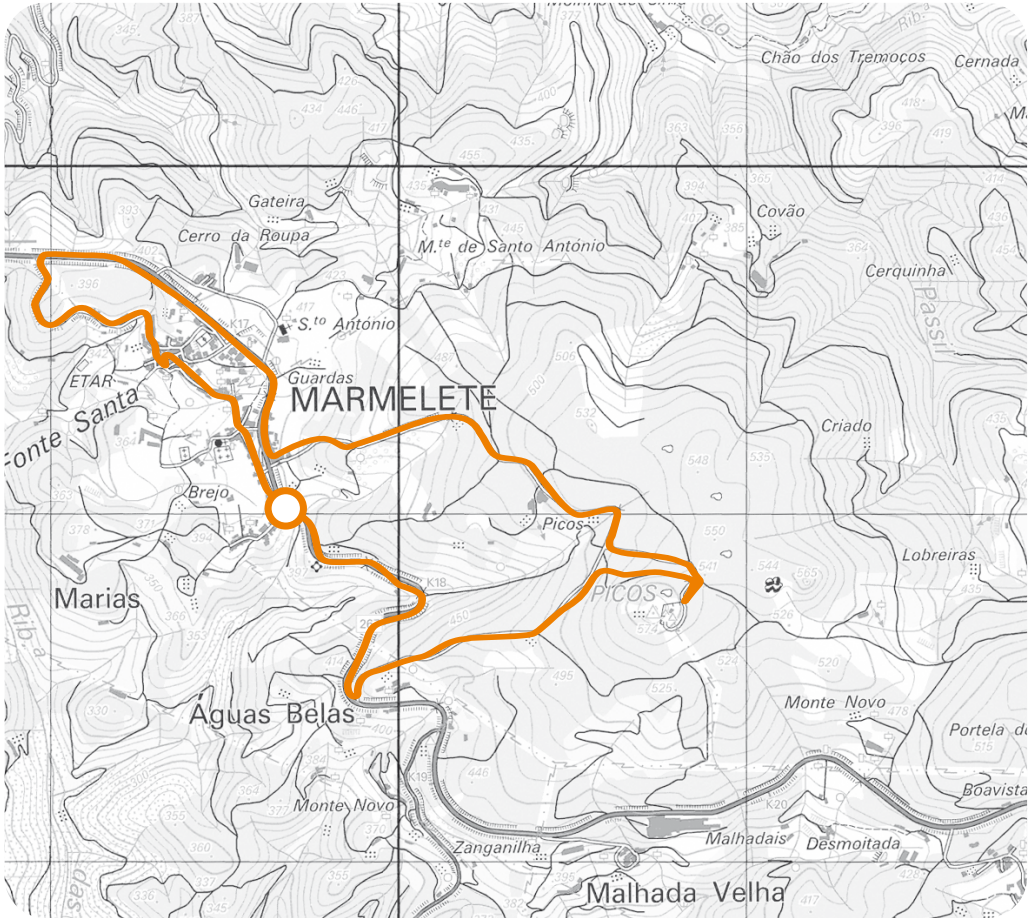
Trail 1 - Marmelete

Summary: in this trail you will be able to observe the different kinds of rock of the Brejeira Formation (shale and greywacke of Upper Carboniferous age), as well as its tectonic deformation; the contact metamorphism aureole (hornfels and mottled shale); nepheline syenite (Border Unit); igneous rock dykes; quartz dikes; tectonic structures (faults and folds); application of the local rocks in stone masonry and urban development features.

Distance: 6230 meters (3.87 miles).

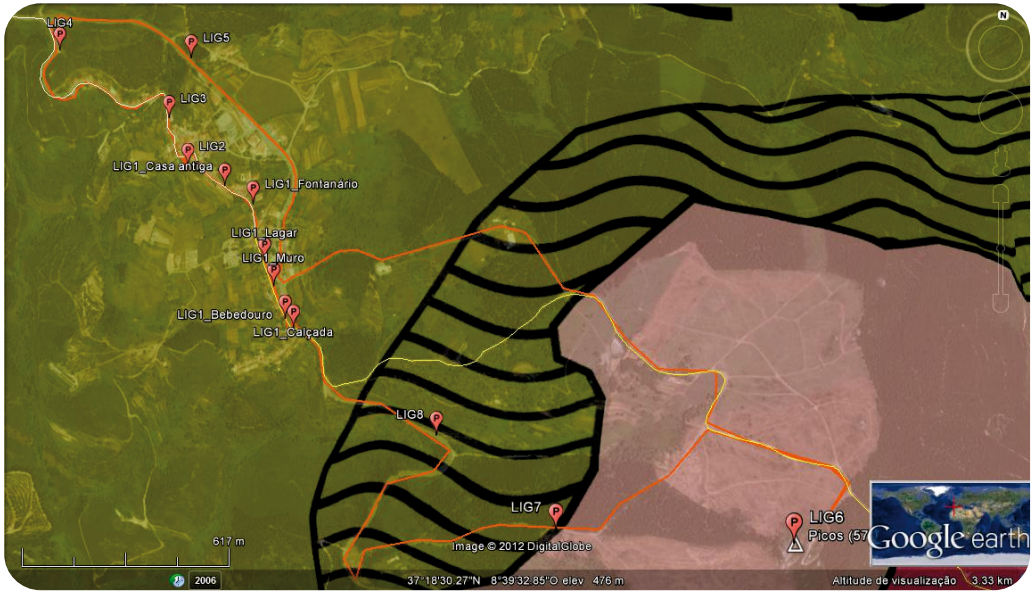
Method of travel: the trail can be done either by car, trail bike or on foot.

Places of Geologic Significance (PGS): 8 PGS.



Map 3 – Trail 1 (Marmelete).

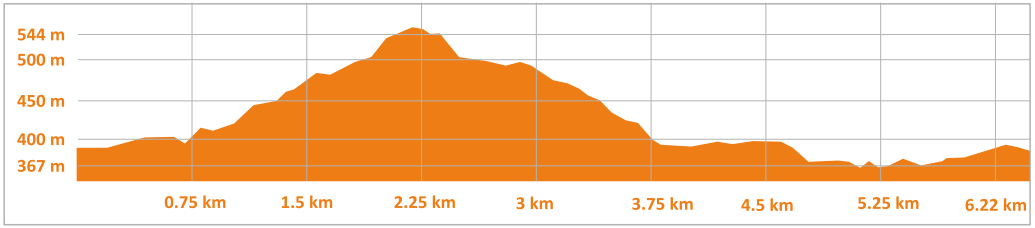
Topography of Trail 1: Marmelete



Key:

– Places of Geologic Significance (PGS, LIG on the image);
Yellow Line : Via Algarviana trail;
Orange Line - itinerary of Trail 1;
Green-BrejeiraFormation;
Wavy Pattern - metamorphic aureole;
Pink- border heterogeneous nepheline syenite..

Map 4 – Geologic setting of Trail 1 – Marmelete



Graph 1 – Topography of Trail 1 – Marmelete.

PGS 1 – Application of local rocks in natural stone masonry and urban development features

• Nepheline syenite road and sidewalk

The pavement of some of Marmelete's roads is made of roughly cubic cobblestones of nepehline syenite hewn from outcrops of the Central Unit. Clearly visible in these cobbles are some characteristic features of the rocks from this unit, such as the relatively constant (fairly homogeneous) crystal size, well-developed crystals (coarse-grained texture) and high percentage of nepheline, the rock's name-giving mineral. Some of the main constituent minerals are easily identifiable: light-colored alkaline feldspar, brownish nepheline and dark-colored pyroxene and biotite. Some of the cobbles may present stripes of dark-colored rock. These are dikes of mafic igneous rocks that intersected the nepheline syenite.



Fig. 1 – Detail of one of Marmelete's cobbled road, where the cubic-shaped nepheline syenite cobbles carved from outcrops of the Central Unit are clearly visible; some cobbles bear stripes of dark-toned rock (dikes of mafic igneous rocks).

• Watering trough for draft animals (renovated public place)

The old watering trough, located in the Inácio Cabrita Street was recently renovated using rocks from the Central Unit, making it a public monument of historic and cultural significance. In the past, this place was used for the rest and recuperation of draft animals while their owners traded their wares, attended mass or were busy with their chores in the village.



Fig. 2 – Inácio Cabrita Street watering trough, renovated using rocks from the Central Unit.

• Stone enclosures and walls from ancient buildings made using stone masonry

The older buildings that can be found along the trail, which were erected before the 1940's, were built using stone masonry, a construction technique that utilizes blocks of natural rock held together by some kind of mortar. Therefore, it is quite common to find enclosures and walls made out of local rocks, either comprised solely of nepheline syenite (foiaite stone masonry, in technical terms) or made out of a mixture of greywacke, shale, nepheline syenite, hornfels and even igneous rocks. The old olive oil mill, located in Inácio Cabrita Street, constitutes a fine example of nepheline syenite stone masonry.

This kind of construction technique not only presents an undeniable aesthetic, cultural and urban integration value but also makes for buildings that are potentially very durable, with good heat and sound insulation. Nevertheless, nepheline syenite stone masonry present some inconveniences such as the reduced indoor space because of the walls' thickness, which is required for structural reasons; the fairly high cost of labor and materials; the extended construction time required and the ever increasing difficulty in finding specialized manpower.



Fig.3 – Enclosure wall in Inácio Cabrita Street built with natural stone masonry technique using several kinds of local rocks, like greywacke, hornfels and nepheline syenite.



Fig. 4 – Old home erected with natural stone masonry technique. A – Home's facade. B – Detail of the wall's exterior, where several kinds of local rocks, like nepheline syenite, greywacke and shale used in its construction can be appreciated.



Fig. 5 – Old olive oil mill in Inácio Cabrita Street built with nepheline syenite stone masonry. A – Overall view of the building. B – Detail of some nepheline syenite blocks used in the construction of the olive oil mill's walls, where a dark-colored inclusion or xenolith (a fragment of a preexisting rock embedded into another rock) can be appreciated.

• Public water spout (renovated public place)

The public water spout located in Francisco Furtado Street was recently renovated using rocks from the Central Unit. Besides serving as water source, it's also a pleasant meeting place.



Fig. 6 – Public water spout on Francisco Furtado Street, renovated using rocks from the Central Unit.

PGS 2 – Fonte Velha (Old Fountain)

The Old Fountain, also known as the Lovers Fountain (can you guess why?) is located in Fountain Lane and is the oldest water spout in Marmelete, dating back to 1926. Its water comes from a water mine, a somewhat long manmade tunnel drilled into the rocks with the purpose of collecting water naturally stored there. This particular water mine was drilled into the Brejeira Formation's rocks, shale and greywacke, which store the water that supply this spout.



Fig. 7 – Old Fountain, the oldest water spout in Marmelete, located in Fountain Lane.

PGS 3 – Marmelete's Parish Council Hall

The outside walls of Marmelete's Parish Council Hall have a veneer of nepheline syenite panels and blocks where one can easily appreciate the main characteristics of the rocks from the Central Unit that were cited in the PGS 1: homogeneous coarse-grained nepheline-rich rocks where several of the main constituent minerals can be easily identified, like alkaline feldspars, nepheline, pyroxenes and biotite. In some blocks of nepheline syenite there can be found differences in the size of the crystals (granularity) since some blocks sport larger crystals than others. A reason why this is so may reside in the rate of cooling of the magma that originated the rock: a slower cooling produces larger crystals than a quicker cooling. So, can you tell now which blocks may have cooled faster and which may have cooled slower?



Fig. 8 – Marmelete's Parish Council Hall. A – Nepheline syenite veneer of the outside walls and stonework on the facade's doors and windows. B – Detail of some nepheline syenite veneer blocks bearing clear differences in granularity (crystal size). Note how the upper block is made of finer-grained nepheline syenite whereas the lower block is more coarse-grained.

PGS 4 – Brejeira Formation: lithology, sedimentary structures and tectonic buckling

In this outcrop one can appreciate some features of the turbiditic sequences (intercalated shale and greywacke strata) of the most recent geologic unit of the Baixo Alentejo Flysch Group, the Brejeira Formation, which dates back to the Upper Carboniferous (318 to 307 million years ago). It is possible to identify the lithological differences between the greywacke (sedimentary rocks formed by coarser sediments of various nature held together by a finer-grained and more resilient groundmass) and the shale (sedimentary rocks formed mainly by clayey materials) that comprise the Brejeira Formation's layers.

The repetitive sequence of intercalated layers of greywacke and shale is explained by their turbiditic origin, in which successive underwater turbidity currents have overlapped the previous sedimentary layers deposited by previous turbidity currents. Later on, all these sediments turned into compact discrete layers of greywacke and shale. Some evidences of this mode of deposition can be found in some of the greywacke layers. If you look closely you can find positive grading of the sediments (the sediment grains become increasingly finer towards the top of the layer) and, at the top of some layers you can see fine parallel-bedding (very fine parallel layers of sedimentary rock) and fine cross-bedding (very fine layers of sedimentary rock truncated by others).

Also apparent in these rocks are folds and faults that resulted from the compressional forces they were subjected during the Variscan orogeny.

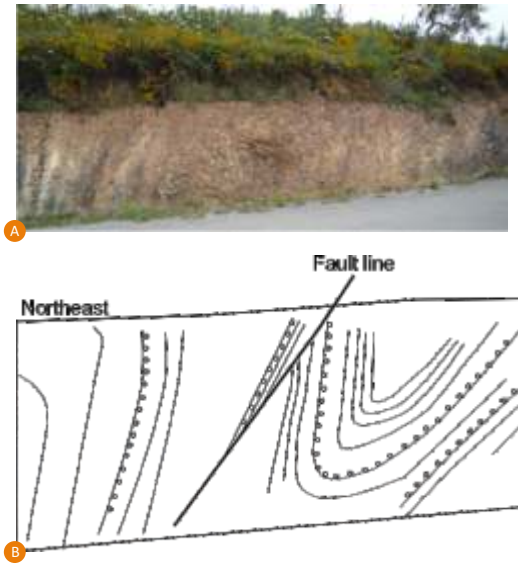


Fig. 9 – Brejeira Formation outcrop, where the repetitive sequence of intercalated layers of greywacke (coarser sedimentary material) and shale (finer sedimentary material) can be appreciated. Positive grading of the sediments (the sediment grain size diminishes towards the top) can be seen on some of the greywacke layers. Also apparent are some folds and faults. A – Overall view of the outcrop. B – Diagram of the outcrop showing some tectonic and sedimentary features. The small circles indicate the bottom of the layer.

PGS 5 – Brejeira Formation: lithology, country rocks cross-cut by igneous mafic rock dikes and quartz veins.

In this place, the turbiditic sequences of the Brejeira Formation (intercalated layers of shale and greywacke) are cross-cut by several igneous mafic rock dikes associated to the emplacement of the Monchique Alkaline Complex. These dikes have suffered extensive chemical weathering and, thus, their color, hardness and appearance differ largely from the newly formed rock.

In the same outcrop one can also appreciate a network of quartz dikes intersecting the country rocks. These dikes originated from the precipitation of quartz from silica-rich fluids contemporary of the shale's and greywacke's tectonic deformation.



A



B

Fig. 10 – Brejeira Formation rocks (intercalated layers of shale and greywacke) cross-cut by an igneous rock dike associated to the emplacement of the Monchique Alkaline Complex. A – Overall view of the outcrop: Brejeira Formation (BF) and igneous rock dike (IR). B – Detail of the intensely chemically weathered dike rock.



Fig. 11 – Network of quartz veins cross-cutting rocks from the Brejeira Formation.

PGS 6 – Picos: geodetic marker and point with an elevation of 574 m (1883 feet); nepheline syenite tors; igneous mafic rock dikes.

Picos is a geodetic marker (sign that indicates an exactly determined cartographic position) and constitutes a lookout point on the highest place on the west end of the Monchique Alkaline Complex. This area is situated in the outer ring of the Complex, in the Border Unit, where the mineral composition and textural characteristics of the nepheline syenite are heterogeneous. It is possible to identify several of the main mineral constituents in the outcrops, such as light-colored alkaline feldspars, brownish nepheline and dark-colored pyroxene and biotite. The rocks from the Border Unit have less nepheline and more pyroxene, biotite and opaque minerals than the rocks from the Central Unit, which are used in cobbled roads and sidewalks and in renovated public places. In the Picos geodetic marker area, the syenitic mass is cross-cut by veins of syenite with pegmatitic texture (very coarse texture, with very large crystals) and by black mafic igneous dikes. Interspersed among the syenitic rocks are several xenoliths (fragments of preexisting rocks included into a more recent rock) of darker rocks, possibly fragments of the first ultramafic, mafic and intermediate rocks originated in the beginning of the Monchique massif's formation. The diversity of rocks found here as well as their stratigraphic relationships (some rocks included into others, some cross-cutting others) provides evidence that the Monchique massif was probably originated by several successive igneous pulses.

This rock outcrop makes up a tor, a marked topographic feature constituted by heaps of leftover smooth rounded blocks of unweathered nepheline syenite. Tors can typically be found wherever solid, massive rocks like syenite, granite and other similar rocks dominate the landscape.



A



B



C



D

Fig. 12 – Picos rock outcrop. A – General view of the eastern slope of Picos. B – Detail of a vein of syenite with pegmatitic texture (very coarse, very large crystals) cross-cutting the finer-grained syenitic mass. C – Detail of a mafic igneous rock dike intersecting nepheline syenite from the Border Unit. D – Detail of a dark-colored xenolith (fragment of a preexisting rock included into a more recent one) included in the nepheline syenite.

PGS 7 – Use of local rocks: building made using rammed earth construction technique.

Here it is possible to appreciate a ruined building built using the rammed earth technique (fig. 13). This construction method utilizes materials and resources from the local environment where the construction is to be erected. Rammed earth buildings are made from compacted earth (clay and gravel) compressed in temporary mobile wooden frames (formwork). Once the formwork is removed, the monolithic homogeneous walls are left standing.

In addition to its architectural, historical, cultural and emotional significance, this technique presents several advantages since, unlike concrete, the raw material it uses (earth) is a natural, abundant, readily available and ecologic resource, it doesn't use non-renewable energy sources (it just needs solar energy), it doesn't make any trash, being biodegradable and completely recyclable, it is a relatively quick and low-cost building system (reduced costs of raw material transport and labor, since it doesn't require qualified, albeit specialized, manpower) and rammed earth constructions have a good thermal, acoustic and humidity behavior – and they're fireproof, too!

There are, however, some disadvantages to be considered when dealing with rammed earth buildings, since the raw material used can be fragile, especially to water damage and, to some extent, to wind damage. Rammed earth constructions can, thus, be found more frequently in dry areas rather than more humid zones. In order to increase the rammed earth walls water damage resistance a bit, in the old days people used to mix straw or dung together with the earth. On the other hand, rammed earth walls do present reduced mechanical resistance, particularly to horizontal movement, which makes them especially prone to falling apart in active seismic areas (like the Algarve).



Fig 13 – Ruined building erected using the rammed earth construction technique. A – Overall view of the ruins. B – Detail of the outside of a wall built with compacted earth.

PGS 8 – Contact metamorphism aureole: contact metamorphism of the Brejeira Formation rocks; intensely weathered mafic igneous rocks intrusions; quartz veins.

In the areas close to the Monchique massif we step into the zone where the country rocks were affected by contact metamorphism (contact metamorphism aureole) caused by the emplacement of the hot magma that later on cooled down and originated the massif's rocks. In the metamorphism aureole, the sedimentary rocks of the Brejeira Formation (country rocks) have turned into metamorphic rocks, namely the solid, dark-colored and very hard hornfels and, less frequently, thin layers of mottled shale, formed from the most clayey sedimentary layers. The sequence of strata is intersected by intensely weathered igneous rock dikes associated to the emplacement of the Monchique massif and quartz veins originated from the precipitation of quartz from silica-rich fluids contemporary of the Brejeira Formation tectonic deformation.



Fig 14 – Contact metamorphism aureole. A – Layers of metamorphised greywacke. B – Layers of mottled shale. C – Detail of a mottled shale outcrop.

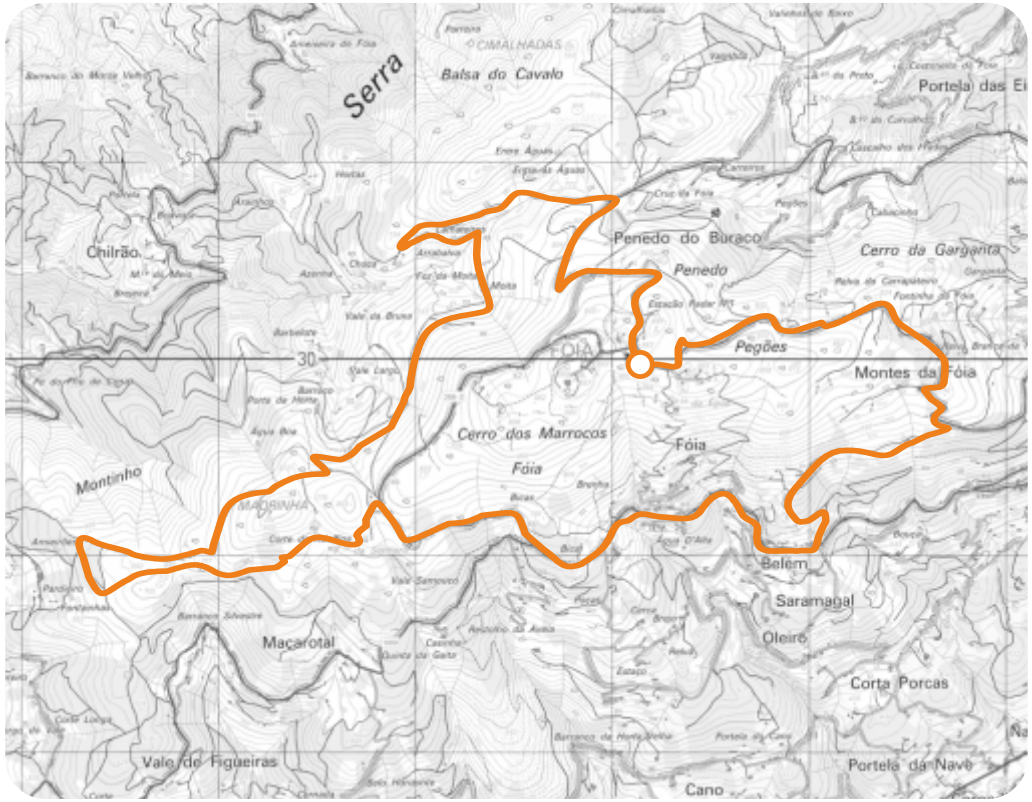
Trail 2 - Foia and surrounding area

Summary: in this trail you will be able to observe several geologic features associated to the Monchique alkaline massif, namely, nepheline syenite rocks, both from the Border Unit and from the Central Unit, ultramafic, mafic and intermediate igneous rocks, breccia-like formations, contact metamorphism aureole with hornfels and mottled shale, weathered nepheline syenite features, natural water spouts and examples of exploration and use of local rocks.

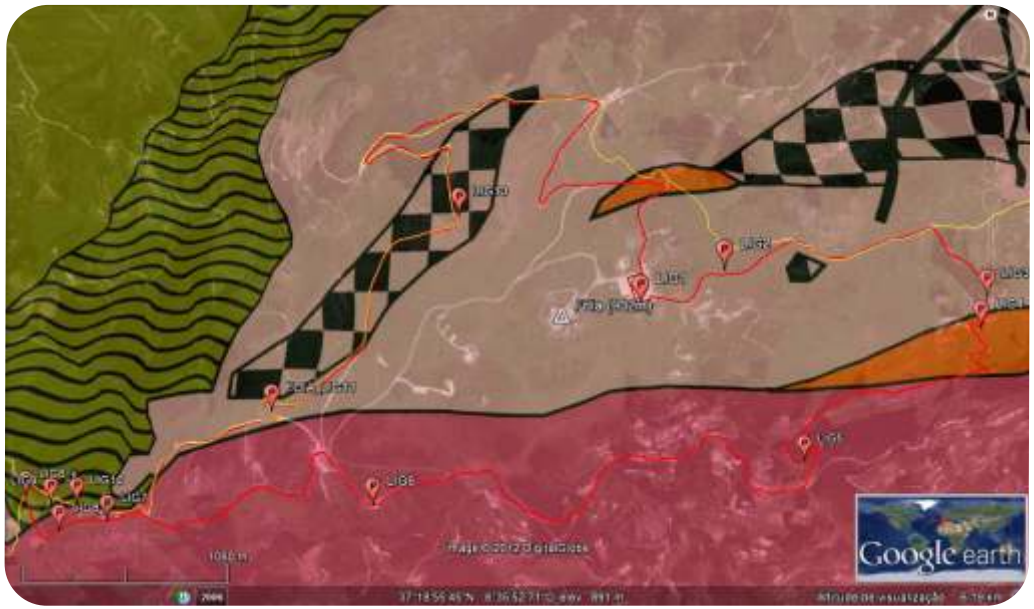
Distance: 15300 meters (9.51 miles).

Method of travel: the trail can be done either by trail bike or on foot. There are a few stretches that can be done by car.

Places of Geologic Significance (PGS): 12 PGS.



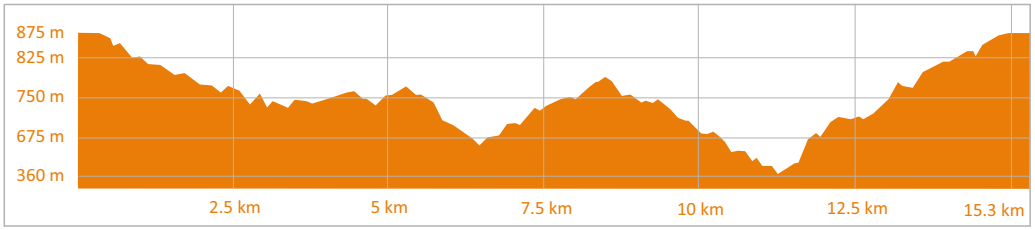
Map 5 – Trail 2 – Fóia and surrounding area.



Key:

Places of Geologic Significance (PGS, LIG on the image);
Yellow Line : Via Algarviana trail;
Red Line - itinerary of Trail 2;
Green - Brejeira Formation;
Wavy Pattern - metamorphic aureole;
Orange - ultramafic, mafic and intermediate rocks;
Light pink- border heterogeneous nepheline syenite;
Dark pink- central homogeneous nepheline syenite;
Chess pattern - breccia formations.

Map 6 – Geologic setting of Trail 2 – Fóia and surrounding area.



Graph 2 – Topography of Trail 2 – Fóia and surrounding area.

PGS 1 – Fóia belvedere viewpoint.

Fóia is a geodetic marker (sign that indicates an exactly determined cartographic position) with an elevation of 902 m (2959 feet) and it is the very summit of the Algarve. From the belvedere, which has a privileged view to the south, one can scan the landscape all the way to the coastline.

The top of Fóia is located in the outer ring of the Monchique Alkaline Complex, in the Border Unit, where the mineral composition and textural characteristics of the nepheline syenite are heterogeneous. It is possible to identify several of the main mineral constituents in the outcrops, such as light-colored alkaline feldspars, brownish nepheline and dark-colored pyroxene and biotite. The rocks from the Border Unit have less nepheline and more pyroxene, biotite and opaque minerals than the rocks from the Central Unit. Interspersed among the syenitic rocks are several xenoliths (fragments of preexisting rocks included into a more recent rock) of darker rocks, possibly fragments of the first ultramafic, mafic and intermediate rocks originated in the beginning of the Monchique massif's formation.

In the Fóia landscape there are several tors, marked topographic features constituted by heaps of leftover smooth rounded blocks of unweathered nepheline syenite. Tors can typically be found wherever solid, massive rocks like syenite, granite and other similar rocks dominate the landscape.





Fig. 15 – Fóia belvedere viewpoint. A – View due south, where one can scan the Algarve's landscape all the way to the coastline. B – One of the tors (heaps of leftover smooth rounded blocks of unweathered nepheline syenite) that can be found in Fóia.

PGS 2 – Farming terraces

In the Monchique Range, as in several other mountainous regions, where plains are hard to come by, it is common to find areas with platforms following the relief's contour lines, like so many steps in a giant ladder. People build these narrow terraces for farming purposes using retaining walls made out of local rocks (chiefly, nepheline syenite, in this case). Although human intervention is, thus evident here, changing the landscape and molding it to better suit the population's needs, this kind of farming constitutes valuable historic, cultural and agricultural heritage.



Fig. 16 – Area where farming terraces are visible.

PGS 3 – Panoramic vista due east: valley, town of Monchique and Picota.

Here one can enjoy a panoramic view over due east, where a marked valley can be seen and, at the bottom of that valley, sits the town of Monchique. On the opposite slope stands out the second highest place in the Algarve, Picota, with an elevation of 773 m (2536 feet).

The valley is oriented in a northeast-southwest line and is the largest valley in the Monchique Range. Its origin and development resulted from the installation and vertical entrenchment of streams. Some researchers considered that its orientation and development are associated to a fracture that separates the easternmost Picota block from the westernmost Fóia block.

Picota and its surrounding area are located in terrains pertaining to the Central Unit, where the rocks are more homogeneous, coarser-grained and have more nepheline.



Fig. 17 – Panoramic vista due east, where the town of Monchique can be seen at the bottom of a marked valley. Also visible is the second highest point of the Monchique Range, Picota.

PGS 4 – Area of the Ultramafic, Mafic and Intermediate Igneous Rocks Unit.

In this place we're crossing one of the eight areas in the Monchique massif that belong to the Ultramafic, Mafic and Intermediate Igneous Rocks Unit. The rocks in this area have a dark color and are quite heterogeneous in terms of their mineralogy (ratios of the different minerals that comprise them) and texture (crystal size). These rocks are interpreted as having been originated by the first magmatic pulses that gave rise to the Monchique Alkaline Complex.



Fig. 18 – Mafic igneous rocks present in one of the areas of the Ultramafic, Mafic and Intermediate Igneous Rocks Unit.

PGS 5 – Panoramic vista due south: Nave nepheline syenite quarry.

As we go down the south slope of the Monchique Range, the scar left in the landscape by the Nave stone quarry pops out. (fig. 19). Nepheline syenite has been mined from this open pit quarry since 1984 and the products extracted are used for construction and urban development projects, both nationally and abroad. The rocks extracted are those of the Central Unit, which is formed of a fairly homogeneous (relatively constant crystal size) and coarse-grained (large crystals) nepheline syenite with a high percentage of its name-giving mineral, nepheline.



Fig. 19 – Nave nepheline syenite quarry.

PGS 6 – Fonte Santa belvedere viewpoint.

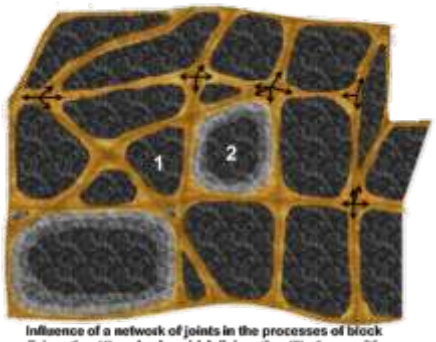
The Fonte Santa belvedere allows for a splendid view due south, where one can scan the terrains all the way to the coastline. This place is very sought after because of the water spout, from which many people stock some crystal-clear water. This water is originated from the rainwater that fall over the surrounding area, seeps through and circulates in the cracks on the rocks of the Monchique massif.

In the road slope above the belvedere one can appreciate the weathering of the syenite along the fractures they sport. Chemical weathering is more severe along the fissures, so rounded structures of various sizes are slowly formed in a process known as spheroidal weathering or spheroidal disjunction. These rounded structures have a concentric zoned rock body, much like the fleshy layers of an onion, with a center made of unweathered (or less weathered) rock surrounded by layers of increasingly weathered rock as we move outward.

On the surfaces where the syenite isn't weathered it is possible to observe its characteristics – in this particular place, the syenite belongs to the Central Unit, which has a high percentage of its name-giving mineral, nepheline, and is fairly homogeneous (relatively constant crystal size) and coarse-grained (large crystals). It is possible to identify several of the main mineral constituents in the outcrops, such as light-colored alkaline feldspars, brownish nepheline and dark-colored pyroxene and biotite.



Fig 20 – Weathered nepheline syenite. A – General view of the weathered nepheline syenite on the slope of the road from Monchique to Fóia, just above the Fonte Santa belvedere. Note the more severe weathering along the network of cracks in the rocks. B – Detail of weathered nepheline syenite. Note the spheroidal weathering (ball-like structures surrounded by concentric layers of weathered rock, just like the fleshy layers of an onion).



Influence of a network of joints in the processes of block disjunction (1) and spheroidal disjunction (2) of a syenitic outcrop. The arrows indicate the direction of weathering along the sides and tips formed by the network of joints.

Diagram 4 – Onset and evolution of the spheroidal weathering process.

PGS 7 – Syenitic breccia.

There are several locations in the Monchique massif where breccia-like formations can be found and here there is a small outcrop of one of the syenitic breccia made from dark-colored mafic igneous rock clasts included into a light-colored syenitic groundmass. The dark clasts are xenoliths, fragments of rocks that are older than the light-colored syenitic mass that enveloped them.



Fig. 21 – Outcrop of syenitic breccia, by the wind turbines west of the Madrinha geodetic marker.

PGS 8 – Contact metamorphism aureole: metamorphised Brejeira Formation rocks.

In the areas close to the Monchique massif we step into the zone where the country rocks were affected by contact metamorphism (contact metamorphism aureole) caused by the emplacement of the hot magma that later on cooled down and originated the massif's rocks. In the metamorphism aureole, the sedimentary rocks of the Brejeira Formation (country rocks) have turned into metamorphic rocks, namely the solid, dark-colored and very hard hornfels and, less frequently, thin layers of mottled shale, formed from the most clayey sedimentary layers. The sequence of strata is intersected by intensely weathered igneous rock dikes and syenitic intrusions associated to the emplacement of the Monchique massif



Fig. 22 – Rocks of the Brejeira Formation (intercalated layers of shale and greywacke) turned into metamorphic rocks. Some layers of mottled shale (formed from the most clayey sedimentary layers of the Brejeira Formation) can be seen.

PGS 9 – Contact metamorphism aureole: metamorphised Brejeira Formation rocks cross-cut by weathered mafic igneous rock intrusions.

In this outcrop one can appreciate several igneous rock dikes intersecting the rock layers of the Brejeira Formation (intercalated layers of shale and greywacke). These igneous rocks have suffered extensive chemical weathering and, thus, their color, hardness and appearance differ largely from the newly formed rock.



Fig. 23 – Outcrop where an igneous rock intrusion (IR) can be seen intersecting the layers of shale and greywacke of the Brejeira Formation (BF).

PGS 10 – Hornfels outcrop.

Here we can appreciate a fairly localized outcrop of hornfels. These dark-colored, solid-looking metamorphic rocks stand out because of their great hardness, which allows for the formation of a small ridge that can be easily observed in the landscape.



Fig. 24 – Outcrop of hornfels, dark-colored, solid and quite hard metamorphic rocks.

PGS 11 – Outcrop of nepheline syenite cross-cut by several dikes: principles of intersection and inclusion.

In this place we can appreciate an outcrop of nepheline syenite that is cross-cut by several dikes (fig. 25). Both structures present xenoliths (fragments of preexisting rocks embedded in a more recent rock) of igneous rocks of various origins. Using two stratigraphic principles, the principle of intersection (any structure cross-cut by another is older than the structure that cuts across it) and the principle of inclusion (any structure embedded into another is older than the structure that embeds the former) we can reconstruct the sequence of events that took place here, just like a detective that tries to solve an age-old mistery! There are several clues that can help us do this:

- there are xenoliths of dark-colored mafic igneous rocks both in the nepheline syenite and in the dark-gray igneous rock dike, which means that these xenoliths are older than any of those two rocks that have them;
- the dark-gray dike intersects the nepheline syenite, so it must be more recent than the latter;
- the dark-gray dike has xenoliths of nepheline syenite within it, which, together with the previous clue, tells us that the dark-gray dike is indeed more recent than the nepheline syenite;
- lastly, there is a very thin dike of microsyenite (with very small crystals) that cross-cuts both the dark-gray dike and the nepheline syenite, so this thin dike must be the most recent rock.

In short, this is what happened in this place:

- emplacement of the mafic igneous rocks;
- emplacement of the nepheline syenite, trapping within it fragments of the mafic igneous rocks;
- intrusion of the dark-gray dike through the mafic igneous rocks and the nepheline syenite, trapping fragments of both rocks within;
- intrusion of the thin dike of microsyenite through the nepheline syenite and the dark-gray dike.

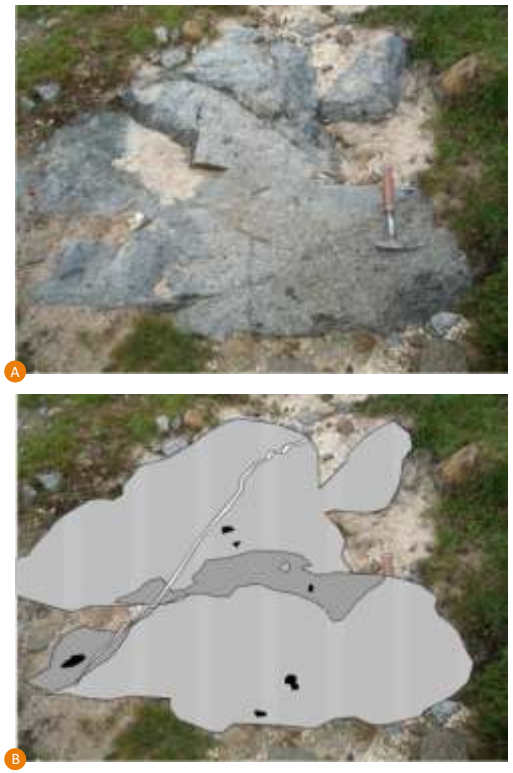


Fig. 25 – Outcrop of nepheline syenite cross-cut by several dikes. Both structures present, within them, xenoliths (fragments of preexisting rocks embedded in a more recent rock) of igneous rocks of various origins. A – Overall view of the outcrop. B – Diagram of the outcrop.

PGS 12 – Area with breccia-like formations.

In the Monchique massif there are several areas where one can find breccia-like formations. Magmatic breccias dominate this area, with clasts (fragments) of various rocks (syenite, foid-bearing gabbro, mafic igneous rocks, hornfels) held together by a light-colored syenitic groundmass or by a dark-colored mafic igneous groundmass.

The older buildings that can be found along the trail, which were erected before the 1940's, were built using stone masonry, a construction technique that utilizes blocks of natural rock held together with some kind of mortar. Therefore, it is quite common to find enclosures and walls made out of local rocks, either comprised solely of nepheline syenite (foiaite stone masonry, in technical terms) or made out of a mixture of local rocks. In this place, for instance, magmatic breccias abound, so the buildings and ruins here mainly present this kind of rock.

This kind of construction technique not only presents an undeniable aesthetic, cultural and urban integration value but also makes for buildings that are potentially very durable, with good heat and sound insulation. Nevertheless, nepheline syenite stone masonry presents some inconveniences such as the reduced indoor space because of the walls' thickness, which is required for structural reasons; the fairly high cost of labor and materials; the extended construction time required and the ever increasing difficulty in finding specialized manpower.



Fig. 26 – Old home erected with magmatic breccia stone masonry. A – Overall view. B – Magmatic breccia. Note the different clasts within it.

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Promotor: Almargem
Address: Rua de São Domingos, nº65, Apartado 251, 8100 Loulé
Phone: +351 289 412 959 | Fax: +351 289 414 104
e-mail: almargem@mail.telepac.pt
Website: http://www.almargem.org/

Inserted at the project: Via algarviana
Phone: +351 289 412 959 | Fax: +351 289 414 104
e-mail: viaalgarviana@viaalgarviana.org
Website: http://www.viaalgarviana.org/

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PARTNERS:

MONCHIQUE MUNICÍPIO

Address: Travessa da Portela, nº2, 8550-470 Monchique
Phone: +351 282 910 200 / Fax: +351 282 910 299
e-mail: geral@cm-monchique.pt
Website: http://www.cm-monchique.pt/

TURISMO DE PORTUGAL algarve

Address: Av. 5 de Outubro, 18, 8000 – 076 Faro
Phone: +351 289 800 400 / Fax: +351 289 800 489
e-mail: turismodoalgarve@turismodoalgarve.pt
Website: http://www.turismodoalgarve.pt/
http://www.visitalgarve.pt

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www.almargem.org
almargem@mail.telepac.pt

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Email: associacaodpga@gmail.com

Texts:
Francisco Lopes [1, 2]
Tiago Neves [3]
([1] Associação DPGA; [2] Professor de Biologia e Geologia no Agrupamento de Escolas Tomás Cabreira, Faro; [3] Professor de Biologia e Geologia no Agrupamento de Escolas Poeta António Aleixo, Portimão)

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