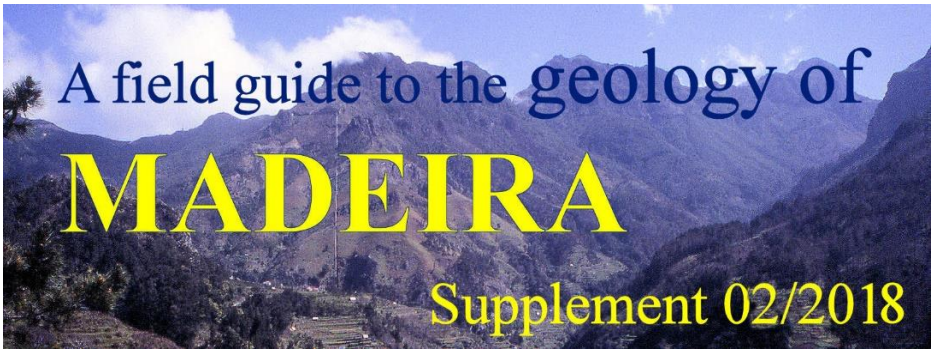

The need has arisen to update some of the information contained in the above Guide. The great storm of February 2010 changed some of the topography, especially in the area of Porto da Cruz and in the same year a new 1:50 000 scale geological map of the island was published along with a revision of the stratigraphy (Brum da Silvera et al 2010). These and other alterations and additions are reflected in the following information. Page numbers relate to the field guide as published in 2008.

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1. New geological map **(replacing Fig. 6. Page 20)**

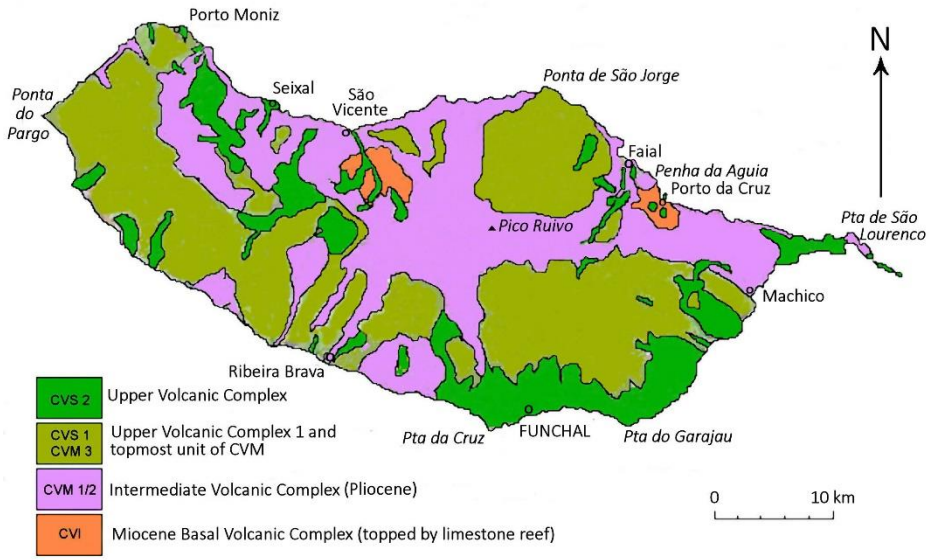

Fig. 1. Simplified geological map of volcanic complexes of Madeira (based on Brum da Silveira et al. 2010).

2. Volcanic Stratigraphy of Madeira

(A. Brum da Silveira et al. 2010)

	Stratigraphy of Zbyszwski et al.
SUPERIOR VOLCANIC COMPLEX (CVS) – Pleistocene to Holocene (1.8 – 0.007 Ma)	
Lombos/Fuchal units undifferentiated (CVS1-2)	Late stage β^6
Funchal Unit (CVS2) Post-erosional activity; represented in the contemporary geomorphology.	Late stage β^5
Lombos Unit (CVS1) Isolated activity, flows tending to fill valleys	
INTERMEDIATE VOLCANIC COMPLEX (CVM) Plio-Pleistocene (5.57 – 1.8Ma)	
Curral das Freiras Unit (CVM3) Third stage of subaerial activity. Essentially Hawaiian* in character from vents probably in the Paul da Serra area.	Mature Stage β^4
Penha D'Águia Unit (CVM2) Second stage of shield construction, increased Strombolean* and Hawaiian activity producing vast quantities of lava.	Main Shield Building stage β^3
Encumeada Unit (CVM1) First stage in the construction of the subaerial shield. Strombolean, Vulcanean* and fissural activity aligned along an E-W rift zone	Main Shield Building Stage β^2
INFERIOR VOLCANIC COMPLEX (CVI) Miocene (>5.57 Ma)	Basal Complex β^1
Lameiros Unit (CVI 2) A sequence of submarine carbonates with an unconformable relationship with CV1	
Porto da Cruz Unit (CVI 1) Probably represents the final phase of submarine shield activity; highly altered rocks including hyaloclastites and submarine lavas cut by a dense network of dykes	

**Explanatory note*: Hawaiian activity is characterised by effusive eruption of fluid lava. Strombolian activity is typified by minor explosions due to build-up of gas pressure in viscous magma. Increasing viscosity leads to greater intensities of explosive activity commonly referred to as Volcanian.

3. Revision of identities of some rock units

The field guide (Burton & MacDonald 2008) was based on the mapping of Zbyszewki et al. (1975). The revised stratigraphy of Brum da Silvera et al. (2010) supersedes previous interpretations of the ages of the strata throughout much of Maderia. The extent of outcrops of the Miocene basal volcanic complex is now confined mainly to the Valley of São Vicente and the area around Porto da Cruz (Fig. 8); most of the rest of what was thought to be basement is now assigned to the lowermost unit of the Median Volcanic Complex (CVM1). This includes areas intruded by the dyke complex along the WNW– ESE axis of the island and much of the strata cropping out on either side of it.

A study of the structure and evolution of the Peninsula of São Lourenço (Klügel et al. 2009) records radiometric age dates of dykes, and the lava flows and associated tephra that they intrude. Dates from 3.96 Ma to 5.21 Ma obtained from the dyke and cone complex (dark shaded area in Fig.9) confirm its identity with the Median Volcanic Complex. Dates obtained from samples collected in the light shaded area (Fig.9) cover a range of 2.43 – 0.94 Ma from the Upper Pliocene to the Quaternary Epoch.

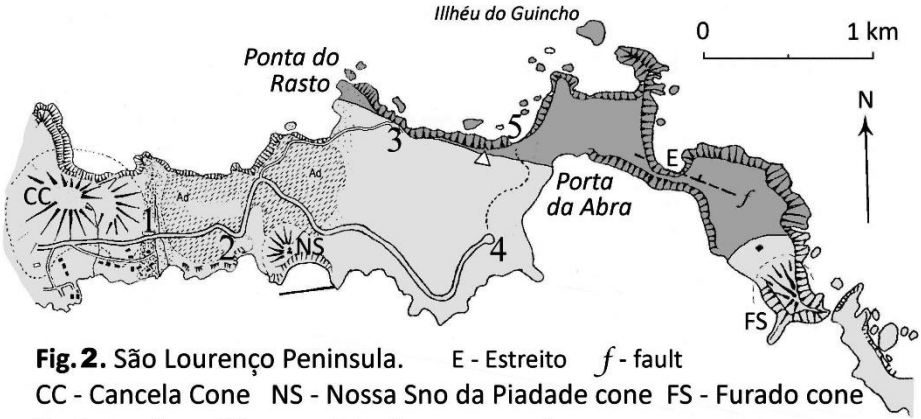

Fig. 2. São Lourenço Peninsula. E - Estreito f - fault
CC - Cancela Cone NS - Nossa Sno da Piadade cone FS - Furado cone
Dark shading - Miocene dyke & cone complex,
Light shading - Quaternary lava and cones, Ad - Aeolian sands
The numbers 1 to 5 refer to localities in Burton & MacDonald (2008)

Fig. 3. São Lourenço Peninsula looking west. Quaternary cones occur at *A* (Cancela), *B* (Senhora da Piadade) and *C* (Furado). The dyke and cone complex crops out in the cliffs at Ponta do Rosto and on both sides of Estreito Bay

4. Update for locality 1.2 Garajau (page 44)

The path (Fig. 4.) constructed below the Christo Rey statue, to provide safe access to the dyke that cuts the Garajau cone was in poor condition and closed as of 11th April 2018. A cable car provides access to a beach 200 metres below where there is a café and scuba diving facilities in a protected area, the Garajau Marine National Park.

Fig. 4. Path at Punta de Garajau

6. Major changes in the vicinity of Porto da Cruz

The storm in February 2010 (Ngyuen et al. 2013) led to flash floods in several parts of Madeira. At Porto da Cruz the main road into the town from the east was swept away and the graveyard severely damaged. A major collapse took place on the seaward side of Rochão Hill destroying the pillar of mugearite lava (Fig. 6) that used to form a feature at Locality 3.10 (page 70). The old Baixo road below the cliff face of mugearite lava (A in Fig.5) had to be upgraded to improve access to the east. Repair work continues to fully restore access to the centre of Porto da Cruz from the main ER101 road.

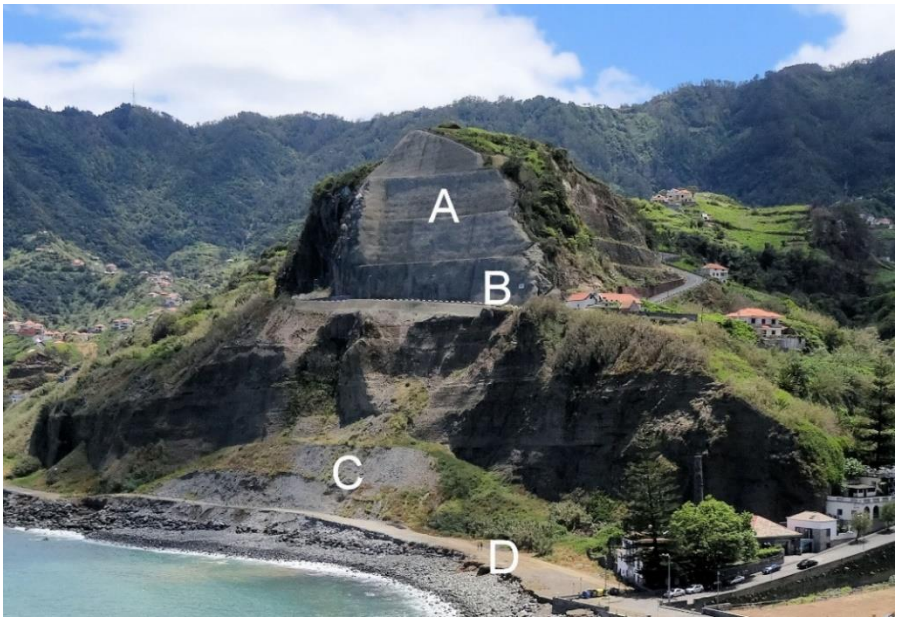

Fig. 5. View of Rochão Hill from the summit of the Cais peninsula in June 2016. Prior to the publication of the guide in 2008 the ocean lapped the foot of the cliff at the left-hand side (see plate 7a in the Madeira Guide). Later a road was constructed (D) close to sea level with rock debris from the construction of the new trunk road between Machico and Santana. A pillar of mugearite (Fig.6) stood at B but had already partially collapsed before the major cliff collapse at the time of the storm in 2010. C is the fan of sediment resulting from collapse of the cliff. The mugearite cliff above the road at B has been stabilised by a cement rendering (A) to protect the reconstructed road from further rock falls.

Fig. 6. The mugearite pillar (Pinnacle) beside the old Baixo road prior to 2008. It was poised on top of a sucession of poorly cemented sediments extending down to sea level. Major cracks in the pillar led to its partial collapse by 2009.

The ankaramitic dyke illustrated as Fig. 5 on page 16 of the guide is now concealed by the building of a view point at the bend of the old road to Cruz and Faial (see fig. 21 page 64). A few metres farther up the road two dykes crop out. The first of them is also ankaramitic in character, (Fig. 7., a one Euro coin for scale). the other contains augite phenocrysts and acicular microphenocrysts of feldspar

Fig.7. Ankaramitic dyke

5. Update of locality Roto da Cal, São Vicente (page 76)

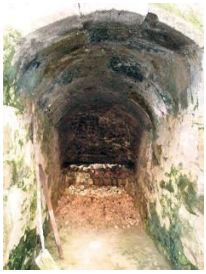

Fig. 8. Lime kiln at Roto da Cal museum

The Miocene Reef Complex locality (page 76) now features a museum complex, Roto da Cal, illustrating the history of extraction of limestone at Lameiros. As well as a restored lime kiln there is a display of fossils found at the limestone quarry featuring specimens of *Clypeaster* a sea urchin, *Gigantopecten* a bivalve and a colonial coral. A kiosk provides light refreshments. Before visiting Rota de Cal it is advisable to check opening times at the tourist information office in Avenida Ariaga in central Funchal, opposite the Fortress.

6. New Itinerary - Ponta da Cruz to Camera de Lobos

This route traverses a variety of lava flows, volcanic cones and sediments (epiclastic rocks) derived from the erosion of volcanic rocks. These are products of the most recent division (Funchal Unit) of the youngest period of volcanic activity in Madeira.

Ponta Da Cruz is on the urban bus route No.1. Prepaid bus tickets can be purchased from a kiosk at Avenenido do Mar opposite Fuchal Marina. Take the bus to **locality 1** (Fig.9), close to the Centromar Shopping Centre. Steps opposite the Shopping Centre give access to a path leading to a fish restaurant built on the side of the thick basaltic lava flow that forms the cliff at the promontory. The lava flow has a thick rubbly top and a massive lower part in which a tunnel has been excavated to provide access to the Praia Formosa beach.

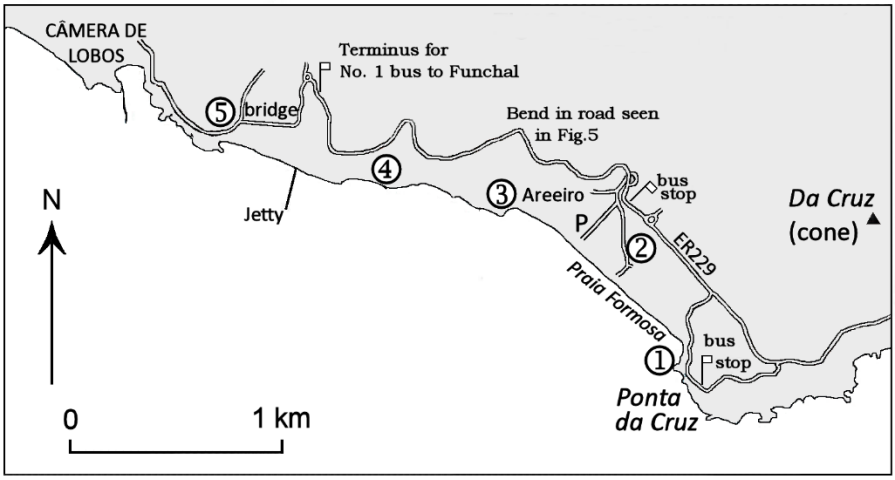

Fig. 9. Localities between Ponta da Cruz and Camera de Lobos.

Beyond the tunnel exit, a wooden slatted footpath leads* along the boulder beach backed by cliffs of lava topped by bedded ash. Immediately past the Pastana hotel complex the path has been washed away by wave action so walk past the hotel entrance to **locality 2** taking care to avoid traffic going to and from the hotels. Cone deposits including ash, lapilli and scoria interbedded with mudflows crop out in the roadside section north of the hotel (Fig. 10).

**Storm damage has recently destroyed the footpath and the tunnel has been closed as at 15th April 2018. It is possible to rejoin the itinerary at locality 2 by taking the bus to the stop past the roundabout on the ER229 (Fig. 9).*

Fig. 10. Bedded basaltic ash interbedded with mudflows. Rain water has washed mud from the upper mudflow down the face of the bedded ash.

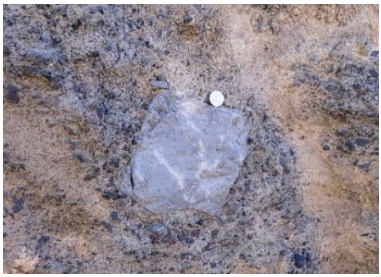

Fig. 11. Angular basaltic lithic clast of microporphyritic lava. (A one Euro coin for scale)

A little farther up the road a lithic clast (Fig.11), is embedded in ash and lapilli. The groundmass texture is characteristic of deposits from a collapsing eruptive column. The large lithic clast would have been torn from the side of the vent. It landed in the ash and lapilli cascading down the side of the vent. See how it disturbed the bedding that has piled up in front of it. To return to the beach take the first turning to the left. At the bottom of the road is a car park and access to the concrete esplanade leading to Câmera de Lobos.

Fig. 12. View north from esplanade towards the cone in the Areeiro area. The ER-229 road takes a right-angle bend at the tall buildings.

Cafés occur at the NW end of Praia Formosa (Fig.9) as far as the kink in the coastline marked by an outlier of black basalt lava at **locality 3**.

Fig. 13. The view from the Esplanade looking NW towards locality 3. The headland in the distance is Cabo Girão.

At **Locality 4** a complex of lava flows and ash beds crops out in the cliffs backing the shoreline as far as the jetty at the fuel storage facility.

Fig. 14. A series of basaltic lava flows near locality 4. The flows are separated by layers of ash and rubble. They are about the same age as the cones, products of late Quaternary volcanic activity in post Glacial times.

Beyond the jetty the path leads to **locality 5** where it joins the ER-229 road to Câmera de Lobos. Here there is the option to cross the bridge along the ER-229 towards the terminus where you can catch the No.1 bus back to Funchal or continue along the promenade towards Câmera de Lobos. Examples of lava and ash also occur at the roadside (Fig. 15.) and beside the promenade. Another Quaternary cinder cone forms the hill on the north side of Câmera de Lobos. If travelling by bus along the ER-229 note how the road cuts through the cone at Areeiro, and lava flows farther west. Flows also crop out at the roundabout and at the roadside between the bus terminus and locality 5.

Fig. 15.
Promenade looking towards locality 5. Note the volcanic ash cropping out underneath the basaltic lava flow beside the car.

7. New locality at Cabo Girão

Some 540 metres in height, Cabo Girão has been claimed to be the highest sea cliff in Europe or the second highest in the world. It can be approached by a winding road from Câmera de Lobos by continuing west from the village via Caldeira and Facho. If approaching from the Via Rapido, exit at Junction 4 and follow the signs for Cabo Girão and Faja de Girão. A narrow winding road about 3 km in length leads to the edge of the cliff at a sharp bend where, next to a restaurant, a cable car provides access to the Faja de Girão, a fan of sediment at the bottom of the cliff (Fig. 16).

Fig. 16. Scar left by a major collapse of the east side of Cabo Girão. Note the intersecting ash beds from adjacent cones.

Continuing via the village of Facha a side road eventually leads to a viewpoint cantilevered out from the cliff edge to give a spectacular vertical view of the base of the cliff from a glass floor (Fig.17.) In the highest part of the cliff the pyroclastic deposits are laced by a north-south trending dyke swarm which is best seen by boat (Fig. 18). Some of the dykes do not appear to reach the top of the cliff but the swarm can be traced inland where mapping (Brum da Silveira et al. 2010) indicates that although a few are recorded as cutting the uppermost (Curral das Fairas) unit of the Median Volcanic Complex (CVM) they are generally confined to the more extensive Penha de Águia unit. The swarm, does not appear to cut the Superior Volcanic Complex so it can be deduced the dykes are of CVM age and that they were feeders for fissure eruptions at that time.

Fig.17. View looking vertically downwards from the glass bottomed viewing platform at Cabo Girão. Faja. The fan of sediment deposited by a major cliff collapse below the view point is now intensely cultivated.

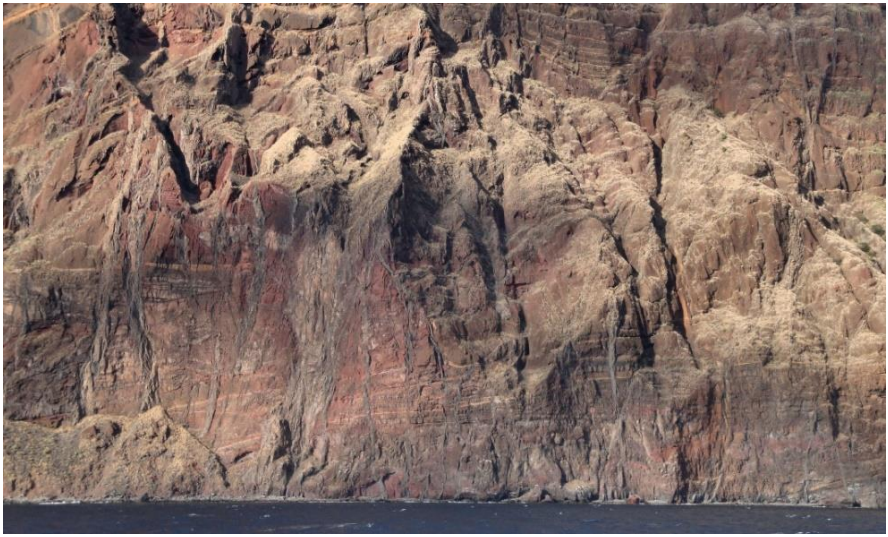

Fig. 18. The cliff at Cabo Girão is composed of overlapping pyroclastic cones belonging to the Pliocene Penha de Águia unit of the Median Volcanic Complex (CVM2). Note the north-south trending dyke swarm cropping out in the central part of the cliff.

8. New itinerary, Eira do Serrado and Pico Ariero.

The opening of a new road* provides an alternative route to Pico Arieiro via the area around Currral das Freiras. From the Via Rapido in Funchal exit at Junction 10 and follow the signs for Curral das Freiras leading to the ER107.

*NOTE: *access to this road is restricted to daylight hours and is unadvised if obscured by low cloud. Some of the hills are very steep so you may prefer to tackle this itinerary in reverse order from the ER202 at the other end.*

1. **Mirodouro Eira do Serrado**. Follow the ER107 as far as the portal of the tunnel leading to Curral das Freiras (about 8 km from central Funchal). Turn sharp left before the tunnel at the sign for Curral das Freiras and continue for about 2 km to the road end where there is a car park and tourist facilities (Fig. 19). Two well-constructed paths provide access to outlook points. On the east side a high cliff rises to about 1400 m. Multiple pahoehoe basaltic flow units alternate with massive individual flows belonging to the Median Volcanic Complex. To the north deep valleys converge on the village of Curral das Freiras built on a tongue of avalanche deposits from prehistoric mass movement (Fig. 20). If you are lucky you might see a falcon soaring overhead.

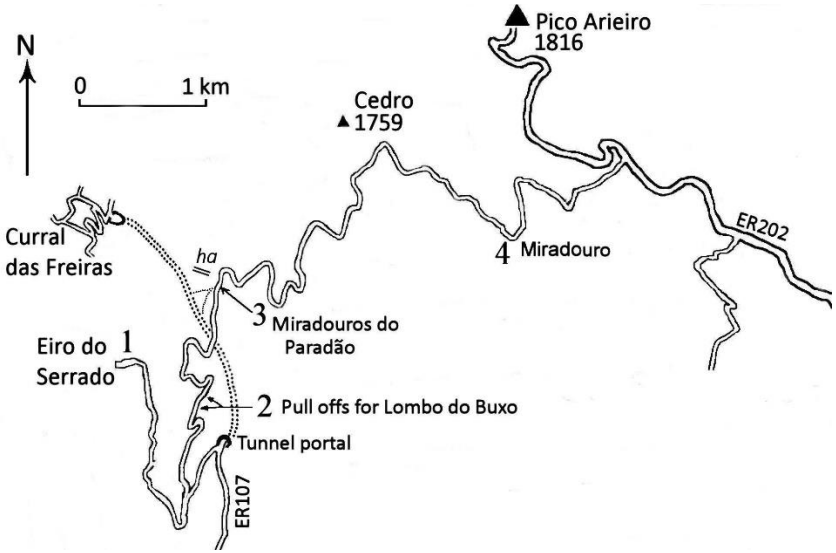

Fig. 19. Eira do Serrado, Corral das Freiras & Pico Areeíro *ha* – hawaiite

Fig. 20. Nun's Valley from Eiro do Serrado

2. Erosion scars below Lombo do Buxo. Head back toward the tunnel portal but before reaching it look out for a sharp turning to the left sign posted for Arieiro. A steep hill rapidly gains height to provide good views towards the valley slopes of the Baxo ridge.

Fig. 21. Steep west facing slope of Lombo do Buxo scarred by landslips. Inset is an enlargement of a scar to illustrate the boulders securing netting

Pull-offs at the road side (locality 2, Fig.19) make good photo stops to examine steep slopes damaged by the great storm of 2010 (Nguyen et al.

2012). A series of landslips took place when torrential rain fell on a thin cover of soil and vegetation already saturated with groundwater. Remediation of the slopes has been carried out by placing netting on the bare rock, held in places by lines of boulders (Fig. 21, inset).

3. Mirodouros do Paradão. A signpost at the roadside (locality 3, Fig.19) marks the starting point for two paths leading to viewpoints that provide spectacular views of the mountains around Curral das Freiras and in the direction of Funchal.

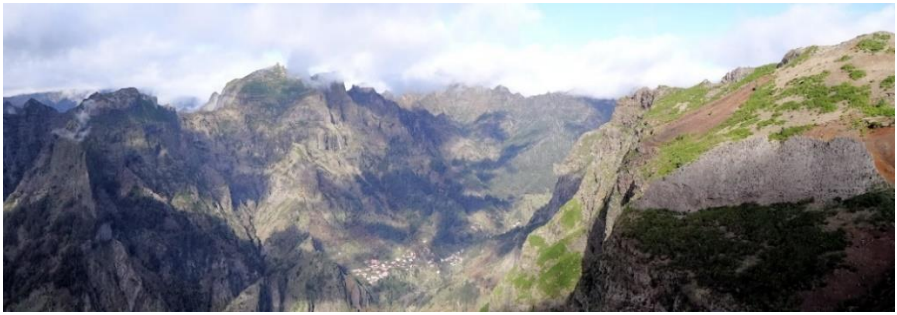

Fig. 21. View north towards Curral das Freiras from locality 3. The grey-coloured rock slab on the right-hand side is a WNW– ESE trending dyke (marked *ha* in Fig.19).

A prominent dyke (Fig.21) can be approached via a poorly defined path to the right of the path to the Miradouros. The path rises to a small summit where an intrusion of dark grey rock crops out. This is probably a continuation of the dyke mentioned in the caption to Fig. 21. To approach the main outcrop, continue downhill along the path until it reaches an extensive area of red volcanic ash into which the dyke has been intruded. Extreme care must be exercised if one wishes to examine the dyke more closely as the surface of the ash is steep and crumbly and the south facing side of the dyke forms a high precipice (Fig. 22).

The dyke is microporphyritic with abundant fresh micro-phenocrysts of olivine and much less frequent augite set in a fine-grained groundmass rich in tiny flow-oriented plagioclase feldspar laths typical of hawaiite. High magnetite content causes the rock to be magnetic. The presence of small, flow textured vesicles suggests the magma was vesiculating at the time of emplacement so may have been feeding a lava flow at the surface.

Fig. 22. End on view of the dyke (see Fig.21) It is intruded into red volcanic ash of the Ecumeada Unit

Fig. 23. Close-up of the dyke. It is about 1 metre thick, vesicular in places

4. Miradouro. The route beyond locality 3 traverses thin lava flows and ash cones of the basal Encumeada Unit of the Intermediate Volcanic Complex. Locality 4, at a sharp bend in the road, affords a fine view towards Funchal if the weather is clear. This area is the source of the Ribeira de Santa Luza that reaches the sea at Funchal, at the Praça da Autonomia. The stone structures in the distance are sheep folds.

9. Possibility of volcanic hazards

Mention has been made (Brum da Silveira et al. 2010, 38) of the possibility that a submarine volcanic eruption took place on the 31st March 1748, east of Ponta de São Lourenço. It is also noted (op. cit.) that hydromagmatic (Surtseyan) fall deposits occur on the top of the SE extremity of the island of Desembarcodouro at the eastern extremity of Maderia. Very fresh-looking agglutinated spatter and bombs occur at Estreito (Burton & MacDonald 2008, 55, Fig.2 of this supplement) but these are probably of Quaternary age. Emanations of carbon-dioxide gas have been encountered extensively in many of the road and water supply tunnels throughout Maderia although not normally in quantities that are considered to be hazardous. The youngest radiometric age dates obtained from the Paul da Serra area suggest that volcanic eruptions took place there about 6 or 7 thousand years ago (Geldmacher et al. 2000). It cannot be assumed that volcanic activity on Madeira is extinct but in the absence of significant seismic activity it is considered that the volcanic hazard level is very low.

10. References

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For explanations of geological terms see pages 11 – 12 of the Guide

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