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Volcanological Field Methods – Time Travel on an Ocean Island

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International Geological Fieldcourse
Gran Canaria, Canary Islands, Spain

With contributions by
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Cover photo: *Hydrothermally altered tuffs at Tejeda caldera margin, West-Gran Canaria. ©Steffi Buchardt*

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This course book is inspired by Prof. Schmincke's achievements and decades of work on Gran Canaria. The present guide was literally only possible by standing on the shoulders of such a giant.

Contents

A. Prologue

The Canary Islands ***(Fig. A1)*** are a well known tourism highlight due to their excellent weather and climate conditions for most months in the year, coupled with sandy beaches and attractive cuisine. The volcanic foundation of the islands, the very material they are made of, is often undervalued, however, or just about noted at the side. This book aims to provide a general background on the volcanic geology of Gran Canaria for the layman and the geology student and suggests a number of scenic drives to geological units and features that will help you to glean an insight into volcanological processes and temporal evolution when on the island. For the professional geologist, in turn, I recommend the specialised guides by e.g. Carracedo and Day (2005) and Schmincke and Sumita (2012). All excursions in this current guide are designed to commence in *Maspalomas/Playa del Ingles* as most visitors are likely to enjoy the southern sun instead of the northern clouds.

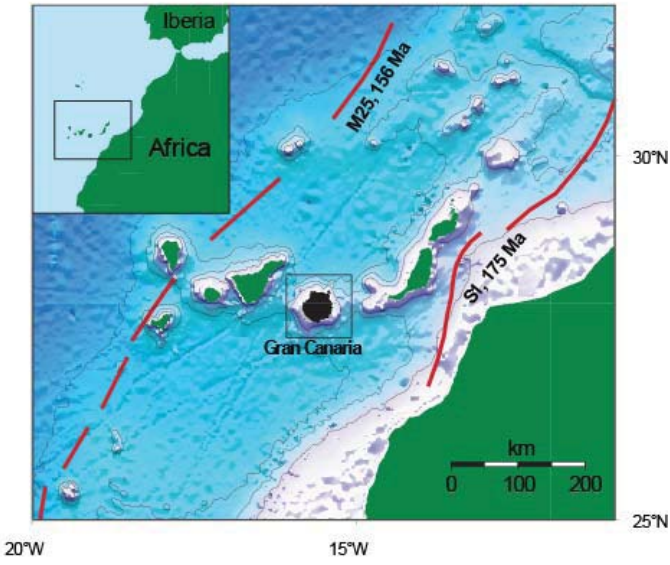


Fig. A1 *Location map of the Canary archipelago. Gran Canaria is highlighted (from Hansteen and Troll, 2003).*

Also, it should be stressed that the present guide to the volcanic history of Gran Canaria is a simple roadside guide. It is not, a list of the best drives on the island *per se*, nor is it a guide of the best outcrops of a particular rock type or unit. It is a series of drives that broadly follow stratigraphic order (unless otherwise stated) and that are aimed at building up a swift and useful overview of the volcanological history of the island using accessible key outcrops near major roads. Where appropriate, however, other localities are suggested where more or better rocks of a type or unit can be inspected or where a more scenic route is possible.

The excursions in this road-side guide follow the principle from 'old to young', which implies inspection of the successive stages that were involved in building this ocean island from the past to the more recent geological events. These stages include the oldest shield stage, made almost entirely of basaltic rock ($SiO_2 \leq 50$ %), that represent the largest part of the island (DAY 1). In fact, more than 90 % of the island is below sea level and we have only a few percent of the rock mass above sea level to unravel the islands evolution from the rocks preserved at the surface.

The basaltic shield makes up the vast majority of the island's edifice, with all younger rocks (those that make up a major part of the exposed rocks) representing perhaps 2 – 5 % of the island's total volume ***(Figs. A2).*** Of these, however, the pyroclastic deposits of the closing shield stage are particularly prominent, forming thick blankets of ash that must have once covered the entire island (DAY 1 and 2). These deposits were erupted from a major caldera volcano (Tejeda caldera) that is superbly exposed and a scenic traverse will take us from the extra-caldera deposits through the hydrothermally altered caldera margin into the fill of the caldera basin (DAY 2) ***(Fig. A3).*** A late resurgence of the caldera can be investigated through numerous sheet intrusions that take the shape of an inverted cone (and hence are called cone sheets) and stocks of coarse syenite (an alkali-version of granite). At the end of DAY 2, a major unconformity will be inspected that is marking the end of the Miocene Tejeda volcano.

DAY 3 starts with a drive to the extra-caldera Fataga ignimbrites, passes into the caldera once more and inspects the Miocene intra-caldera rocks, but more importantly the Roque Nublo type breccias that rest unconformable on the Miocene. After a volcanic quiescence of several million years, the Roque Nublo era saw the evolution of a large stratovolcano, probably similar in size and character to present day Teide on Tenerife. Much of this volcano is now eroded and we are left with some remnants only that are exposed in the central highlands of Gran Canaria. The Roque Nublo rocks themselves were later covered – at least in part – by yet younger Pleistocene and Holocene and recent basaltic deposits mainly in the Northwest of the island. Another pause in volcanic activity is evident, as destructive processes eroded the island significantly prior to this renewed and most recent activity. The second part of DAY 3 will focus on Pleistocene and Holo-

cene cinder cones, maars and scoria deposits that are of very mafic alkaline character. These fresh volcanic landforms are vivid reminders of the last eruption on Gran Canaria dating back only some 1500 to 2000 years. An inspection of the 'Las Palmas Volcanic field' follows, which is a cluster of eruptive vents of this recent geological period, shaping the NE of the island by producing a characteristic 'nobbly' terrain.

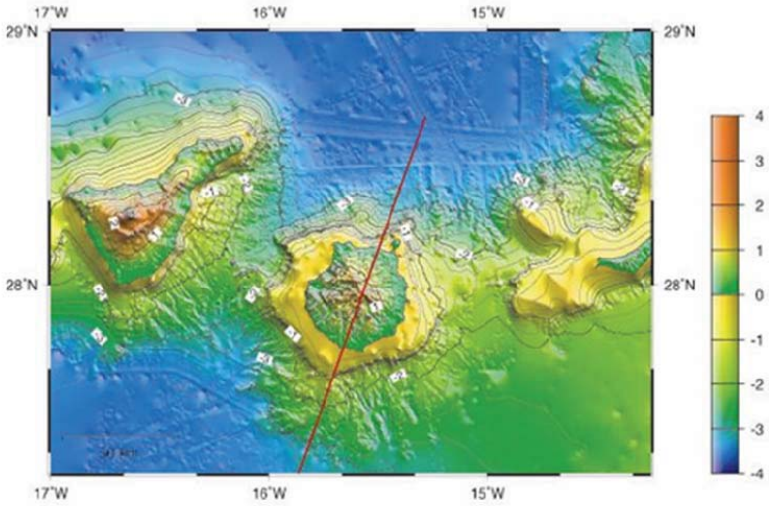


Fig. A2a *Bathymetric map of the Canary Islands and the surrounding seafloor (Courtesy of S. Krastel).*

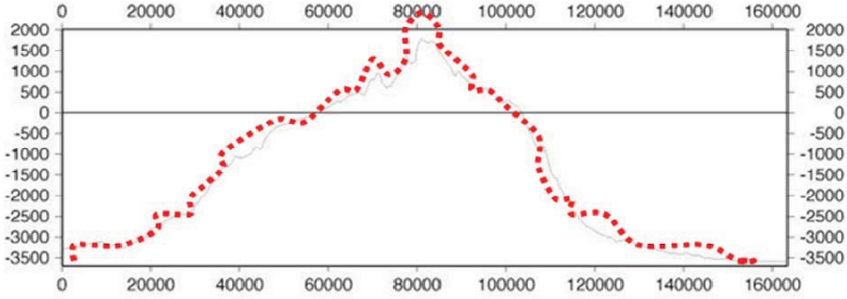


Fig. A2b *Relief of Gran Canaria island from ocean floor. The bulk of the island's volume lies beneath the sea and less than 10% of the island is accessible to us (Courtesy of S. Krastel).*

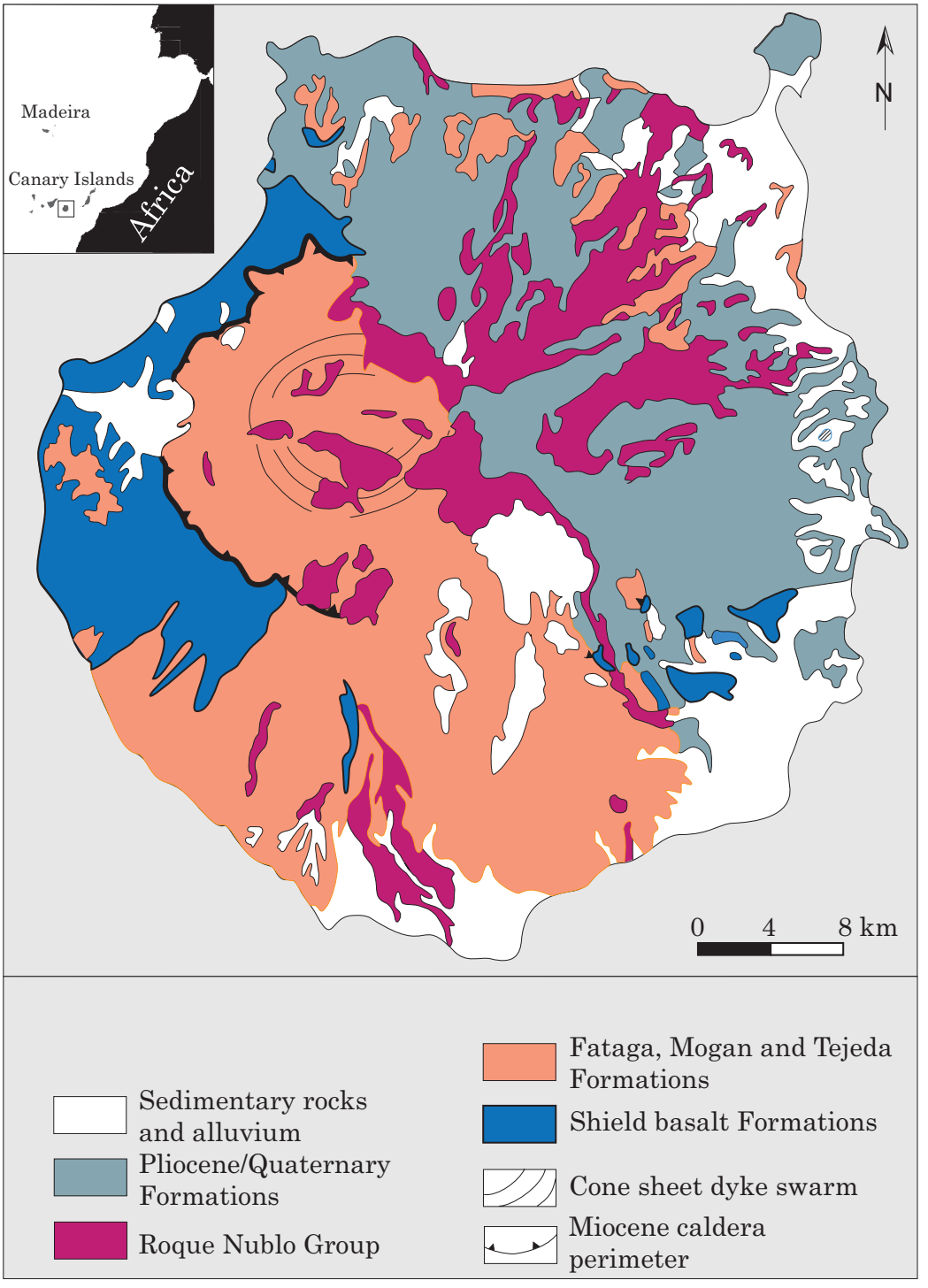


Fig.A3 *Simplified geological map of Gran Canaria based on IGME, 1992 (Courtesy of N. Urbanski).*

DAY 4 is devoted to the 'End of ocean islands'. As like everything else, ocean islands also have a 'sell by date'. Day 4 commences with inspecting uplifted Roque Nublo pillow lavas in NE Gran Canaria that indicate rise of the land in that region. On the other hand, frequent evidence for coastal erosion is obvious, with small to medium-scale landslides being assessed that day as well. The Canary Islands have also been a subject of hot debate in the late 1990s, when the ideas of 'giant' landslides were first formulated in the scientific community ***(Fig. A4)***, giving rise to speculations on resulting giant tsunamis (mega-tsunamis). These collapse scars do indeed exist and both, the sources and the consequences will become apparent that day, in form of *(i)* an enormous landslide scar in NW-Gran Canaria and *(ii)* by witnessing a widespread tsunami deposit swept up the barrancos in NW-Gran Canaria due to a giant landslide on Tenerife, some 80 kilometers away. These large-scale destructive events, plus gradual erosion due to wind and waves, wear the islands down, eventually leaving but a submarine remnant sticking up from the ocean floor, no longer visible to those who travel above the waves.

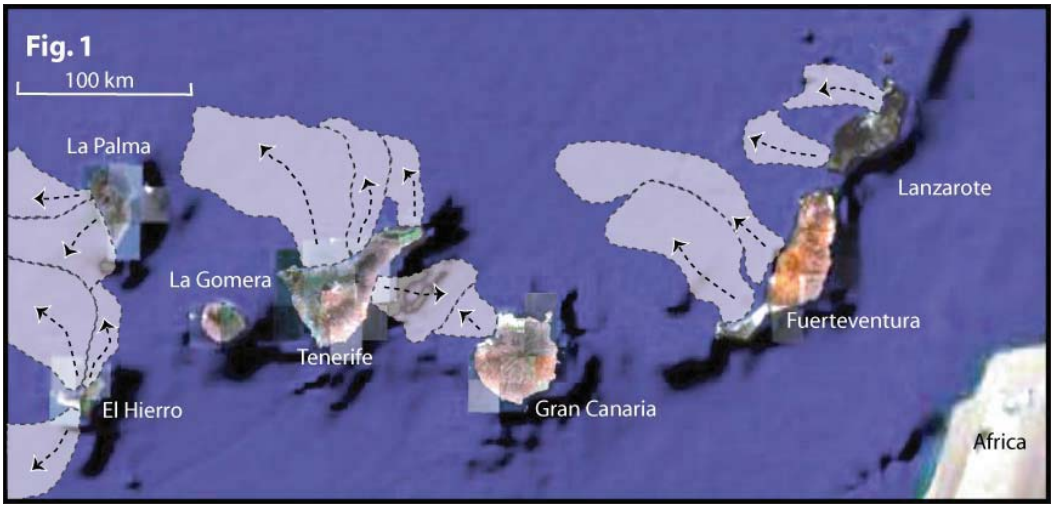


Fig. A4 *Map of confirmed giant landslides in the Canary archipelago (after Walter et al., 2005).*

DAY 5 is intended as a summary day that traverses the island from South to North, revisiting some familiar rock types and formations, but in new outcrops and with the aim of creating a sense of the successive volcanic events. DAY 5 will thus include Miocene ignimbrites and altered intra-caldera rocks, Roque Nublo breccias, Holocene lavas and pyroclastics as well as their craters, before descending down to the Northern shore again.

Three potential exercises are added, the first a traditional geology student occupation – the detailed logging of a rock succession. In this case ignimbrites (hot ash flow deposits) in a spectacular Gran Canyon-like landscape. The second exercise is a hike with the goal to inspect an extra-caldera fault system in the West of the island. The third one is

a little more relaxing and will take place at Maspalomas beach, but is geologically not less intriguing … you shall be surprised.

A note on supplies and logistics. You will need to rent a car and plenty of companies are available offering medium-sized vehicles for between 150,- and 200,- Euro for a full week. You should always have a detailed roadmap with you in the car. The ones supplied by car hire companies are frequently insufficient. Besides this, clothes for warm as well as cold weather (e.g. high in the mountains) should be carried at all times. Further, a first aid kit, plenty of water, sun block and a sun hat are good companions in Gran Canaria, but ideally you also carry a woolly hat, a raincoat and gloves, but let's hope you will not need these during your visit ***(Fig. A5)***.

Fig. A5 *Newspaper clipping from 2004. Heavy rainfall and winter storms can cause flash floods and promote rock falls. Please be prepared, even if this occurs rarely.*

Advisable field equipment includes a compass, a GPS instrument, mountain boots, and a hammer for taking some samples. But please, do not spoil the outcrops in obvious places where others are going to want to admire the rocks at some later point!

Lastly, it is always recommended to fill the cars with petrol before heading into the islands' interior. More and more petrol stations crop up these days in even the smaller settlements on the island, but these may not be open during weekends and public holidays or can have seemingly random opening hours ***(Fig. A6).***

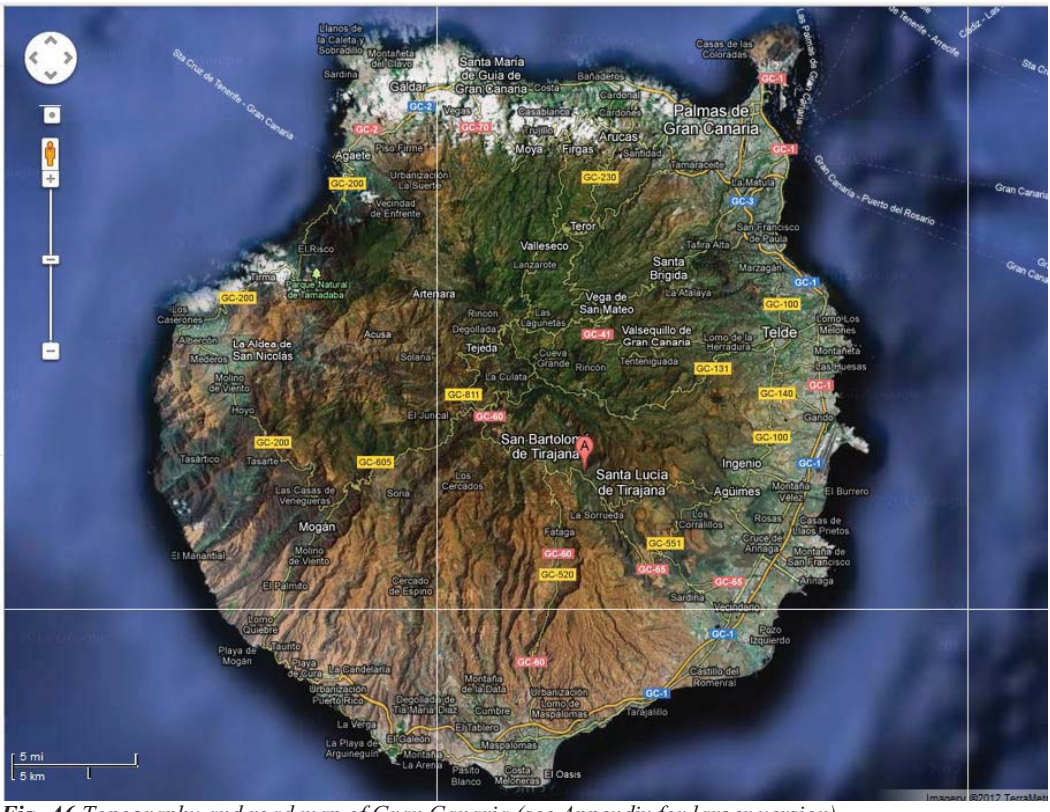


Fig. A6 *Topography and road map of Gran Canaria (see Appendix for larger version).*
Make sure your car is filled with petrol before heading into the mountainous interior (Image ©Google Inc., 2012).

Enjoy the Drives!

B. Brief Introduction to Gran Canaria and its Volcanic History

Gran Canaria is a member of the Canary archipelago, a group of volcanic islands off the coast of North-West Africa. The island is 1532km² in aerial extent and 236km in perimeter. It is situated at 27 43' - 28' West.

The oldest rocks on the island are estimated to be between 14 and 15 Million years (My) old and the youngest about 2 000 years or a little less. There have been many propositions as to how the entire archipelago formed, and two theories prevail. On the one side there is the 'Hotspot Theory' (Schmincke, 1973) and the related 'Blob Model' (Hoernle & Schmincke, 1993) that propose a deep upwelling mantle plume beneath the Canaries. On the other side, there is the 'Propagating Fracture Model' (Fúster, 1972) and the 'Unifying Model' (e.g. Anguita & Hernàn, 2000) that relate the Canary volcanism to the Atlas mountain fracture zone. The fundamental difference is that a plume represents an 'active' upwelling of material from the Earth's deep interior, whereas the fracture theory implies that magma ascent is 'permitted' by a crustal weakness, rather than being forceful in itself.

Gran Canaria is situated on the slow moving African plate (Carracedo et al. 1998) and it is estimated that the plate moved at about 10mm every year for the last 60My (Hoernle & Schmincke, 1993). Gran Canaria is situated near the continental margin on the transition between Jurassic oceanic crust and the adjacent continental crust (Hoernle et al., 1998). A seismic anomaly below the island shows that it sits on a lithospheric swell, masked by the weight of kilometers of sediment above it (Carracedo et al., 1998).

The 'Blob Model' (Hoernle & Schmincke, 1993) proposes that rather than a simple plume, the islands were formed by distinct blobs of mantle-derived magma that reached the surface successively. The 'Blob Model' can account for the varied petrology of the region – as each section of the blob would give a different magma type. This theory also allows for the long volcanic history of islands. The 'Propagating Fracture Model' (Fúster, 1972 Anguita & Hernán, 1975) relates times of volcanic activity to stresses along a fracture propagating westwards from the Atlas Mountains. The 'Unifying Model' (Anguita & Hernán, 2000) combines both theories, suggesting that the Canary Islands lie on an old Atlantic fracture junction that overlies plume material. The effects of the alpine orogeny on the Atlas Mountains caused it to reactivate and erupt magma (Garcia & Cruz, 2001). The debate is ongoing and will probably only be resolved in decades to come, however, most scientists seem to have a preference for the plume/blob model and this may be leading to certain wordings in this book that likely reflect an element of 'interpretation'.

This is because there is little geophysical evidence to support the 'Propagating Fracture Model', whereas a low velocity anomaly has been seismically detected below the eastern Atlantic region – suggesting a large narrow upwelling feature (200 km x 2000 km), which suggests an asthenospheric origin for the Canary Islands – a mantle plume or mantle blobs. Time periods where there was no magmatism on the island then translate to times of 'no blob' beneath the island and hence no magmatic source. This occurred, for example, approximately between 9-6 My on Gran Canaria. During this period there was extensive erosion of the island's subarial surface (>150 m/My). Widespread sediments were deposited in aprons on the volcano's flanks. This combined with the broad age progression observed in the archipelago (old in the East, young in the West) and the corresponding erosion profiles of the islands, the 'Hot Spot Model' seems to satisfy most observations at present ***(Figs. B1, B2).*** Irrespectively of what exactly fed the volcanism, the development of the islands is characterised by three main stages. An initial seamount and shield stage, a volcanic hiatus and erosional stage, and a stage of renewed volcanism. This is followed by another hiatus that, in turn, leads to the final post-erosional renewal of volcanism that itself seems to come in sporadic pulses.

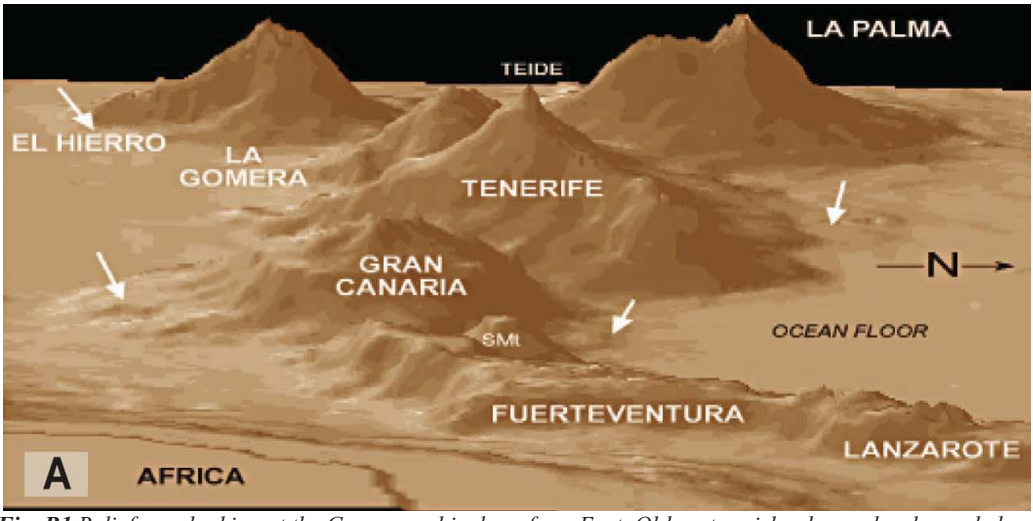


Fig. B1 *Relief map looking at the Canary archipelago from East. Old eastern islands are deeply eroded, the central islands are in their mature evolutionary stage, and the youngest, highly active, basaltic shield stage islands are found in the western part of the group (Courtesy of J.C. Carracedo).*

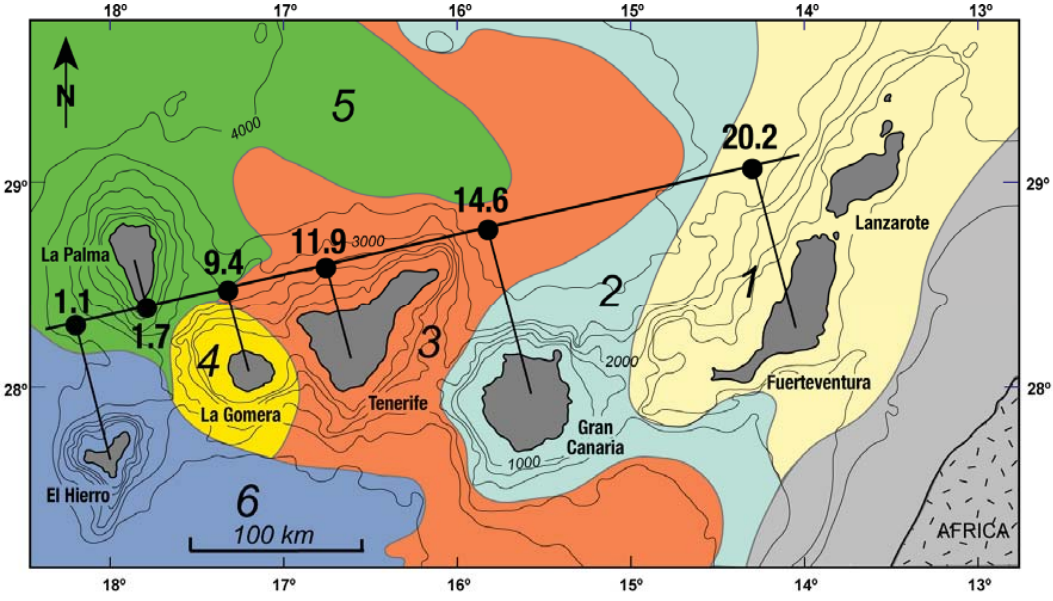


Fig. B2 *Oldest exposed rocks from each of the Canary Islands in My (Million years) and the areas of sedimentary deposition from the respective edifices. Note the decrease in ages from East to West (Courtesy of J.C. Carracedo).*

The geological evolution of Gran Canaria is thus differentiated into three main evolutionary stages – the Miocene shield and seamount stage with its late felsic phase, the Pliocene post-erosional stage of 'Roque Nublo' volcanism, and the Pleistocene, Holocene and recent alkaline volcanic activity in North and North-East Gran Canaria. Each stage has its own distinct magma compositions and types – related to the dis-

crete magmatic processes at depth, and likely to three successive blobs of variable make ***(Figs. B3)***.

The first stage of island building consists of the seamount phase, followed by the main basaltic shield phase. The oldest era recorded on Gran Canaria is the shield phase, which began between 14.5 and 16My ago (Carracedo et al., 1998; Schmincke & Sumita, 1998). The first subaerial eruptions commenced from about 500m below sea level (Schmincke & Sumita, 1998) as a blob of magma made its way to the surface of the sea bed. This type of seamount is characterised by a 'basal complex' of sediments and pillow basalts with intrusions of dyke swarms and gabbroic plutonics, as we know from e.g. Fuerteventura and La Palma. The sheer mass of volcanics produced at that point (very high rate of magmatic production) allowed the edifice to grow despite ocean currents, wind and waves ***(Fig. B3b)***. A variety of rocks was produced at this stage, ranging from basaltic picrites, tholeiites and alkali basalts, to felsic lavas like phonolite, trachyte and explosive rhyolite ignimbrites. A felsic-rich period (Mogán and Fata Groups) seems to have concluded the earlier high productivity of the basaltic shield stage, marking the "shut-down" of the Miocene magmatic system (e.g. Sumita and Schmincke, 1998).

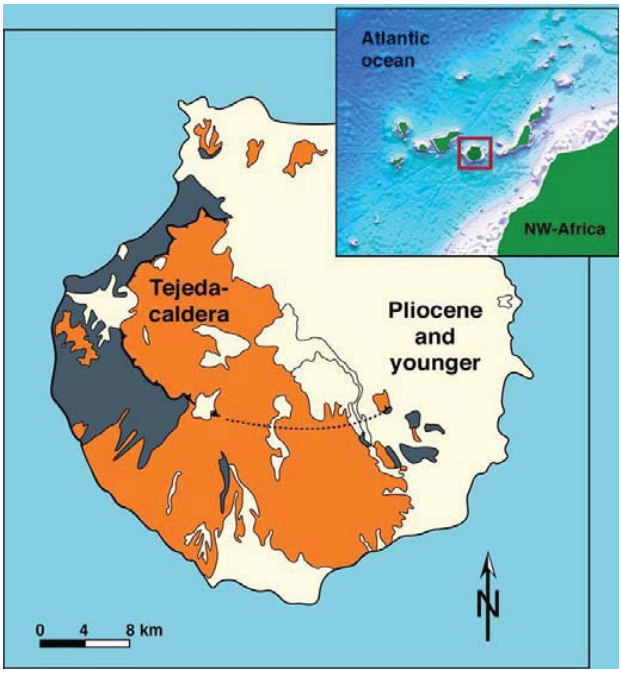


Fig. B3a *Simplified geological map of Gran Canaria. Blue = shield basalts, orange = Miocene rhyolites and trachytes, and white = Pliocene and younger deposits.*

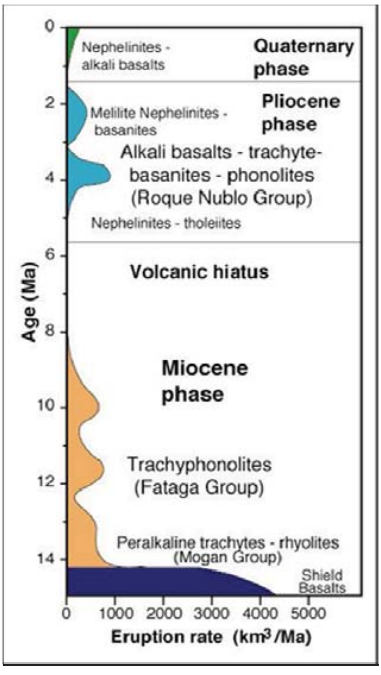


Fig. B3b *Estimated eruptive volumes on Gran Canaria versus geological time. (after Sumita and Schmincke, 1998).*

Following a several Million years hiatus marked by intense erosion, activity commenced again in form of the Pliocene Roque Nublo stratovolcano and associated

volcanism. Another, smaller, eruptive pause followed before the recent alkaline volcanism in the North-East of the island commenced ***(Figs. B3).*** This final stage of Gran Canaria's evolution was characterised by another post-erosional renewal of volcanic activity and probably represents the arrival of a new blob to form the most recent alkaline vent alignments in North and North-East Gran Canaria. These most recent eruptions are no older than ~2000-1500 years before present. Gran Canaria, like all the other Canary Islands ***(Table B1)***, must therefore be considered active in the sense that eruptions can occur again despite the present quiescence.

Should an eruption occur today on Gran Canaria, it will most probably be a basaltic small scale eruption in the North and North-East of the island or offshore in that region. Chance is that it would probably look very much like the two most recent Canary eruptions, the 1971 cinder cone eruption on La Palma ***(Fig. B4)*** and the 2011/12 submarine eruption off El Hierro ***(Figs. B5)***.

Fig. B4 *1971 La Palma eruption, Teneguia (Cour tesy of J. C. Carracedo).*

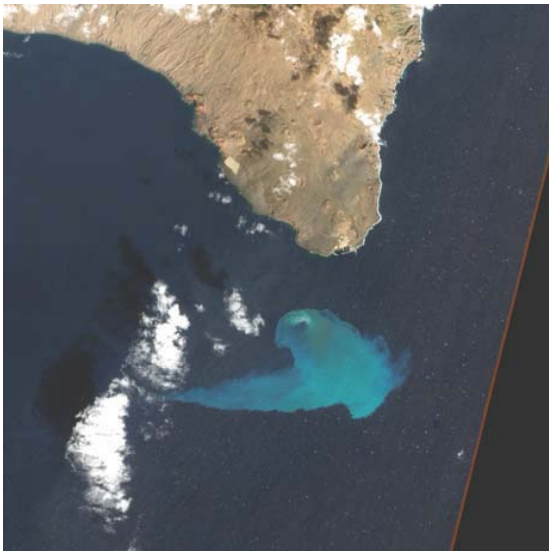


Fig. B5a,b *Satellite images of El Hierro November 2011, showing 'the stain' in the sea above the vent-system of the submarine flank eruption (©Rapid Eye & NASA).*

TABLE B1: Recorded Volcanic Eruptions in the Canary Islands

AD	DURATION		VOLUME	AREA	ISLAND	ERUPTION NAME
	(years)	*(days)*	*km³*	*km²*		
1341					Tenerife	Uncorrelated. Report from maritime accounts
1396	55				Tenerife	Uncorrelated. Report from maritime accounts
1430	34				Tenerife	Taoro (Orotava Valley)
1435	5				Tenerife	Uncorrelated. Report from maritime accounts
1444	9				La Palma	Uncorrelated. Montaña Quemada
1492					Tenerife	maritime accounts
1585	101	84	0,016	3,7	La Palma	Tajuya - Jedey
1646	61	78	0,029	7	La Palma	Montaña Martin
1676-1677	30	6	0,025	4,5	La Palma	San Antonio (not San Antonio cone)
1704	27	13	0,027	6,7	Tenerife	Siete Fuentes (Fasnia - Güímar)
1705	8				Tenerife	Siete Fuentes (Fasnia - Güímar)
1706	1	9	0,066	6,5	Tenerife	Montaña Negra
1712	6	56	0,02	10,2	La Palma	El Charco - Montaña Lajon
1730-1736	18	2000	1	150	Lanzarote	Timanfaya (Montañas del Fuego)
1793	57	1	0,02	0,5	El Hierro	Uncorrelated. submarine volcano in El Golfo
1798	5	92	0,012	4,7	Tenerife	Chahorra
1824	26	90			Lanzarote	Tinguatonant Tao
1909	8	10	0,011	1,5	Tenerife	Chinyero
1949	40	38	0,021	4,8	La Palma	San Juan
1971	22	25	0,04	3,1	La Palma	Teneguia
2011	40	>90	in progress	~ 5	El Hierro	Submarine, ca. 200-150 m bsl. off La Restinga

DAY 1 – Miocene Rocks of Gran Canaria: Shield Basalts and Ignimbrites

Highlights

- Era del Cardon: Shield basalt lava flows and basaltic feeder dykes.
- Barranco Argueneguín (at slope): P1-ignimbrite on shield basalts; Zoned ignimbrites and zoned magma chambers; The vitrophyre concept.
- Barranco Arguineguín (on hill): View of Mogán and Fataga ignimbrite succession and extra-caldera fault system.
- Barranco Arguineguín (return towards coast): Magma mixing in P1; Fiamme concept.
- Drive back to coastal motorway towards the West; Potential re-freshment stop in Arguineguín village.
- Barranco Medio Almud: Ignimbrites A, B, C, D, E; Internal ignimbrite stratigraphy determination; Rheomorphic flow and brittle deformation, flow direction.

Start of DAY 1

- Starting point is *Maspalomas*.
- Drive North towards *Las Palmas* on GC-1 (blue).

Set km-counter to zero when entering the motorway.

- Follow signs for *Agüímes.*
- Leave motorway after 21 km at signs for *Exit (Salida) 25* following *Vecindario* and *Agüímes*.
- Follow the road (GC-194) for 2 km, then turn right, still heading for *Agüímes.*
- Keep in the left hand lane. After about 1 km you reach *Cruce de Arinaga*.
- Enter *Cruce de Arinaga* and turn left onto GC-100 (towards *Agüímes*) at the next roundabout. You will follow GC-100 for a little while now.
- After 5 km on GC-100, note Miocene basalt flows and basaltic breccia deposits in road cuts on the right hand side. Follow road up-hill.
- Note more shield basalts on bendy road up to *Agüímes* village. There are light coloured pyroclastic deposits of Miocene age when entering *Agüímes* village to your right.
- Drive through *Agüímes* village on the main road until you hit a major fork. Turn **sharp** left at the fork towards *St. Lucia*.

Set km-counter to zero when leaving *Agüímes*.

- A little less than 1 km after you leave *Agüímes*, follow road towards *Los Corralillos* (GC-551, yellow) at a little fork.
- Drive through landscape of Pliocene basalts (bendy road!).
- Approx. 2.5 km after *Agüímes*, a quarry in Pliocene basalts appears on your right hand side. For basalt enthusiasts certainly worth a brief stop, although note that these are much younger then the Miocene shield basalts we are looking for. Continue on GC-551.
- After another 500 m, another fork, follow GC-551 (yellow).
- About 4.7 km after *Agüímes* you will come across strongly columnar jointed Pliocene basalts on either side of the valley ***(Fig. 1.1).*** These are again relatively young rocks of the Pliocene *Roque Nublo* volcano (DAY 3).

Fig. 1.1 *Columnar jointed Pliocene basalts along GC-551.*

- About 8.3 km after *Agüimes*, 1st major stop ***(Fig. 1.2)***.

Fig. 1.2 *STOP 1.1, Era del Cardon outcrop when approached from Agüimes. Park in lay-by before the outcrop.*

STOP 1.1 Era del Cardon – Miocene Shield Basalts

Location:
[N27º 52' 37.5" W15º 29' 45.42'']

.

- A stack of 8 – 10 lava flows is exposed ***(Figs. 1.3a-c)*** with flows showing top and bottom breccias and high vesicle contents in upper parts of the flows. Average thickness of the flows is below or around one metre. Lava cools while in motion, developing a brittle skin on top, which rolls over to form top and bottom breccias respectively. The centre is still liquid at that point, which is underlined by the bubbles that were still able to migrate upward within the ductile interior ***(Fig. 1.4)***.

Figs. 1.3a,bc *Road section near Era del Cardon with several flat-lying lava flows of the shield-basalt stage.*

Fig. 1.4 *Vesicles in basaltic shield lava. Note vesicles are concentrated at the top of the flows.*

- Several generations of dykes (basalt and picrite) cut the lavas and some of them form sill-like intrusions and off-shoots, especially at the right hand side of the outcrop ***(Figs. 1.5a,b; 1.6a,b)***.
- Dykes trend dominantly 150 – 160º and are therefore radial to the centre of the island. It appears that some lava flows are separated by purple and beige Palaeosol horizons, implying some time in between eruptions ***(Fig. 1.5a)***.
- There is a multiple dyke with country rock screens at the western end of the outcrop ***(Fig. 1.5b)***. Successive batches of magma must have exploited the same fissure pathway over an extended period of time. See how many pulses you can identify?

Fig. 1.5a *Picrite dyke at Era del Cardon that intruded shield basalt lava flows. Note the palaeosol that appears to terminate the dyke.*

Fig. 1.5b *Multiple dyke at Era del Cardon where successive intrusions have exploited the same pathway to the surface.*

Fig. 1.6a *Close-up of small dyke. Note the markedly different texture along the margins relative to the intrusion centre.*

Fig. 1.6b *Close-up of irregular intrusion side that shows pronounced chilled margin against vesicular lava rock.*

- Continue Westward on GC-551. Soon, one is back in Pliocene basalts.
- You will encounter a fork at approx. 10 km after *Agüimes*.
- Park on open space on the right side of road ***(Fig. 1.7)***.

STOP 1.2 Fork at Era del Cardon – Geological Overview

Location:
[N27º 52' 17.5" W15º 29'45.4"]

- Looking North, you will encounter a very useful overview section of shield basalts at the base overlain by light coloured Miocene pyroclastic units, which are, in turn, unconformably overlain by Pliocene lavas and deposits of the Roque Nublo cycle (brown in colour) ***(Fig. 1.7)***.

Fig. 1.7 *Fork at Era Del Cardon; shield basalts at base are overlain by Miocene pyroclastic rocks and a brown Roque Nublo (Pliocene) cover sequence.*

- From here you have two options. You can either continue down the stratigraphic route to *Sardina* (GC-65, red) or explore a diversion, that is not strictly stratigraphical, but several superb outcrops of felsic Miocene strata can be seen along the road to *St. Lucia* GC-65 (red). If you prefer the stratigraphic route, please go to page 37.

Alternative Route:
Miocene Strata Near St. Lucia

- Follow GC-65 to *St. Lucia*. Note *St. Lucia* is the bendy road uphill whereas *Sardina* is the bendy road downhill.
- Drive uphill into Miocene pyroclastic rocks and cross over into the next barranco some 2.5km after the last fork. Follow bendy road, but drive carefully!

- Stop at a little lay-by right after km 14 on the GC-65 road sign ***(Figs. 1.8a,b)***.

Figs. 1.8a,b *Mogán-aged ignimbrite 'Vi' is exposed in steep orientation here, implying deposition on a slope!*

STOP 1.3 Road to St. Lucia – Valley-fill Ignimbrite

Location:
[N27º 52' 09.1" W15º 30' 32.5"]

- Here, a densely welded ignimbrite of lower Mogán Age (Vi) overlies a Miocene debris avalanche / breccia deposit. Note a dark vitrophyre at the base of the ignimbrite. The vitrophyre is dipping steeply towards the valley floor, implying one is located on the flanks of a palaeo valley. The main body of the ignimbrite shows steep foliations that also dip generally towards the valley floor. Striations on bedding planes (140º), are parallel to the axis of the present barranco, implying transport along a course of a palaeo-valley of similar orientation to the present-day barranco ***(Figs. 1.9a-d)***.

Fig. 1.9a *Steeply inclined pyroclastic deposits suggest a pre-eruptive topography and a high energy depositional regime.*

Fig. 1.9b *Exposure of 'Vi' ignimbrite at STOP 1.3. Note the unit dips toward you. You are on a Miocene valley flank ... and on a present day one as well.*

Fig. 1.9c *Internal fabric (folded) in 'Vi' ignimbrite.*

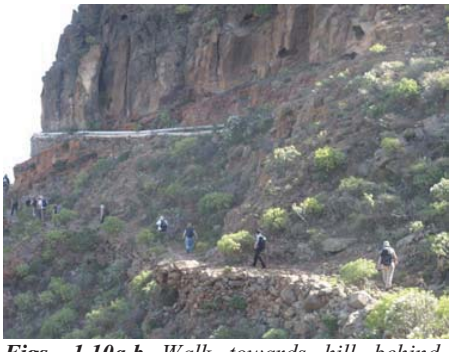
Fig. 1.9d *Exposure of striations in 'Vi' ignimbrite at STOP 1.3 that give a sense of transport direction.*

- Return to car and continue on GC-65 towards *St. Lucia*.
- After only a short drive, enter a dirt track to your right and park on the open space to your left.

STOP 1.4 Mt. Carboneras – Mogán Ignimbrites

Location:
[N27º 52' 32.0'' W15º 30' 36.8'']

- The hill behind the parking ground is called *Mt. Carboneras*. From here you can follow a small dirt track to the NNW (on foot), into the valley, until you see two white water pipes in the rock face to your right, below which you will find narrow walking path ***(Figs. 1.10a,b)***.



Figs. 1.10a,b *Walk towards hill behind parking space, where a white water pipe is visible in the hillside.*

- Follow this path for about 5 minutes until you meet an outcrop of Mogán ignimbrites with a pronounced vitrophyre at base.
- Note: The draping of the ignimbrite over the palaeo-landscape with steep dips toward the palaeo-valley that must have been to the East ***(Figs. 1.11a,b).***

Fig. 1.11a *Mt. Carboneras outcrop.*

Fig. 1.11b *Steeply inclined vitrophyre of ignimbrite 'TL', resting on a poorly sorted gravel deposit.*

- This indicates that much of the deposition of ignimbrites occurred in valleys, consistent with the ground – hugging nature of historically observed ignimbrite deposits (e.g. Augustine, Alaska).
- Follow path around corner until you find only partly altered vitrophyre ***(Fig. 1.12)***.
- Note the extremely strong welding in the ignimbrite above and the "former valley gravel" deposit below ***(Fig. 1.13).*** Return to car.
- Return to the road and turn right. Drive for 600 m toward *St. Lucia* and enter a parking space on the left (*Mirador El Guriete*) ***(Fig. 1.14).***

Figs. 1.12 *Vitrophyre remnants in clay matrix at base of ignimbrite 'TL'. Note gravel and blocks below the clay layer.*

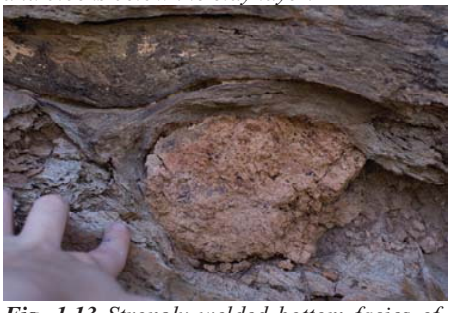


Fig. 1.13 *Strongly welded bottom facies of the ignimbrite with solid clast enclosures (lithics), likely 'picked up' from gravel layer below.*

Fig. 1.14 *Park at Mirador El Guriete for STOP 1.5.*

STOP 1.5 Mirador El Guriete – Mogán Ignimbrites in Valley Flank and Roque Nublo Valley Fill

Location:
[N27º 52' 32.5" W0.15º 30' 36. 8"]

- Walk down a little path (3 minutes).
- In the background on the other side of the valley, you will see a thick package of Miocene Mogán and Fataga ignimbrites that are disrupted along a caldera periphery fault system. Note that the upper units (Fataga) are not faulted.
- This fault belt strikes parallel to the caldera. The actual caldera margin, however, can be found several kilometers further into the island on the road to *St. Lucia*.
- In the foreground though, are elongate ridges that rise from the valley floor. These are remnants of the Pliocene Roque Nublo-type lavas and sediments. This implies that major barrancos on the island got filled and eroded several times, in the Miocene, in the Piocene and again as the recent valley system of the island ***(Figs. 1.15a,b)***.
- Return to the car and then to the *Era del Cardon* fork, i.e. do **not** continue toward *St. Lucia*.
- When at *Era del Cardon* fork, follow GC-65 (red) to *Sardina* (downhill to your right).

Figs. 1.15a,b *Roque Nublo-ridge in Miocene valley at Mirador El Guriete.*

- Drive through the villages on GC-65 to motorway GC-1, e.g. through the outskirts of *Vecindario,* heading back towards *Maspalomas*.

  Note: Close to the Motorway you have to turn right and drive parallel to the motorway for a while before being able to join it.

  Set km-counter to zero when entering the motorway!

- Drive towards the South for 27.5 km, passing *Maspalomas* on the way!
- Turn off for *Arguineguín* after 27.5 km and two major tunnels (GC-500 green; Exit 56).

- Just outside *Arguineguín* turn off to the main road to the right and drive over a little bridge that goes over the road you just came from. Set km to zero again.
- After about 1 km, turn left again at another roundabout ***(Fig. 1.16)***. Drive towards *Cercados Espino* GC-505 (yellow).

Fig. 1.16 *Cercados Espino turn.*

- You should be passing a brown to cream-coloured, pumice-rich pyroclastic deposit of Fataga age, overlain by a more typical 'green' Fataga welded ignimbrite deposit.
- After approximately 1.4 km into the barranco, you will pass a major quarry on the right hand side. This delivers pumice-rich rock aggregate as raw material to the cement works in *Arguineguín* village (from non-welded ignimbrite). Continue up *Barranco Arguineguín* and note greenish Fataga phonolite ignimbrites on either side of the valley now.
- Now you will be driving along the bottom of a major barranco with Fataga deposits on either side. Note the gentle dip of these units towards the coast, implying that we are driving into older units as we drive along the rather horizontal barranco floor.
- About 11.3 km into the barranco, you will meet a fork, go left towards Soria.
- Approximately 1.5 km after La Filipina (~ 14.6 km into barranco), park the car in a sharp curve that is running uphill, so that your car is visible by road users from both sides (STOP 1.6) ***(Figs. 1.17a-c)***.

Figs. 1.17a,b,c *Parking for STOP 1.6.*

STOP 1.6a Barranco Arguineguín – 'P1' Ignimbrite

Location:
[N27° 52' 32'' W15° 40' 17.1'']

- First uphill bend on GC-500 after village of La Filipina.
- The rock exposed in the road section is 'P1' – vitrophyre. At the base of the outcrop, just slightly above the tarmac, you will find a black vitrophyre, the initially chilled horizon when a hot ash-flow meets the cold substrate ***(Figs. 1.18a-d)***.
- The main body of the ignimbrite, in turn, is made of a pinkish-ash-rich matrix and a very high percentage of feldspar crystal (fines-depleted?)
- The high crystal content is astonishing and it seems plausible that strong winds have removed fine ash from the eruptive cloud(s), producing a crystal enriched near vent deposit. Note the dark lumps of basalt scattered throughout the outcrop. These are enclaves of a more basaltic magma mixed into the erupted material at depth ***(Fig. 1.18d)***.

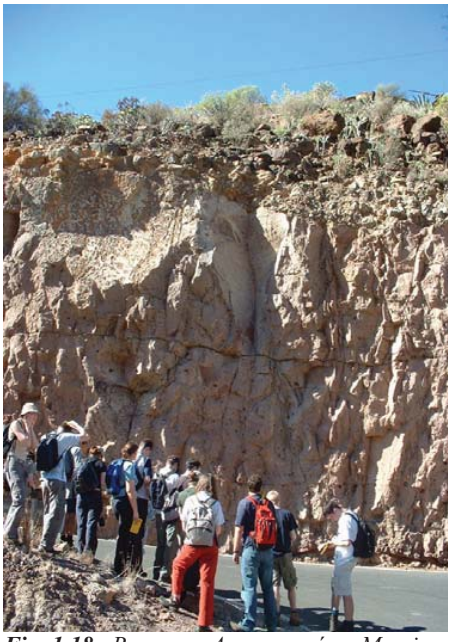


Fig. 1.18a *Barranco Argueneguín – Massive deposit of P1 rhyolite ignimbrite.*

Fig. 1.18b *Note the considerable thickness of the deposits.*

Fig. 1.18c *At road-level part of the basal vitrophyre is exposed.*

Fig. 1.18d *'P1' ignimbrite with mafic blobs. Also note the crystal-rich nature of the main ignimbrite deposit.*

STOP 1.6b Barranco Arguineguín – 'P1' Ignimbrite

- Walk down towards *St. Filipina* village for about 300 m. Note the basalts underlying 'P1' are shield basalts again ***(Figs. 1.19a-d)***.

Fig. 1.19a *Upper Barranco Arguineguín. Walk back for a few steps and turn into a small road to your left.*

Fig. 1.19b *'P1' in valley floor, Upper Barranco Arguineguín, underlain by shield basalts.*

Fig. 1.19c *Walk down the little paved road.*

Fig. 1.19d *Down in the valley, walk towards inclined 'P1' deposits on the left hand side of the valley slope.*

- Enter a little road towards valley bottom (Sharp left-hand turn)
- After another 300 m at little bridge you can see 'P1' dipping towards the valley floor. 'P1' is thus also a characteristic ground hugging valley infill deposit.
- Follow the little road and a few 100 m ahead, a base of shield basalt is overlain by pink 'P1' on your left. Continue uphill for a few steps until you come to a small but wide cave in the rock face.

Location:
[N27º 52' 45.3" W15º 40' 15.4"]

- At this location you will find P1 vitrophyre again ***(Fig. 1.20).***
- Walk uphill from the cave and observe changes in 'P1' composition. Note increasing amount of basaltic enclaves are present on the way up until 'P1' grades into a fully basaltic whole-rock composition.
- No boundaries between the various compositions are observed, implying that the different lithologies come from the same, compositionally zoned, magma chamber. Then, the low-density felsic magma would reside high up in such a chamber and erupt first. Denser, mafic magma would reside lower in this chamber and hence erupt later ***(Fig. 1.21)***.

Fig. 1.20 *Just at the little cave you will pick up the base of ignimbrite 'P1' again, but now a little lower down in the valley.*

Location:
[N27º 52' 49.1" W15º 40' 13.7"]

Fig. 1.21 *Zoned liquids in scaled container. This is a 'Cafe Cortado leche leche' and contains milk-foam, coffee and condensed milk, forming density-specific layers. A bit like different magmas in a magma chamber. Try one yourself.*

- Return to car.
- Drive up bendy road, climbing through Mogán ignimbrite succession.

- About 2 km after the last stop, (or ca. 16.5 km into the barranco) you will find a spectacular exposure of a vitrophyre on your right hand side in the passing road section. This vitrophyre separates ignimbrite 'O' from the one below. Note the undular nature of the contact, suggesting an uneven substrate onto which the ignim-brite was layed down ***(Fig. 1.22)***.

Fig. 1.22 *Basal vitrophere of ignimbrite 'O', Barranco Argueneguín.*

- Continue on this road uphill until you find a larger open area on a plateau on your right hand side (~4 km after last stop). Park your car here.

STOP 1.7 Barranco Arguineguín – Overview Mogán-Fataga Succession

Location:
[N27º 53' 08.1" W15º 40' 39.6"]

- On the front of the plateau an extra-caldera Fault in Mogán units is visible in the Eastern barranco wall. In turn, Fataga units (on top) are undisturbed, implying that caldera movements largely stopped before the end of the Fataga period ***(Figs. 1.23a,b).***
- Also note the Roque Nublo valley fill to your left ***(Fig. 1.23c)***.

Fig. 1.23a *View of the East-Wall of Barranco Arguineguín with full succession of shield basalts, Mogán and Fataga ignimbrites.*

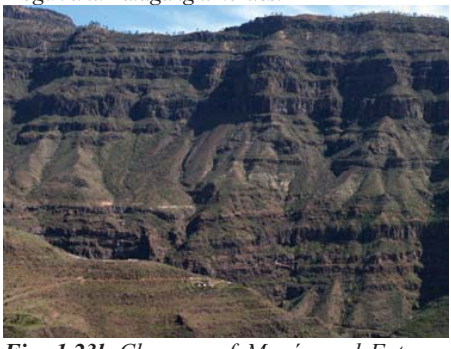


Fig. 1.23b *Close-up of Mogán and Fataga succession. Not the offset of units in the lower part of the photo (Mogán Group) that is absent in the higher units (Fataga Group).*

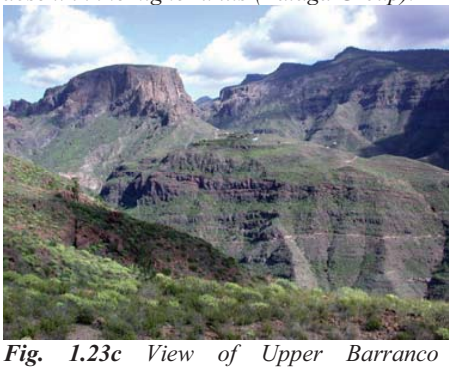
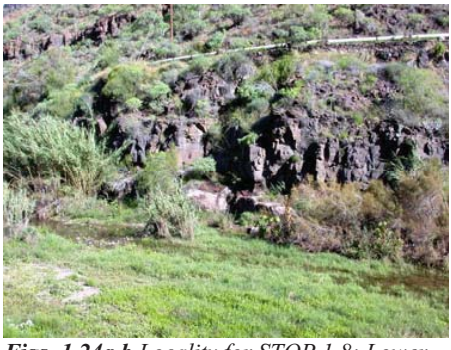


Fig. 1.23c *View of Upper Barranco Arguineguín. Note hill in far left is Pliocene Roque Nublo-type valley infill.*

- Turn around and return same way to barranco bottom!
- About 8.8 km after one passes 'P1' in the sharp bend on the return drive (STOP 1.6a), look for a flat area on the left hand side where a water pipe almost meets the road ***(Figs. 1.24a,b).***
- Park a few meters further on in a little lay-by and walk back for about 100 – 150 m onto flat ground next to the road ***(Figs. 1.24a,b)***. There, we have 'P1' composite ignimbrite exposed, displaying spectacular mixing of the individual layers.



Figs. 1.24a,b *Locality for STOP 1.8; Lower Barranco Arguineguín.*

STOP 1.8 Lower Barranco Arguineguín – Zoned Ignimbrite 'P1' with Mixing Features

Location:
[N 27º 48'27.9'' W15º 40'03.3"]

- Note the veins of the lower units intrude into the upper basaltic units. This implies that the lower rhyolite was still plastic at the time the basalt was deposited, implying them to be 'co-magmatic' and thus likely from the same eruptive source and event. ***(Figs. 1.25a-c)***.
- For those that want to take a break, continue on GC-500 (green) into *Arguineguín* village. This is also the recommended route as it offers breathtaking coastal expo-sure of Mogán and Fataga Ignimbrites.
- A quick break in *Arguineguín* can be taken at the petrol station that offers petrol and a decent coffee-shop with simple bathroom facilities.

Fig. 1.25a *Outcrop of zoned 'P1' deposit in lower Barranco Arguineguín.*

Fig. 1.25b *Lower rhyolite layer of 'P1' intruded the more mafic layers above, indicating the felsic and mafic compositions were co-magmatic (i.e. liquid at the same time).*

Fig. 1.25c *Plan view of the lower rhyolite intruding into the more mafic (reddish) middle part of the deposit.*

- Continue on GC-500 towards *Puerto Rico*, first through the southern holiday resorts, but also along breathtaking coastal exposures of the Miocene Mogán ignimbrite succession.
- Just after *Puerto Rico* below a major cliff, are superb exposures of ignimbrite 'E' (Upper Mogán Group). Here, you will see a beautiful sandy beach – *Playa de Amadores*. Virtually all of the sand at this beach has been shipped in from the Sahara, though.
- Around the next cliff nose you will enter the mouth of *Barranco Tauro*. Note the pebbly and boulder-rich beach here. This is the more natural appearance of beaches in the Canaries.
- Soon after entering *Barranco Tauro* you will meet a roundabout. Go left towards *Mogán* when coming from the coastal road, and go right when coming from motorway (short route).
- Continue on GC-500 (green) for about 2.5 km and park at the mouth of *Barranco Medio Almud.*

STOP 1.9 Barranco Medio Almud – Zoned Ignimbrite Deposit 'A'

Location:
[N27º 48' 31.0'' W15º 44' 15.8'']

- The reddish/brown exposure to your right is Ignimbrite 'A' of the Upper Mogán Group ***(Figs. 1.26a,b)***.

Fig. 1.26a *Ignimbrite 'A' exposure at STOP 1.9; Barranco Medio Almud.*

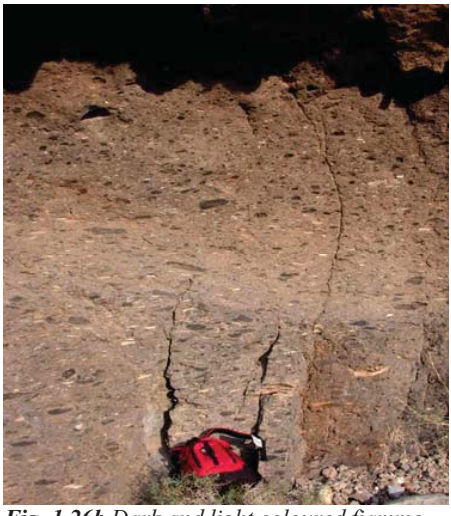


Fig. 1.26b *Dark and light coloured fiamme in ignimbrite 'A'.*

- This ignimbrite is characterised by dark and light fiamme in a finer ash matrix ***(Fig. 1.27)***. Feldspar content is highly variable with more complex and abundant types in the dark fiamme. Time to think about crystal settling and zoned magma chambers. How would you 'put the unit back' into the magma chamber?
- Also, note the major 'flow unit boundary' within the exposure. Although very similar in composition above and below this boundary, a pause in eruption and a high-energy new pulse is the most probable explanation ***(Figs. 1.27a,b)***.

Fig. 1.27a *Note the internal boundary within ignimbrite 'A'.*

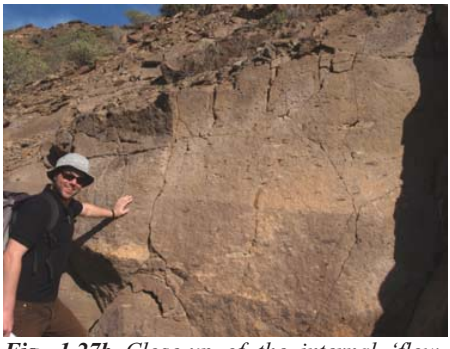


Fig. 1.27b *Close-up of the internal 'flow unit boundary' within ignimbrite 'A'.*

- Walk up towards the tunnel – note greenish densely welded ignimbrite above 'A'. This is ignimbrite 'B' – separated from 'A' by a pronounced vitrophyre ***(Fig. 1.28)***. This vitrophyre, however, is largely altered to clay ***(Fig. 1.29a)***. Note the rotated clasts and the flow fabrics in 'B' and the sparcity of crystals it contains ***(Fig. 1.29b)***.
- Continue up road to next vitrophyre (base of ignimbrite 'C').

- Cross to the other side of the road. Look at exposure from a distance and you shall see vertical reddish stains, probably fossil fumaroles that have degassed volatiles from the hot deposit, similar to the valley of 10,000 smokes, perhaps ***(Fig. 1.29c)***.
- Walk up the road to just before the tunnel and continue walking up the dirt track to the right.

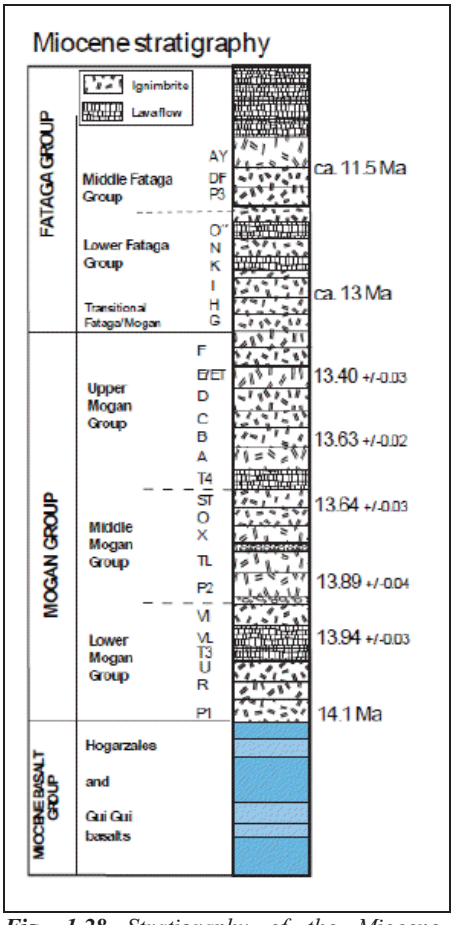


Fig. 1.28 *Stratigraphy of the Miocene ignimbrite succession on Gran Canaria (from Hansteen and Troll 2003, after Sumita and Schmincke 1998).*

Fig. 1.29a *Ignimbrite 'B' resting on ignimbrite 'A'. Note vitrophyre (clay-rich) at base of ignimbrite B.*

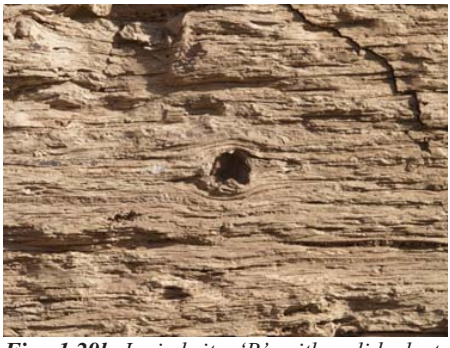


Fig. 1.29b *Ignimbrite 'B' with solid clast now weathered out. Note 'B' is very crystal-poor.*

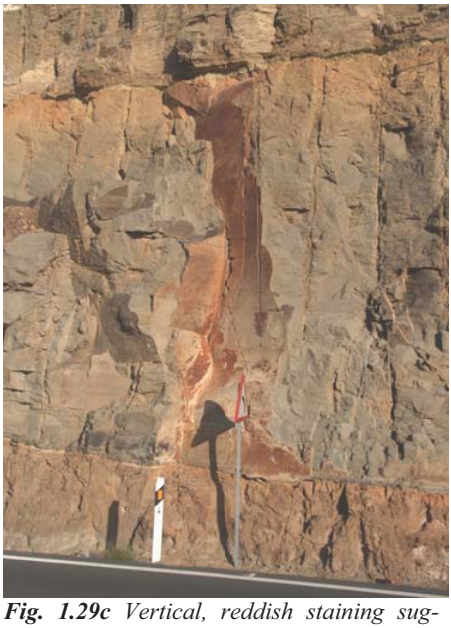


Fig. 1.29c *Vertical, reddish staining suggests fossil fumaroles activity in ignimbrite 'C'.*

STOP 1.10 Barranco Medio Almud – Ignimbrite 'D'

Location:
[N27º 48' 27.0'' W15º 44' 16.1'']

- The ignimbrite there is ignimbrite 'D'. Note rotational clasts, dense welding and the fair number of plutonic fragments such as syenites and gabbros that must have been ripped out from the chamber and conduit walls of the original magma reservoir at depth ***(Fig. 1.30)***.
- Note also the horizontal flow unit boundary exposed boundary in ignimbrite 'D'. Locally these truncate fiamme, suggesting several pulses or units that make up the individual deposit of an ignimbrite.

Fig. 1.30 *Syenite clast in densly-welded ignimbrite 'D'. Note compaction and rotation features around the syenite clast.*

STOP 1.11 Barranco Medio Almud – Ignimbrite 'E'

Location:
[N 27º 48' 17.9'' W15º 44' 17.8'']

- Continue up track until next vitrophyre (ignimbrite 'E'). This unit displays dense welding, abundant and much flattened white pumices with abundant 'tension gashes', a rheomorphic flow features that indicates post-depositional down-slope movement in the still plastic state ***(Figs. 1.31a-d).***

Fig. 1.31a *Very long fiamme with tension gashes in ignimbrite 'E'.*

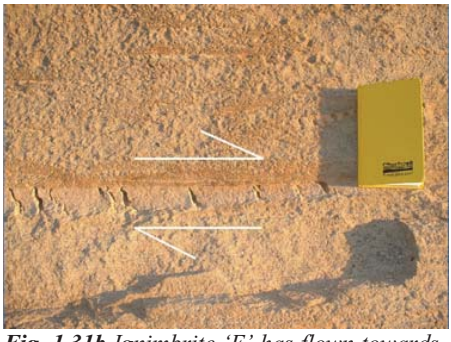


Fig. 1.31b *Ignimbrite 'E' has flown towards the sea! Note the open the 'tension gashes'. A flow of top to the right is needed.*

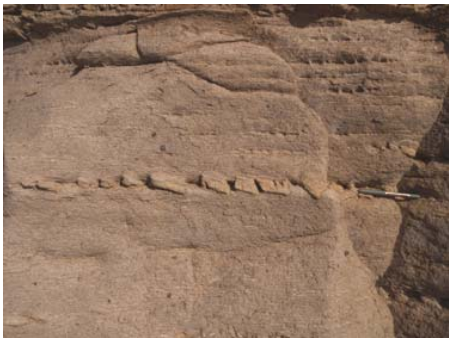


Fig. 1.31c *Tension gashes in fiamme of ignimbrite 'E'. Note that this fiamme is now largely broken up.*

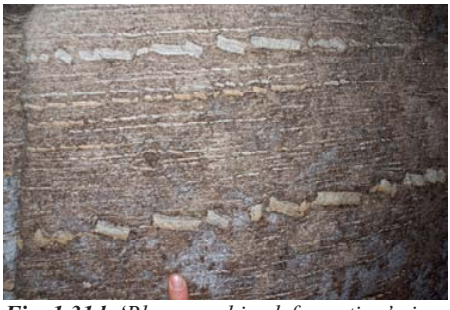


Fig. 1.31d *'Rheomorphic deformation', i.e. post-depositional plastic flow, can break up fiamme entirely and rotate them due to stretching and down-slope movement.*

- Continue to walk to top of cliff nose. Note trachytic unit (peaks) in upper part of ignimbrite 'E'. This ignimbrite is in fact another example of the compositional zoning of magma chambers, which must have given rise to these highly explosive eruptions back then in the Miocene ***(Fig. 1.42)***.

Fig. 1.32 *Looking uphill, you can see the dark trachyte top of ignimbrite 'E' that stands in strong contrast to its light-coloured rhyolitic base. Another vertically zoned ignimbrite!*

STOP 1.12 Barranco Medio Almud – Ignimbrite 'E' Sunset

Location:
[N27º 48' 13.2'' W15º 44' 19.5'']

- If your timing is right and the weather plays along you will find yourself now watching a beautiful sunset ***(Figs. 1.33a,b)***. You might even find the silhouette of Teide on the far western horizon.

Fig. 1.33a *At the end of the path, sunset should now come any second.*

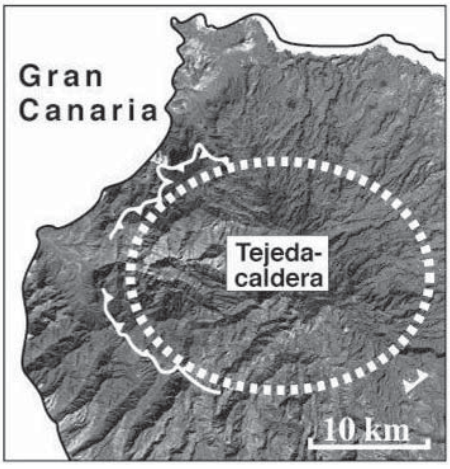
Fig. 1.33b *Sunset at last. Enjoy the end of a long day!*

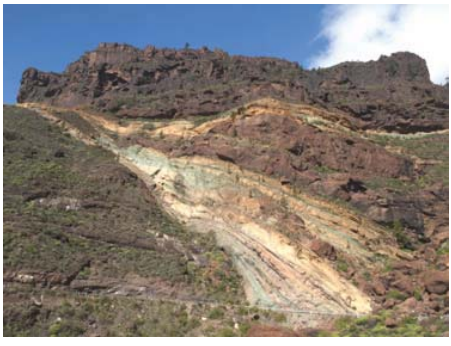
End of DAY 1

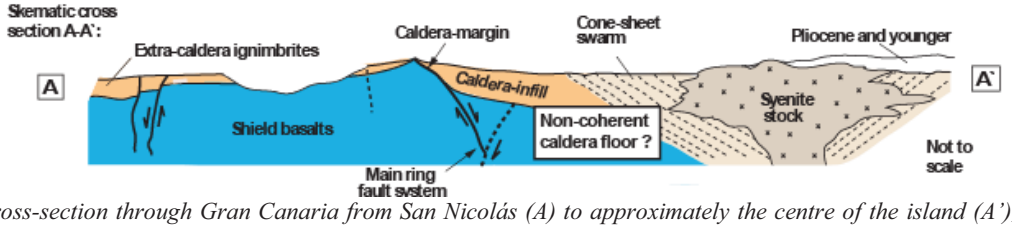
DAY 2 – The Miocene Tejeda Caldera

Highlights

- Los Azulejos; Caldera margin and hydrothermal-alteration.
- Radial feeder dyke with mafic enclaves (from distance). Disintegration of magma in conduit.
- Lunch in St. Nicolás.
  Drive into La Aldea towards Artenara (into the central part).
- Intra-caldera: Cone sheet intrusions and intra-caldera-fill deposits.
- Intra-caldera syenite intrusion.
- View Miocene-Pliocene unconformity – end of Miocene (Artenara road)!
- Return same route or, if time left, go across the island to the North-East.







Cross-section through Gran Canaria from San Nicolás (A) to approximately the centre of the island (A'), i.e. approximately West-East (from Troll et al. 2002).

Start of DAY 2

Set km- counter to zero when leaving.

- You can either take the motorway to *Mogán* and *Puerto Rico* GC-1 (blue) or the more scenic route along the coast from *Maspalomas* to *Arguineguín/ Puerto Rico* GC-500 (green).
- If you choose to drive along the coastal road (recommended), you will soon drive through a golf resort, before extensive Miocene conglomerates, breccias and ignimbrites give a glimpse into the dynamic erosional and eruptive processes that shape an ocean island ***(Figs. 2.1a,b)***.
- We shall come back to the relevance of this major upper Miocene erosion episode later in the day. Note that the beaches here are very popular with tourists and locals alike. These are natural beaches, i.e. with boulders and pebbles, not 'imported' ones.
- After a few kilometers the *Arguineguín* cementworkS will become visible in the distance (front left) ***(Fig. 2.2)***.
- Around the level of the cementworks, a complex intercalated sequence of conglomerates, Fataga-age pyroclastic deposits and local debris avalanches is visible in the road cuts to your right.
- Join Motorway to Mogán GC-1 or drive into *Arguineguín* to enjoy a morning coffee.

Fig. 2.1a *Extensive Miocene conglomerates along GC-500.*

Fig. 2.1b *Close-up of Miocene conglomerates with mainly pebbles of ignimbrite and some basaltic rocks.*

Fig. 2.2 *Once the Arguineguín cement works come in sight, you are within Miocene Fataga Group pyroclastic deposits that are intercalated with the conglomerates.*

- Continue on GC-1 (blue) towards *Puerto Rico-Mogán*.
- Soon you will pass a spectacular series of Fataga ignimbrites to the left and right along the motorway in a relatively new

road sections. Also note extensive debris avalanche and debris flow deposits of similar age that are intercalated with the pyroclastic units.

- After driving through four short tunnels you will reach the termination of the motorway. At the first roundabout, take the 1st right and stay on GC-500 green for direction *Mogán* (after ca. 18 km from Maspalomas).
- At the next roundabout drive to the right, following signs for *Taurito/Mogán* (still on GC-500).
- Drive by *Barranco Tauro* and then *Barranco del Cura*.
- At km 39 on GC-500 go through a short tunnel.
- Drive past *Barranco El Medio Almud*, where we have inspected ignimbrites the day before (STOP 1.9).
- Go through another small tunnel and pass *barranco Tiritaña*.
- After a few more kilometers, you should find *Barranco Taurito* to your right (km 42 on GC-500 road signs).
- Drive carefully on bendy coastal road, while enjoying the view. After another 2-3 km, the road will decent into a valley, now with direction inland and you are at the mouth of *Barranco de Mogán*.
- At the 1st roundabout in *Barranco de Mogán*, turn right for *Mogán* (GC-200 green) <u>not</u> *Puerto de Mogán* (now approx. 27 km from start of journey).
- At km 63 on GC-200 road sign, pass through village *Los Palmitos*.
- After another 3 - 4 km (km 60 on GC-200 road sign) pass through *Las Casillas* and *Molina de Viento* villages. Note the giant furniture and kitchen utensils, designed by a German ex-patriot who lives on the island for many years.
- Drive past a traditional windmill to your left (*Molino*) and continue through *El Tostador* village.
- At km 59 on GC-200 road sign you will reach *Mogán* village itself. This is the type locality for the Mogán group ignimbrites of DAY 1 (e.g. the cliffs to your far right are made of "Mogán ignimbrites").
- Follow GC-200 until signs for *Veneguera* and *La Aldea* appear at approximately 56 km road-sign on GC-200. You are now back in old shield basalt rocks that underlie the ignimbrites as you were driving inland, reasonably on flat ground.
- Continue on GC-200 towards *Veneguera/La Aldea*. The road soon gets very bendy and will bring you uphill again. You are advised to drive with caution in this part of the island.
- Continue for a while on GC-200 until you see spectacular views of colourful hydrothermally altered rocks at *Fuente de Los Azulejos* in the distance ***(Fig. 2.3).***

Fig. 2.3 *Caldera margin (Mt. Horno) viewed from the South. Note the strong colours of green, orange and cream in the hillside.*

- A little after km 51 on GC-200 road sign, a major dyke intrusion is cut by the road. A small lay-by to your left opposes the outcrop ***(Figs. 2.4a-d)***.

STOP 2.1 South-West Gran Canaria – Mogán Rhyolite Dyke

Location:
[N27º 54' 50.1" W15º 43' 46.0"]

- The dyke is rhyolitic in composition and of Mogán age and strikes radial to the centre of the island (i.e. to the central caldera). Note the abundant feldspar crystals and the steep flow banding in the dyke ***(Fig. 2.4c)***.
- Continue on GC-200. Only a few km further, a major stop of the day approaches.

Fig. 2.4a *Approaching STOP 2.1. Park on the left hand side in the lay-by.*

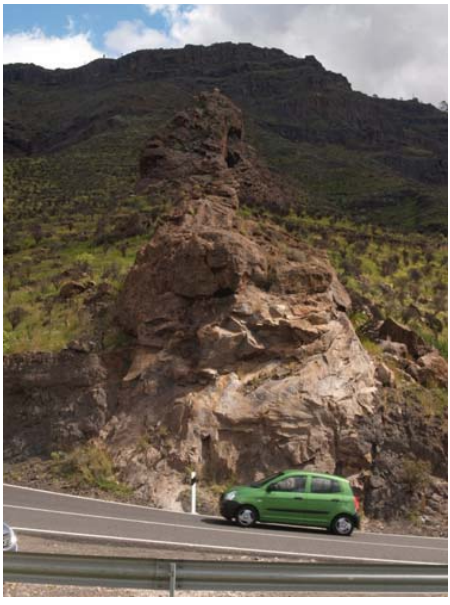


Fig. 2.4b *Mogán rhyolite dyke in road section. Please be careful when crossing the road.*

Fig. 2.4c *Dyke rock in detail. Note the steep banding, indicating magma flow and abundant feldspar crystals.*

Fig. 2.4d *Looking uphill where the intrusion thickens.*

- Km 49 on GC-200 road sign) This spot (*Fuente de los Azulejos*) also offers itself for a refreshment stop ***(Fig. 2.5).***

Fig. 2.5 *Topographic caldera margin at Fuente de Los Azulejos. Shield basalts to the lower left are unconformably overlain by steeply dipping intra-caldera Mogán-aged tuffs. Note the progressive shallowing of the intra-caldera deposits to a flat geometry on top of the pile.*

STOP 2.2 Fuente de Los Azulejos – Hydrothermal Alteration at Caldera Margin

Location:
[N27º 55' 27.0'' W15º 43' 40.4'']

- Looking north-west from the parking place you will see semi-horizontal shield basalts in unconformable contact with Mogán age ignimbrites to the right. Note the steep dip of the tuffs near the contact and their thickness increase further to the right. This is the topographic margin of the central Miocene Tejeda caldera. Note it is not the caldera fault itself, but an erosional margin of the caldera perimeter that got eventually covered.
- Higher up on the right hand side, the dips of the units tend to shallow out, implying the basin got successful filled with tuffs at that time.
- The sequence is covered by massive green to brown Fataga ignimbrites that are flat-lying and unaltered, giving an age constraint to the alteration event (12.5 My in this case).
- Two large brownish units appear within the altered rocks. These are likely to be sill intrusions of Fataga age or major ignimbrites that have escaped alteration (perhaps due to high compaction?). However, their convex up-ward shape indicates intrusive inflation and the former idea may be more likely.
- The entire side is also a classic case of relief inversion where the younger rocks are found at higher altitude although they had previously been in a lower topographic position (the basin fill now).

- The vivid colours of the tuffs are characteristic for low-temperature hydrothermal alteration due to extensive fluid flow in the faulted caldera marginal areas. A variety of hydrothermal minerals are present, such as clays, zeolites, micas and chlorite as well remnants of the original rock composition ***(Figs 2.6a,b; 2.7).***

Fig. 2.6a *Hydrothermally altered tuffs show a variety of vivid colours and internal textural features.*

Fig. 2.6b *Take a little walk into the small gorges to inspect the full range of features exposed.*

- Ignimbrite relicts that escaped this alterations event can be found a few steps further along the road:

Location:
[N27º 50' 23.0" W15º 43' 35"]

Fig. 2.7 *Close-up of hydrothermally altered intra-caldera tuffs at Fuente Los Azulejos. Note how the colours grade into each other, indicating a complex alteration mineralogy.*

- Here, in a drainage pit, an ill-defined lens of still glassy ignimbrite is found that escaped extensive overprint (maybe due to locally high compaction and welding) and the transition from altered to fresh can be studied in detail ***(Fig. 2.8).***

Fig. 2.8 *Hand specimen of glassy obsidian lens in hydrothermally altered tuffs at Fuente de Azulejos. (Courtesy of E. Donoghue.)*

Location:
[N27º 55' 26.5'' W15º 43' 41'']

- Walk to N-NW along the road (300 m). Here you will see the contact between the shield basalts and the caldera-infill tuffs. Note the large number of

'pick up' clasts here and a spectacular pinkish fiamme near this spot (set in a green ash matrix).

- This fiamme displays internal flow folding. Both, way up (out of caldera) and way down (into caldera) are indicated, implying that many of these tuffs had a hard time to escape from the caldera, with only the bigger eruptions producing extra-caldera outflow deposits as well ***(Figs. 2.9a-d)***. If you are keen, several small footpaths lead up these cliffs for some great views.

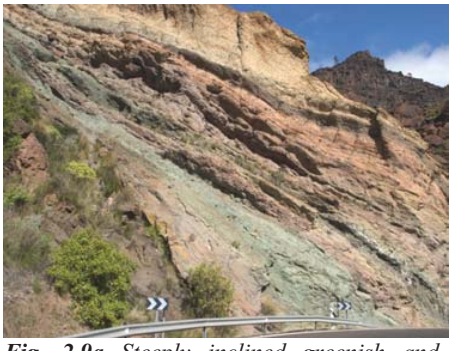


Fig. 2.9a *Steeply inclined greenish and cream coloured ignimbrites at caldera margin.*

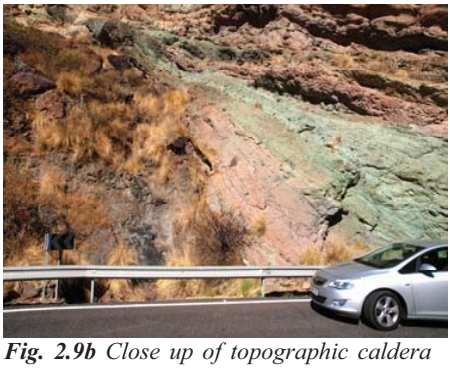


Fig. 2.9b *Close up of topographic caldera margin.*

Fig. 2.9c *Intense colouration and alteration rims around accidental fragments (lithics) and fiamme are superbly exposed here.*

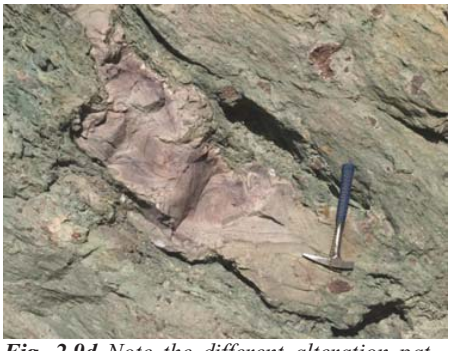


Fig. 2.9d *Note the different alteration pattern of the host-tuff (green) and the more solid fiamme. The fiamme shows flow structures that indicate back-flow into the caldera.*

- Continue on GC-200 towards *San Nicolás/La Aldea*. Soon the road will climb uphill again.
- Only a short distance further at ca. km 45.5 on GC-200 road signs, on the ridge to *Barranco de Tasarte (*up on little hill) you may view the dyke from the earlier road cut in a distance. Park in small lay-by just after the crossover to the next barranco ***(Fig. 2.10).***

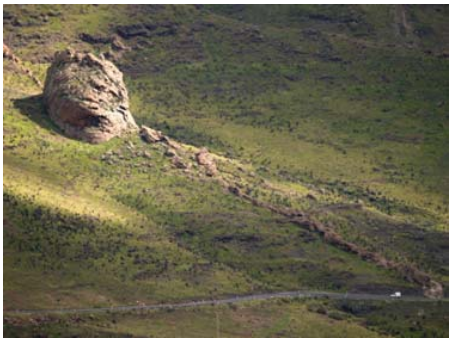
Fig. 2.10 *Crossover from Barranco de Mogán to next barranco (Barranco de Tasarte).*

STOP 2.3 West-Gran Canaria – Mogán Dyke Intrusion Viewed from Distance

Location:
[N27º 55' 33.4'' W15º 44' 51.1'']
(Altitude ca. 670 m asl)
(parking)

- The dyke shows giant magma mixing and fiamme features that seem to have been caught in the process of disintegration during conduit transport ***(Figs. 2.11a-c).*** Unfortunately, most of the mafic material is now weathered out, leaving big holes in the dyke. Also note the late plug, in the distance, which seems to have channelled the final part of the eruption. Plug-flow is considered to be the less energy demanding type of flow as opposed to dyke flow ***(Figs. 2.12a-c).***

Figs. 2.11a,b,c *Rhyolite dyke with large holes – weathered out large mafic enclaves.*



Figs. 2.12a,b,c *Looking back, the dyke can be traced all the way to the caldera rim and it shows a late, semi-cylindrical plug close to the caldera.*

- Continue on GC-200 for some time now. After the next major ridge, you will descent again – now into *Barranco La Aldea*. If the weather permits, you might catch a glance of Northern-Tenerife (Anaga) in the far distance. The rocks you are passing now are shield basalts but, in places covered by recent rock fall debris.
- When GC-200 meets a T-junction in the outskirts of *San Nicolás* (km 35 on GC-200 road sign), turn right into GC-210 (green) towards *Artenara*.
- You may want to consider lunch in the lovely old village core of *San Nicolás*. Then drive towards the church and park there.
- Otherwise, drive toward centre for 1 kilometer and turn right at 1st roundabout continue to follow signs for *Artenara* GC-210 (green).
- Turn left at next roundabout, still following GC-210 (*Artenara*).
- After only a few blocks you will meet another T-junction. Go right and 10m after that go left again, still following GC-210 signs.

Note: **Some signs are old and give obsolete road numbers, which can be a little confusing.**

- Once you have left *San Nicolás,* continue to drive on a narrow road into *Barranco La Aldea* following signs for Artenara.
- After about 1 km, a bridge crosses a small river which is generally dry in summer (just after km 33 on GC-210 road sign). After only another 0.5 kilometers you will cross the same river again, and another time after another 200 metres.
- Continue now on the left bank of the barranco uphill. Shortly after the 3rd little bridge, you will encounter a large overhanging block on the valley side ***(Fig. 2.13),*** which looks as if it is ready to fall at any point. Best to pass quickly ...

Fig. 2.13 *Large overhanging block on road into the caldera. Barranco La Aldea.*

- In this area, much of valley walls to the right and left are covered with scree and coarser block deposits.
- After about 1-2 km in the barranco, the very vivid colours of the hydro-thermally altered rocks occur again. However, not all of this material is *in situ* ('in place'). Recent debris avalanche deposits, possibly as young as 4 million years, have redistributed much of the original rock here.
- Note that various large blocks of altered rock are partially disintegrated within these younger debris deposits.
- Higher up the slopes, however, *in situ* caldera infill with original hydrothermal alteration colours can be observed, which is the most probable source region for the debris flows and avalanche deposits to your left.
- Continue into caldera along GC-210 (green). The road gets very narrow here and driving is not for the fainthearted.
- Note the massive ignimbrite packages and intrusive sills while continuing your drive into the caldera.
- At about km 30 on GC-210 road sign you will note coarse caldera infill breccias to your left.
- Continue downhill, passing a mixture of caldera infill sediments and pyroclastic rocks, cut by an increasing amount of cone sheet type intrusions.
- The landscape of this inner part of Gran Canaria was once referred by a Spanish poet as a "Thunderstorm frozen in rock". Accordingly the road is very adventurous, much like this description ...
- Just after a steep and narrow drive uphill you will reach a plateau on your right hand side at km 28 on the GC-210 road sign. Park your car here on the open ground ***(Fig. 2.14).***

Fig. 2.14 *Parking for STOP 2.4.*

STOP 2.4 Inside the Caldera – Cone Sheet Intrusions

Location:
[N27º 59' 09.0'' W15º 44' 14.1'']

- Just beside the parking space on your left hand side, follow a little dirt track for ~ 500 m ***(Fig. 2.15)***. Usually a chain is mounted so that one cannot drive up. About 50 m before the little finca, walk "straight uphill" (no path), walk over rough ground with numerous boulders of dark rock until you reach the top of the little ridge (~200 m) ***(Fig. 2.16a,b).***

Fig. ***2.15*** *Entrance to small track, looking West-N-West. Walk up the track for about 500m and walk up the rocky slope just before the little finca.*

Fig. 2.16a,b *Walk almost to the little finca and then straight up the little slope on your right for about 200 meters.*

- Walk until approximately ***(Fig. 2.17)***
Location:
[N27º 59' 22.1'' W15º 44' 12.0'']

Fig. 2.17 *Take a rest on the grassy slope opposite a magnificent hillside.*

- Here you will get a superb view of the caldera infill with abundant cone sheets cutting through the infill at angles around 40-50º. With a bit of good light, one can even work out a time sequence of the intrusions from the cross-cutting relationships of the individual sheets ***(Figs. 2.18a-c).***
- This is the transitional zone between the almost cone sheet free outer belt of the caldera and the inner portion that is extensively intruded by them ***(Figs. 2.19a,b).***

Figs. 2.18a,b,c *Cone sheet intrusions cutting intra-caldera deposits in central part of the island (STOP 2.4).*

Figs. 2.19a,b *To your left remnants of older caldera fill are still visible, but are displaced relative to each other by intensive cone sheet intrusion.*

- Walk back to the car.
- At 6.5 km into the barranco, note that the number of cone sheets that cut into the caldera fill has been steadily increasing.
- From our parking space on the little plateau, one can see, above the lake in the cliff face opposite side of the barranco, a cone sheet lifting the interior strata up by nearly its own thickness ***(Fig. 2.20)***. Indeed it is assumed that the combined intrusion of the hundreds of cone sheets caused considerable vertical growth of the island (perhaps 1 km or more).

Fig. 2.20 *Cone sheet intrusion in hillside behind parking place showing displacement of the massive horizontal unit by the thickness of the sheet intrusion.*

- Continue to drive along the lake shore and further into the islands interior. A major dam in the lake will appear on your right.
- A short while after km 27 on the GC-210 road sign, park your car in a lay-by to your left hand side (under overhanging rock) ***(Figs. 2.21a-c).***

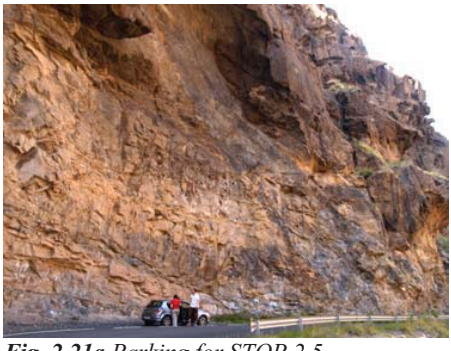


Fig. 2.21a *Parking for STOP 2.5.*

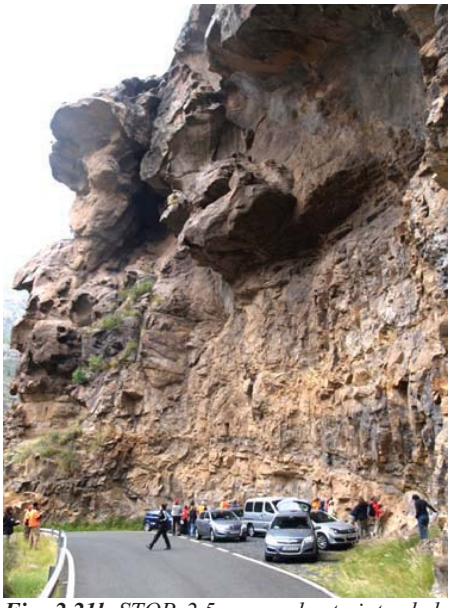


Fig. 2.21b *STOP 2.5; cone sheets intruded by cone sheets.*

Fig. 2.21c *Close-up of cone sheet contacts.*

STOP 2.5 Cone Sheet Intrusions – Close Up

Location:
[N27º 58’ 55’’ W15º 43’ 23’’]

- In this area, almost 100% of the rock mass consists of cone sheet intrusions. This is an excellent location to inspect intrusive contacts, chilled margins, and cross cutting relations of cone

sheets as the little cavenous outcrop behind the lay-by gives a good 3D insight into structure and geometry of these sheets.

- Continue along the road into the caldera. You will pass numerous cone sheets along the bendy road. They are of variable freshness and coloration, with virtually no country-rock relict's in-between. So, they have effectively 'cooked' each other giving rise to the many degrees of freshness and colouration.
- Continue on GC-210 for a short drive to reach the base of a second major dam. Park car with nose parallel to the dam ***(Figs. 2.22a,b).***

Fig. 2.22a *Second major dam along GC-210.*

Fig. 2.22b *Parking place for STOP 2.6.*

STOP 2.6 Central Gran Canaria – Syenite Intrusion

Location:
[N27º 59' 33'' W15º 42' 25.4'']

- Just to your left is a jagged rock surface, dipping towards you with about 45º ***(Fig. 2.23a).*** It is cut by several dykes. This is a small syenite intrusion with a sanidine crystal foliation, and evidence for 'ballooning'.

Location:
[N27º 59'31.4" W15º 42'26.0"]

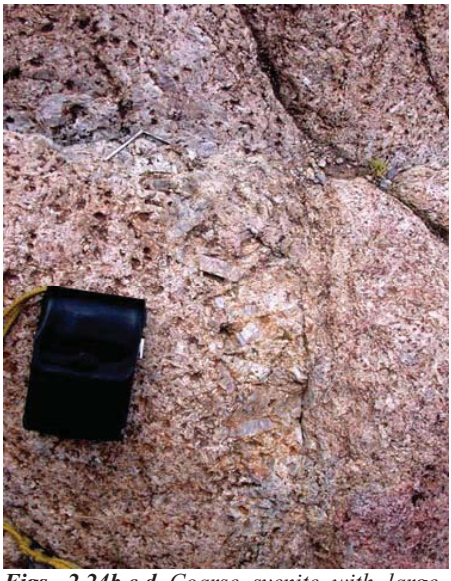
- At the rock slab (***Figs. 2.23a)*** crystals plunge to the west (30º) and east (20º) on either end of the outcrop, but are fairly horizontal in the top part of the rock mass. This suggests a curved foliation that mimics upward flow of magma!
- Note in places one can see syenite crystals being caught in the process of being incorporated into one of the cross-cutting dykes (xenocrysts) ***(Fig. 2.23b).***

Fig. 2.23a *Rock mass of syenite at side of dam. This warrants a closer inspection.*

Fig. 2.23b *Dyke intruding syenite. Have a close look and see if you can find 'xenocrysts'.*

- On the other side of the road ***(Figs. 2.24a)***; one can find yet more coarsely crystalline syenite. Big sanidine crystals of varying morphology can be studied with variably crystalline domains in visible contact.
- This is the very top of the plutonic heart of the island – a window into the upper magmatic system of Miocene Gran Canaria ***(Figs. 2.24b-d).***

Fig. 2.24a *Coarse syenite of the plutonic core of the island is exposed just on the other side of the road.*



Figs. 2.24b,c,d *Coarse syenite with large potassium feldspar crystals showing domains of former crystal mushes.* ***2.24c*** *shows a syenite rock with coarse pegmatitic mineral vein present.*

- Continue up the bendy road on the right hand side of the dam. Once you are on the flank of the

dam, follow the lake outline for the next little while ***(Fig. 2.25).***

Fig.2.25 *After driving uphill on the side of the second dam, follow the lake shore for a little while.*

- Note Roque Nublo in the far distance along the valley axis and also *Roque Bentayga,* somewhat closer. Also a little windmill to the top left of your position is now becoming visible ***(Figs. 26a,b)***. The windmill is our next stop.
- Continue to follow GC-210 into the barranco until you meet a fork at km 22 on road sign. At the fork, continue to follow GC-210 (green) towards *Artenara,* which is initially downhill.

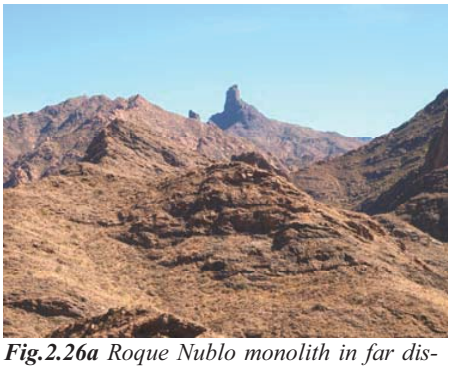


Fig.2.26a *Roque Nublo monolith in far distance.*

Fig.2.26b *Note little windmill to your left, our next destination.*

- On the way, you will encounter numerous more cone sheets intruded into each other (a cone sheet swarm), many of which are also hydrothermally altered with green and beige alteration colours ***(Fig. 2.27)***.

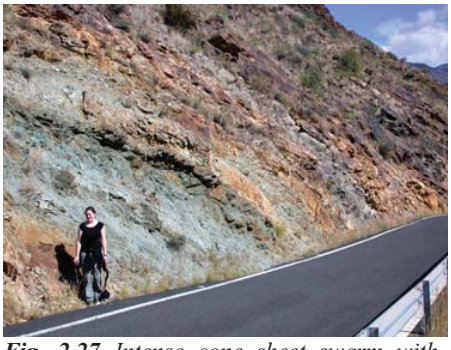


Fig. 2.27 *Intense cone sheet swarm with highly variable colours near STOP 2.7. Note, variable degrees of alteration are indicated by the colours.*

- These rocks, how-ever, are not as strongly altered as the rocks near the caldera margin *(Fuento Los Azulejos).* This difference is likely the result of less severe alteration near the top of a major hydrothermal cell, or represents the final and weakest gasp of

repeated pulses of hydrothermal activity.

- Black staining is frequently visible, the result of low-temperature precipication of Manganese oxides from running (and evaporating) ground and surface waters.
- Continue uphill towards the windmill which will provide us with a major viewpoint. Use parking space next to windmill – major stop ***(Figs. 2.28a)***.

Fig.2.28 *Parking site for STOP 2.7. at traditional Canary windmill.*

STOP 2.7 Central Gran Canaria – Miocene-Pliocene Unconformity

Location:
[N27º 59' 34.3'' W15º 41' 39.0'']

Looking South

Overlying the extensive cone sheets in the lower rock face are flat lying Roque Nublo lavas and pyroclastic rocks, separated from the cone sheets by an irregular angular unconformity ***(Figs. 2.29a-d).***

Figs.2.29a, b, c *Major Miocene-Pliocene unconformity visible when looking South. Note the irregular topography of the Miocene rocks. A bit like here today.*

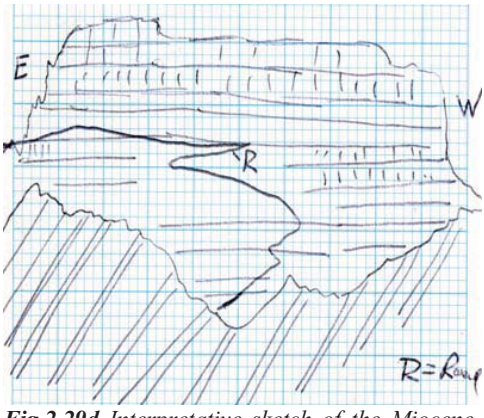


Fig.2.29d *Interpretative sketch of the Miocene-Pliocene unconformity.*

This implies a major erosional hiatus between the late Miocene cone sheet events and the Pliocene Roque Nublo volcanic episode that must have stripped away much of the entire Miocene volcanic edifice - literally to its roots. If you recall the extensive late Miocene conglomerates from early in the morning, this is where it all went. Mostly into the sea!

Also note the strike of cone sheets below you that swings around when you revolve around your own axis ***(Figs. 2.30a-c),*** giving you a good 3D sense of a cone sheet swarm (i.e. an inverted cone geometry).

- Enjoy the views as the drive back is kind of long. Return the same way to *Maspalomas* now (ca. 2 hours).
- If you have sufficient time left, proceed to *Artenara*, then to the NE-side of the island and return to *Maspalomas* via *Las Palmas* (see below).

Fig. 2.30a *View to North-West, note inclined cone sheets when revolving around your own axis.*

Fig. 2.30b *Note inclined cone sheets down at lake level when looking West, South-West.*

Fig. 2.30c *View of central Gran Canaria from windmill. Note the inclined cone sheets in the foreground when looking South and South-East.*

Alternative return route:

- From stop 2.6 follow road uphill to *Acusa* and *Artenara*.
- Drive through more cone sheets for several kilometers until the massive flat-lying Roque Nublo sequence above *Acusa* village appears ***(Figs. 2.31a,b).***
- At about km 17 on GC-210 road sign, one can view the cone sheet-Roque-Nublo contact especially well. This place is a beautiful stop for taking photos.
- When entering *Acusa* village, you are driving already through Roque Nublo Group sediments, flat lavas and pyroclastics.
- Continue on this road until you see a sign for *Vega de Acusa.* – Enjoy some spectacular views over central Gran Canaria from here. To the South, you can see *Roque Nublo* and *Roque de Bentayga* and various scattered mountain settlements ***(Fig. 2.32).***

Fig. 2.31a,b *Acusa village at boundary between Miocene cone sheets and Pliocene Roque Nublo deposits.*

Fig.2.32 *View to the South from Vega de Acusa onto central Gran Canaria.*

- A little road to *Acusa Seca* goes off to the right offering some of the best views, but is narrow and you might need to watch time by now.

- Drive on until you reach a major cross-road. There follow GC-210 (green) to *Artenara*.
- When you reach the roundabout in *Artenara*, you have several options, i.e.:

1. return via *Las Palmas* GC-211 (red)
2. via *Tejeda* GC-210 (green)
3. Return the way you came (2.5 hours).

Option 1. (ca. 3-3.5 hours)

- From this roundabout to *Las Palmas* is a 2-2.5 hours drive and from there ca. 40 minutes to Maspalomas.
- If you decide to drive to *Las Palmas* on GC-21, a few km after *Artenara* you will pass a slope of recent cinder deposits (*Picón*) (ca. km 34 on GC-21 road sign).
- You will quickly note the lushness of the vegetation on this side of central Gran Canaria, which gets the highest amount of rainfall due to its exposure to the North, the weather side of the island.
- GC-21 will bring you onto GC-3 (blue) but only after quite some driving. Follow GC-3 towards *Las Palmas* and the airport and join GC-1 towards *Maspalomas* after a while.

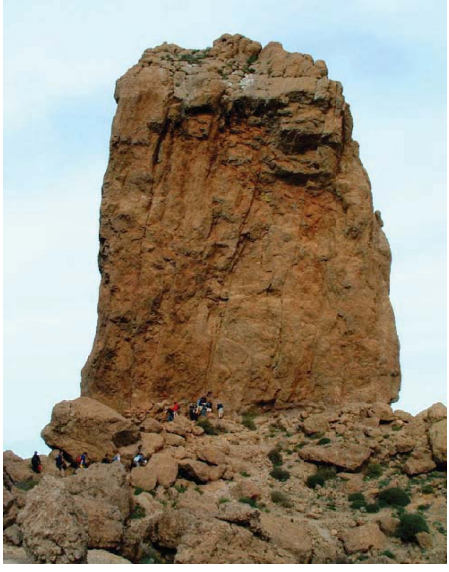
Option 2. (ca. 3-3.5 hours)

- Only if you have time left, go to *Tejeda* (not recommended now) and from there towards the South. It is better to do *Tejeda* on another day and in daylight! *Tejeda* is scenic but geologically complex and you may want to enjoy a hike there in good daylight using the field guide by Carracedo and Day (see list of references). Otherwise *Tejeda* as part of DAY 5 of this guide.

End of DAY 2

DAY 3 – Roque Nublo Volcano and Recent Volcanism: (Las Palmas Volcanic Vield)

Highlights



- Fataga succession at type locality.
- Centre of the island with spectacular view of Pliocene lavas and Pliocene Risco Blanco intrusion.
- Mountain village Ayacata.
- Roque Nublo debris avalanche breccias.
- Roque Nublo hike to monoliths.
- Roque Nublo age dyke intrusions to determine magma flow directions.
- Highest point of the island with overview of Gran Canaria from Los Pechos.
- Highland forests and plantations; the use of "picón" for agriculture.
- Caldera de Los Martelles; phreatomagmatic deposits at recent maar volcano and Holocene bomb- beds in North-East Gran Canaria.
- Recent cinder cones (1500 to 3000 years) in Jinámar and Bandama; overview Las Palmas volcanic field.

Start of DAY 3

- From *Maspalomas*, drive up to *Playa del Ingles*, and find *Avenida de Tirajana* (one of the main roads). Drive uphill and follow signs for *Fataga*. Go straight across several roundabouts until you approach the end of the village.
- When at the last roundabout, you will have to go "10 o'clock", following signs for *Fataga* (GC-60 red).
- Pass through village of *San Fernando* that is following almost directly after *Playa del Ingles*. There is a pleasant restaurant near the village end called *Casa Vieja* is worth an evening visit.

Set km-counter to zero when leaving *San Fernando.*

- Follow GC-60 (red). Soon it gets a little bendy (around km 47 on GC-60 road sign).
- After a short while, you will note a quarry in the valley below on your left. The quarry breaks Fataga rock for road gravel and building stones. Cathedral de St Anna in Las Palmas is constructed from Fataga rock, for example.
- Continue on GC-60 and soon you will drive through Pliocene former valley fill deposits (inspection of similar rocks follows later in the day).
- About 5 km after *San Fernando* (a little after km 43 on GC-60 road sign), you will pass a Guanchee Interpretation Centre '*Mundo Aborigen'*. If you are interested in the way of life on the island prior to the Spanish conquest, have a stop here.
- Otherwise follow GC-60 uphill for another 2 km. Brief stop on the little plateau *Degollada en las Yeguas* (480 m altitude).

STOP 3.1 Degollada en Las Yeguas – Late Miocene Fataga Ingnimbrites and Lava Succession

Location:
[N27º 49' 10.0'' W15º 34' 44.2'']

- If weather permits you will have some scenic views of the *Fataga* lava and ignimbrite succession to the NW of your position ***(Fig. 3.1)***.

Fig. 3.1 *View from Degollada en las Yeguas into Barranco Fataga and onto the Fataga succession.*

- Continue to follow GC-60, now downhill. Drive to valley bottom along the bendy road with Fataga-age lavas, tuffs, and debris avalanche deposits in the cliffs next to the road.
- Note the large but recent rock fall to your left, about 3 km after the plateau stop (around km 38 on GC-60 road sign).
- Continue on GC-60 towards *Fataga* and drive along spectacular Fataga units on your left and right. Optional stops between e.g. km 34 and 35 on GC-60 are very recommended ***(Fig 3.2)***.
- Inspect the succession and try to distinguish between lavas and ignimbrites. Lavas often show irregular top surfaces, where as ignimbrites tend to form more 'flattish' top surfaces at least in this succession. This locality, by the way, is the type locality for the entire Fataga group (as the name would of course imply).
- Continue uphill and drive through the village of *Fataga*.
- Follow signs to *San Bartolomé*.
- Just after *Fataga* village, you will see the typical colours of the hydrothermal intra-caldera rocks from Day 1 to your left ***(Fig. 3.3)***. Much of the material is reworked here however, i.e. it is no longer the original rock, but part of younger slump and slide deposits.
- Continue uphill for several kilometers along another bendy stretch.
- At km 28 on the GC-60 road sign, you will enter a zone of pine forest. Just after the next little bend, drive into the parking area of a larger restaurant.

Fig. 3.2 *Barranco Fataga; Fataga ignimbrites and lava succession. This is the type locality of the Fataga group.*

Fig. 3.3 *Hydrothermal colours at caldera margin after Fataga village, Upper Barranco Fataga.*

STOP 3.2 Risco Blanco – Phonolite Intrusion

Location:
[N27º 54' 27.0'' W15º 34' 08.0'']

- Walk a few steps towards the North until you reach a small cliff (~100 steps) ***(Figs. 3.4a-c)***.

Fig. 3.4a *Approaching Risco Blanco view-point.*

Fig. 3.4b *Risco Blanco phonolite intrusion.*

- Note the inclined and rocky slope to your left (NW), where no houses are found, is made up of a massive land-slide deposit that has collapsed from the headwall of the cliff into the barranco ***(Fig. 3.5).***
- Return to car and continue to follow GC-60, but now downhill. About 2 km after stop 3.2 follow signs for *St. Bartolomé* and *Tejeda,* which point uphill (still on GC-60 red).

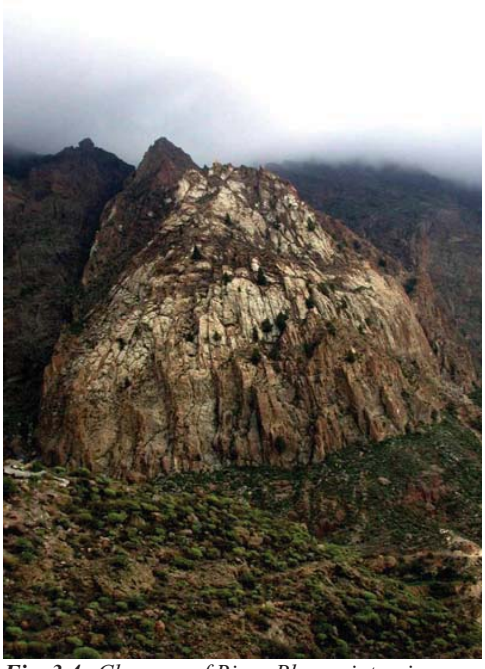


Fig. 3.4c *Close-up of Risco Blanco intrusion.*

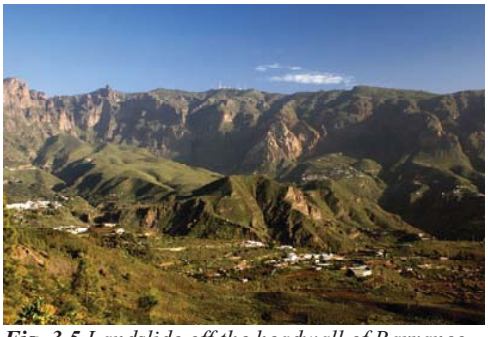


Fig. 3.5 *Landslide off the headwall of Barranco Tirajana.*

- Drive through village of *St. Bartolomé* and continue on GC-60 after village towards *Tejeda*. The road quickly climbs up-hill again, allowing some closer views of the *Risco Blanco* intrusion ***(Fig. 3.6)*** and also down the full length of *Barranco Tirajana.*

Fig. 3.6 *Risco Blanco intrusion (oblique view).*

- A little after km 23 on the GC-60 road sign, you will also get some close-ups of the headwall of the barranco that is made up of Pliocene lavas and sediments. At this point you should see brown road signs for *Roque Nublo*.
- Drive over the pass into the next barranco just after km 20 on GC-60 road sign (*Cruz Grande*). Now you will drive along Miocene caldera infill (note the altered colours again but in part reworked), on which the Pliocene deposits rest.
- Drive on until you hit a fork. There, follow GC-60 (red) for *Ayacata* and *Roque Nublo*.
- To your left (in the distance) you can see Miocene caldera infill and cone sheets of the cone sheet swarm of DAY 1, which are overlain by massive Roque Nublo group debris avalanche deposits. Drive further and into the mountain village of *Ayacata,* just a few kilometers further. Park the car in front of the small restaurant *Casa Melo*. I warmly recommend a "café con leche y un bocadillo de queso y jamon" for sustainance before the next stop and the Roque Nublo hike!

STOP 3.3 Roque Nublo – Breccia Deposits

Location:
[N27º 57' 30.0'' W15º 36' 31.0'']

- After your break, walk NW along the road GC-60 for a few 100 meters, until km 14 on GC-60 sign appears. Walk towards the rock exposure of steeply dipping Roque Nublo breccia to your right now ***(Fig. 3.7).***

Location:
[N27° 57' 31.1'' W15° 36' 40.6'']

- Note the deposit looks massive on the first glance, but contains many volcanic fragments that are variably altered. Clast alignment might be detected and seems very steep. A peculiar jointing (perhaps related to depositional bedding planes) is observed. One would think that a giant volcano must have given rise to such large-volume breccia deposits.
- Return to car and follow GC-600 (green) up to *Roque Nublo* monolith (direction *San Mateo*). Note you have to go back on GC-60 for a few metres from your parking place. Do not follow GC-60 any longer!
- After a short while in Miocene intra-caldera sequences, the road will bring soon you into Roque Nublo breccia units.

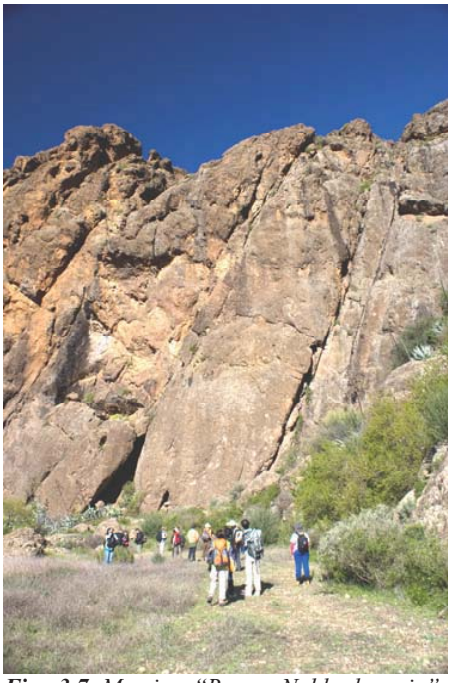


Fig. 3.7 *Massive "Roque Nublo breccia" deposit. Here, the clasts are mainly mafic volcanic rocks. Note the steep jointing present in the rocks.*

- After about 3.5 km on GC-600, a lay-by marks the start of the *Roque Nublo* track. Park the car here. Parking may be limited in high season and you may need to park along the road several hundreds of meters up from here.

STOP 3.4 Roque Nublo Hike

Location:
[N27º 57' 56.5'' W15º 36' 05.4'']
(altitude 1579m asl at parking space)

- Follow the layed out hiking path up to the monolith. Just a few 100 m up the path you will see Roque Nublo breccia to your right. Walk on the path through pine forest for perhaps 25 to 30 minutes ***(Figs. 3.8a,b,c; 3.9a,b)*** and stop in second major bend just before reaching a little plateau. Elevation 1702 m ***(Figs. 3.10).***

Fig. 3.8a *Roque Nublo from distance with Roque Nublo path in foreground.*

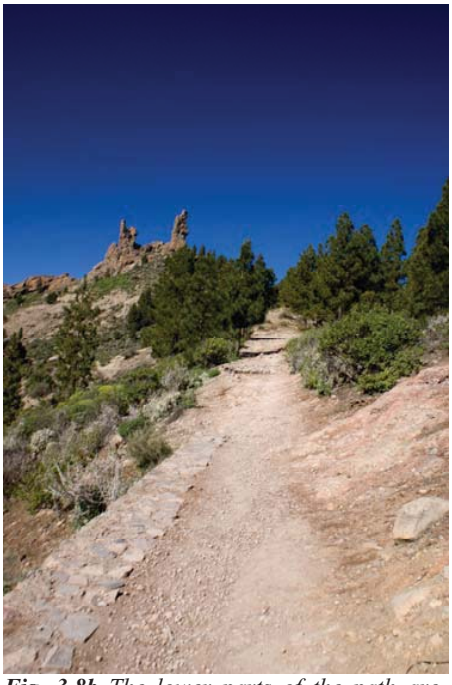


Fig. 3.8b *The lower parts of the path are wide and well layed out.*

Fig. 3.8c *On the Roque Nublo Hike.*

Fig 3.9a *Soon, however, it narrows a little.*

Fig. 3.9b *Higher on the Roque Nublo path, it can get a little rougher yet, so good equipment is advised.*

Fig. 3.10 *Reaching the first plateau at ~1700 m asl.*

Location:
[N 27° 58' 04.8'' W15° 36' 36.2'']
(1719 m asl), ***(Fig. 3.10)***

- At this locality, Roque Nublo breccia and other volcanoclastic layers with medium (40°) dips to the Northeast are exposed. Note these units dip opposite to the ones you inspected before the coffee-break. This material here is generally held to be an intra-crater facies of the long lost Roque Nublo volcano ***(Fig. 3.11).***
- Walk up to plateau now. Note the blocks of Roque Nublo ignimbrite in the stairs to the next plateau. Although these rocks are not directly exposed on the path, they occur nearby, highlighting the in part explosive nature of the Roque Nublo volcano.

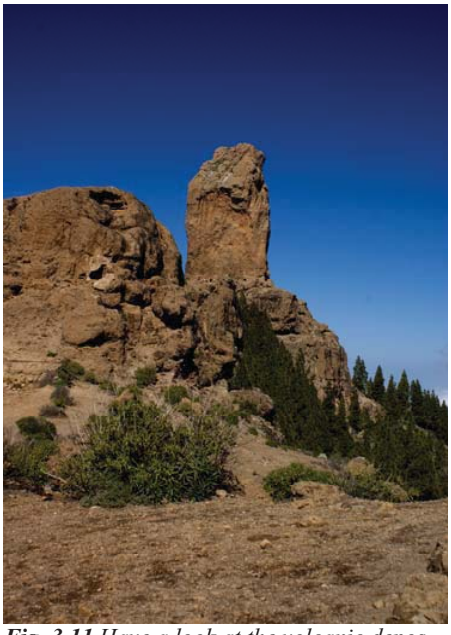


Fig. 3.11 *Have a look at the volcanic deposits here. They dip differently to those earlier in the day.*

- Make your way up to the main plateau now ***(Figs. 3.12a,b***).
- Keep your eyes open when walking toward Roque Nublo monolith. Once your eyes have adjusted, abundant clasts of gabbro, diorite, amphibole crystals and aggregates, and amphibole megacrysts can be found on the main plateau ***(Figs. 3.13a,b).***

Fig. 3.12a *Main (2nd) plateau before Roque Nublo monolith.*

Fig. 3.12b *Approaching the monolith.*

Fig. 3.13a *Large amphibole crystals from Roque Nublo deposits on main plateau.*

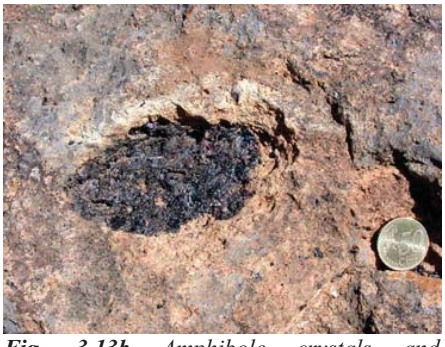


Fig. 3.13b *Amphibole crystals and aggregates in Roque Nublo deposits.*

- Think back to the first Roque Nublo breccia stop before coffee and the occurrence of volcanic clasts, i.e. the complete lack of plutonic clasts in those rocks

earlier. This has been used to suggest progressive collapse of the Roque Nublo volcano down to its plutonic roots, through three or more collapse events that gave rise to the three major flow units of the Roque Nublo breccia deposits on the island.

- There is a particularly nice amphibole aggregate at the location below, but please do not hammer or remove anything here. It is a protected area!

Location:
[N27° 58' 12.0'' W15° 36' 44.4'']

- On an elevation of about 1750 m, across the plateau and at the monolith, you can walk on the western side of the base of Roque Nublo monolith to a small area where the monolith shows an internal boundary (***Figs. 3.14; 3.15)***. It is made of breccia on both sides of the boundary but displays many features of plastic deformation; a shear zone ***(Figs. 3.16a,b).***

Location:
[N27° 58' 14.3'' W15° 36' 46.9'']
(1753 m asl)

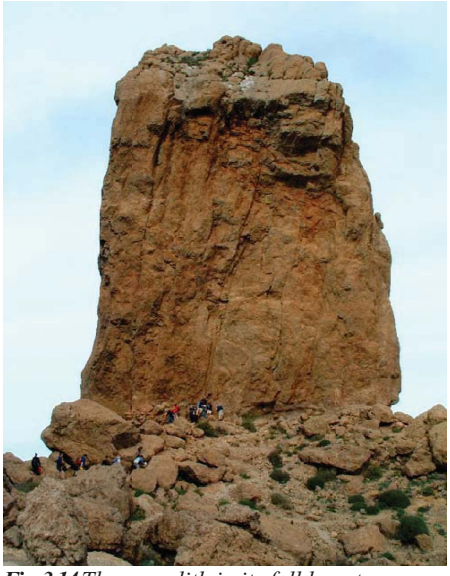


Fig. 3.14 *The monolith in its full beauty.*

Fig. 3.15 *At the foot of Roque Nublo monolith.*

Fig. 3.16a *Looking at the base of Roque Nublo monolith.*

Fig. 3.16b *Shear zone at the base of Roque Nublo monolith. Shear sense indicators suggest top to the right.*

- Take a short rest here and enjoy the views. This implies that the original breccias of the rock mass was on a shallow slope (not steep) and it was of high energy to allow for plastic deformation of the base.
- To the west you can see *St. Nicolás* in the distance, and the windmill on cone sheets from DAY 2 is visible, too. If cloudy, be very careful here, as the drop is kind of steep.
- Walk around to the east-side of the monolith, where you will find the shear zone again just behind a little plateau which lends itself for a short rest too. The view to the east down into the barranco yields a glimpse into the Roque Nublo's volcano roots. A major gabbro intrusion and a number of dykes can be seen in the valley across, suggesting that the centre of the Roque Nublo volcano was probably located around this part of central Gran Canaria.
- Roque Nublo monolith is also popular with climbers and you might find a bunch of them attempting to make their way up the monolith, employing elaborate climbing equipment. Be careful and watch out for falling rocks if climbers are around! Also, please do not take souvenirs. Roque Nublo is a protected area!
- Return to the car. Once you are there, walk up the road for about 500 m after the car park, until you come to a sharp right-hand bend ***(Fig. 3.17).***

Fig. 3.17 *Dyke of Roque Nublo age with large gabbro xenoliths.*

STOP 3.5 Roque Nublo Age Dyke Intrusion

Location:
[N27° 57' 58" W15° 35' 52"]

- This is the second sharp road bend after the Roque Nublo car park (!) and you will encounter an irregular dyke cropping out across the street, with an overall strike of NE-SW to N-S. Note the larger gabbro fragments (xenoliths) within the dyke and the striations on the dyke's margins (in the chilled part). The striations dip with about 30° towards the S and SW, indicating not only a vertical flow component, but also a lateral one for this dyke!
- The dyke is phonolite in composition and belongs to the Roque Nublo dyke radial swarm. So, from where did the dyke come from now?

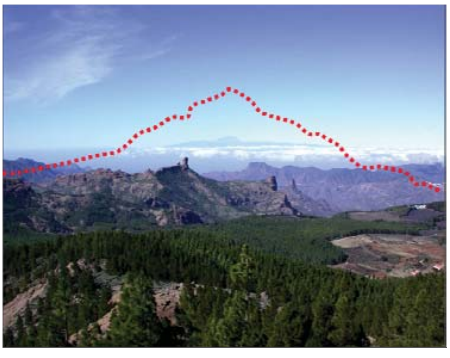
- Return to car and continue to drive uphill on GC-600 with Roque Nublo breccia in the road sections on your right.
- After about 3 kilometers you will pass some cavenous weathering Roque Nublo deposits to either side of the road. Similar weathering patterns have frequently been employed as shelter and seasonal settlements by aboriginal Guanchees in lower altitudes.
- Continue on GC-600 through dense pine forest and pass a larger barbecue place in less dense forest that is usually packed on summer weekends.
- Approximately 4 kilometers after the *Roque Nublo* (STOP 3.4), you will pass a number of agricultural fields on both sides of the road. Note the dark scoria that forms the top layer on the fields. This fine scoria (lapilli) material is derived from Holocene volcanoes.
- Its local name is "picón" and it has the ability to hold water for much longer than the top soil due to its internal porosity (vesicles), making it an extremely useful helper in local agriculture where rainfall can be very sparce.
- Shortly after the agricultural fields you will come to a road junction. Turn right towards *Pozo de las Nieves* (*Los Pechos*) on to GC-130 (green).
- Continue on bendy road for about 2 km and then turn right for Mirador *Pozo de las Nieves* (GC-134 yellow).
- Drive up to the Mirador and the radar station and use the small road just to the right of the radar station. Drive up this road for 2 minutes until you meet a parking place ***(Fig. 3.18).***

Fig. 3.18 *Parking at Pozo de las Nieves.*

STOP 3.6 Pozo de las Nieves (Los Pechos) >1900 m Altitude – the Highest Point on the Island

Location:
[N27° 57' 43.7" W15° 34' 19.4"]

- This is the highest point of the island with more than 1900 m of altitude. On a clear day you will get some amazing views of Miocene rocks in the south, the Roque Nublo monolith, and even the active Teide volcano on Tenerife in the far distance ***(Figs. 3.19a-c).***



Figs. 3.19a,b,c *View from Pozo de las Nievas (1948 m asl), the highest point on the island. Note Pliocene deposits with Roque Nublo monolith in foreground and Miocene and Pliocene rocks in distance to the right. Pico de Teide on Tenerife is sometimes visible in the far distance! Imagine the full Roque Nublo volcano, using Teide on Tenerife as an analogue.*

- Return to the junction GC-134 (yellow) with GC-130 (green). Now, follow the signs for *Telde* (GC-130 green).

Set km-counter to zero here.

End of Pliocene, Start of Holocene

- After about 1 km you will encounter scoria deposits to your right, originating from a maar volcano that is located just behind the trees, but that is for another time.
- Continue downhill. About 5 km after the last junction you will find Caldera de Los Martelles (another maar) to your right. A lay-by to your right will offer a safe parking space.

STOP 3.7 Caldera de Los Martelles – Maar Deposits

Location:
[N27° 57' 39.3" W15° 34' 08.8"]
(1544 m asl)

- Walk back on the road for about 150 m to the next bend to inspect early maar deposits that are mainly made up of country rock fragments (Roque Nublo lithologies), grading upwards into more juvenile magmatic deposits (scoria) ***(Figs. 3.20a-c).***

Figs. 3.20a,b,c *Caldera de Los Martelles; tuff ring deposits.*

- Return to the car and look into the Los Martelles crater, which now hosts several fertile fields. The crater is dated at some 90.000 years before present, but may also be younger according to some researchers. Local concentric settling fractures are still obvious ***(Fig. 3.21).*** A larger post- or syn-maar dyke is visible near the parking site ***(Figs. 3.22a,b).***

Fig. 3.21 *Pleistocene Caldera de Los Martelles is ca. 90 ky old.*

Fig. 3.22a *Dyke at Los Martelles.*

Fig. 3.22b *Dyke intrusion in maar deposits.*

- Continue on road GC-130 for about 0.5 km to inspect more pyroclastic deposits from Los Martelles maar. You will have to park at the side of the road there, so please be careful.

Location:
[N27° 57' 30.4'' W15° 31' 57.6'']

- Again, the deposits grade from country rock-rich to more juvenile magmatic material, reflected by an increasingly darker colour ***(Figs. 3.23a-d).***
- Drive on for about 1 kilometer and park on left hand side lay-by in a sharp right-hand bend.

Fig. 3.23a *Caldera de Los Martelles deposits. Note the many country rock fragments in the lower part of the outcrop.*

Fig. 3.23b *Caldera de Los Martelles deposits. Note the darker, juvenile magmatic component that makes up the deposit a little higher up (to left of image).*

Fig. 3.23c *Detail of juvenile magmatic Caldera de Los Martelles deposits.*

Fig. 3.23d *Looking back on Caldera de Los Martelles from the North.*

STOP 3.8 NW-Gran Canaria – Holocene Lapilli and Bomb Deposits

Location:
[N27° 57' 10.7" W15° 31' 41.7"]

- Walk back for about 50 metres to inspect a beautiful Holocene bomb deposit ***(Figs. 3.24a-e)*** and if you are lucky, some white, foamy ocean crust sediment xenoliths too, but they are very rare. The bombs are beautifully spindle shaped indicating that they experienced ballistic transport while still plastic.
- Continue downhill towards *Telde,* but note frequent Holocene lapilli scoria and bomb deposits along the way.
- Drive through the village of *Cazadoras* with direction *Telde*. A short break might be appropriate here.

Fig. 3.24a *Scoria and bomb deposits near Los Martelles.*

Fig. 3.24b *Getting a feel for scoria.*

Fig. 3.24c *Bomb deposit near Los Martelles.*

Fig. 3.24d *Close-up of loosely consolidated bombs.*

Fig. 3.24e *Individual bombs of basanite composition showing twisted spindle shapes.*

- Continue on GC-130 and about 2 kilometers after the village of *Cazadoras* you will get some nice views over the Las Palmas volcanic field. The volcanic field comprises clustered and isolated cinder cones and maars that may be aligned, although this is hard to make out from here and the distribution of vents appears rather random from our position.
- At km 16 on GC-130 road sign (or approximately 14 km on your km-counter), you will pass a little cinder cone on your left that is quarried for lapilli (picón).

STOP 3.9 NW-Gran Canaria – Trees vs. Fumarole Pipes in Pleistocene Cinder Deposits

Location:
[N27° 57' 48.8" W15° 29' 20.6"]

- Some beige to brown vertical colours that are frequently associated with decimetre sized holes can be seen in the road sections of the scoria deposits here. The suggestion that these represent remnants of former trees, however, is unlikely. Some are mere animal burrows, others plant-root discoloration and yet others may be fumaroles or degassing pipes. So, there are more plausible and simpler explanations for these features then burned tree trunks ***(Fig. 3.25a)***.
- Follow GC-130 downhill and after 3 to 4 kilometers another cinder cone with bombs and scoria is passed(El Hoyo, ca. 6000 years old) and several more cones become visible in the distance soon ***(Fig. 3.25b)***.

Fig. 3.25a *STOP 3.9; Cinder cone that is quarried for 'picon'.*

Fig. 3.25b *'Nobbly' landscape of the Las Palmas volcanic field.*

- Follow GC-130 to *Telde* and make your way to the motorway GC-1 (blue) near the coast. Enter the motorway with direction towards the North (*Las Palmas*). You will need to join GC-10 (red) first, which will bring you to GC-1!
- Once you are on the motorway, drive toward *Las Palmas* for about 2.5 to 3 kilometers.
- In the distance (front right), La Isleta appears, which is another product of the most recent volcanic episode. The area is, however, closed as it hosts another military facility.
- Exit motorway after about 3 kilometers toward *Valle de Jinámar* and turn right beneath the blue-green bridge.
- Continue towards *Valle de Jinámar* and *Marzagán.*
- Drive through outskirts of *Las Palmas* for a short while until you see a petrol station to your right that has a cinder cone behind it. Park opposite to it ***(Fig. 3.26)***.

Fig. 3.26 *Jinámar cinder cone lurking behind a petrol station. Park on opposite site of the petrol station for STOP 3.10.*

STOP 3.10 Jinámar Volcano – Holocene Cinder Cone Deposits

Location:
[N 28° 02' 9.0" W 15° 23' 3.6"]

- Walk for a few hundred meters to inspect the cinder cone behind the petrol station. A little path leads to the outcrop from behind the station ***(Fig. 3.27).*** Note the freshness of the deposits and the often blue shine on it from surface oxidation. The scoria carries pyroxene crystals as well as olivine and is generally of very alkaline character – like all the other Holocene volcanic of the island and is dated at 2500 years before present.
- Note the steep slope of the deposits, making it quite a slide

to try to walk uphill on it ***(Figs. 3.28a-c)***.

Fig. 3.27 *Walk towards the exposure behind the petrol station.*

Fig. 3.28a *Outcrop of Jinámar cinder / scoria cone deposits.*

Fig. 3.28b *These deposits are poorly consolidated only, making its slopes rather unstable.*

Fig. 3.28c *Collapsed face of cinder cone viewed from the West.*

- Return to car and continue towards *Marzagán* (GC-800, green).
- After *Marzagán* village, follow signs for *Bandama* (GC-801, yellow).
- After about 4 kilometers on GC-801, a sharp turn to the left will bring you to *Bandama* (GC-821, yellow).
- Soon this road climbs steeply and joins GC-802 and then GC-822 before it circles around *Bandama* hill, leading up to *Bandama* peak.
- View point *Pico Bandama*, (Elevation 569 m).

STOP 3.11 Pico de Bandama – Holocene Activity in NW-Gran Canaria

Location:
[N28.2° 2' 16.1'' W15° 27' 28.0'']

- To the North, you can inspect low-lying hummocky deposits and a collapse scarp of the *Bandama* cinder cone. These two are related!

- To the S-SW, you will look into the *Caldera de Bandama* ***(Figs. 3.29a-c)***, another maar with Roque Nublo basement found as country rock in the maar deposits on the crater's flanks.
- Bandama is only about 2000 years old and is one of the youngest volcanoes of the island.

Figs. 3.29a,b,c *Caldera de Bandama; Looking inside the crater.*

- The maar is older than *Bandama* cone, which implies that an early phreatomagmatic phase was followed by cinder cone activity.
- On a good day you will also get some spectacular views of Las Palmas volcanic field to the North-East ***(Fig. 3.30a)*** with *La Isleta* in the far distance. Almost all topographic rises in this area are little Holocene volcanoes and one can count up to a dozen of them in the wider field of view.
- The alkaline basalts that form the Bandama lapilli also carry some rare nodules of mantle origin (peridotite fragments) with nice big (up to 5mm) olivine crystals and also with spinel present. The mineral spinel is stable under upper mantle conditions between 20 and 80 km depth, thus providing us with an estimate of the depth of mantle melting and magma generation beneath the recent volcanic field (i.e. >20km <80km).

Fig. 3.30a *View from Pico Bandama towards the North: La Isleta in far distance with Las Palmas in centre of the picture. Note, La Isleta is a recent volcanic cone complex as well.*

- Once you have taken in the fine views of Bandama ***(Figs. 3.30a,b)***, return to GC-1 (blue)

the way you came and join GC-1 towards *Telde*, *aeropuerto* and *Maspalomas* to return to the Southern residential centres.

Fig. 3.30b *Looking East from Bandama.*

End of DAY 3

DAY 4 – Coastal Geology and Destruction of Oceanic Islands

Highlights

- Drive along spectacular North and NW coast of Gran Canaria.
- Uplifted marine rocks and pillow basalts in Northern-cliffs.
- Pico de Gáldar (volcanic cone and cone stability).
- Agaete and the "bite in the apple"; The decline of volcanoes.
- Tsunami deposits in Barranco Agaete.
- Small scale coastal landslide just before village of El Risco.
- Drive toward St. Nicolás, along breathtaking coastal cliffs, inspect basaltic shield stage rocks and felsic ignimbrites along the way.
- Descent to St. Nicolás; with views of La Aldea and Porto de St. Nicolás. Find rest and recreation in Porto de St. Nicolás.

Start of DAY 4

- From *Maspalomas* drive North toward *Las Palmas* on main motorway GC-1 (blue). Drive on for about 40 minutes. Some ten kilometers before *Las Palmas* the motorway GC-1 (blue) splits, but we shall stay on GC-1 that is going into *Las Palmas*. Note, traffic can be busy and it might take you a while to get there if you get caught in the rush hour.
- Once in *Las Palmas,* drive along the coastal motorway for several kilometers and eventually along Las Palmas' main harbour area.
- Turn off onto GC-2 toward *Agaete* after a while.
- You will have to turn into a roundabout and soon you shall drive through a major tunnel. Keep on right hand lane in tunnel and turn right directly after the tunnel. Follow the white signs for *centro ciudad*.
- Follow this street for ca. 1-2 minutes only until you meet another major roundabout.
- There, you exit after a ca. 320° turn (i.e., almost the same direction that you came).
- Follow this road for a short while. It will bring you over to a bridge over the Motorway, from where it leads uphill. After ca. 1 km a petrol station appears on your right hand side.
- Directly after the petrol station, a small road goes off to the right, which leads to *Cuartel De Marina Manuel Lois* (an old disused navy base). **Note ongoing building activity may change this junction significantly (2011).**
- Follow this small road for ca. 0.5 km until you encounter very light coloured marine sediments overlain by pillow lavas of *Roque Nublo* age on the left hand side in a NE-SW road section ***(Figs. 4.1a,b)***.

Figs. 4.1a,b *Pillow lavas on marine marls at STOP 4.1.*

STOP 4.1 Las Palmas Outskirts, Barranco Tamaraceite – Uplifted Pillow Lavas

Location:
[N28° 0.7' 13.3" W15° 27' 30.8"]
(97 m asl)

Figs. 4.2a,b,c *Pillow lavas on marine marl deposits. Pillow lavas form from lava erupting into water, implying these rocks, now at ~97 m asl, were once below sea level.*

- Here beach boulders are overlain by whitish carbonates and mares of shallow marine origin, which in turn are overlain by pillow lavas. Higher up in the outcrop the pillows are followed by hyaloclastites, i.e. fragmental rocks from submarine eruptions.
- Pillow lavas are characteristic for submarine eruptions where hot extruding lava chills against cool seawater and rapidly forms a solid crust. Within this crust, the hot lava is thermally insulated and can continue to flow, forming tubular structures that appear as pillows in most cross-sections. Eventually the magma in the tube hardens as well forming radial cooling cracks, or drains out, leaving an empty shell.
- The occurrence of pillow lavas at this elevation (97 m asl) implies uplift on this order of magnitude since the time of original formation of the pillows (these are Pliocene and belong to the Roque Nublo group).
- The reason for this uplift, which is only seen in NE Gran Canaria, could be that the recent magmatic activity (e.g. *Bandama*) which is likely being fed from a larger magma storage area underneath this part of the island. Alternatively, it is conceivable that the younger and larger island of *Tenerife*, with the active volcano of Pico de Teide, exerts flexural strain onto the ocean crust causing the entire island of Gran Canaria to become slightly tilted towards Tenerife. It is hard to distinguish between these two hypothesis for now and the two are also not mutually exclusive.
- Return to GC-2 and drive toward *Arucas, Agaete* and *Gàldar*, i.e. westward.
- About 2 km after entering GC-2, drive along an impressive cliff exposure to your left (Miocene

and Pliocene lavas, breccias, conglomerates).

- Continue on GC-2 and after a short drive of a few minutes only and stop in a larger lay-by on your right hand side.

STOP 4.2 Northern Cliffs – Miocene and Pliocene Rocks

Location:
[N28° 0.7' 40.3" W15° 27' 45.4"]

- Two-third up the cliff ***(Fig. 4.3),*** a thin but persistent white (marine) layer is visible for kilometers, but is locally down faulted into blocks, forming a horst and graben arrangement (e.g. looking towards SW from your position). This is the marine layer beneath the pillow lavas *STOP 4.1.*

Fig. 4.3 *Northern cliffs expose Miocene and Pliocene –strata in spectacular semi-vertical sections. A thin white band is visible high up in the cliffs. This is the marine band of STOP 4.1 again.*

- Continue on GC-2 westward. After some 2 kilometers, you will see a recent cinder cone that deposited scoria over the steep cliff ahead of you. It is presently quarried for picón (lapilli for agriculture).
- Continue towards *Agaete* and *Gáldar* on GC-2 for another 2 kilometer and leave the motorway at the *Arucas* Exit. Park right in the bend of the motorway exit that leads onto the bridge over the motorway.

STOP 4.3 Arucas – Uplifted Marine Platform

Location:
[N28° 0.8' 38.7" W15° 30' 35.6"]

- From barrier at parking site, walk downhill for a few minutes until you see a coastal platform with a light coloured cover. Walk downhill until the road splits. Take the left hand turn ***(Figs. 4.4a-c).***
- Once you reach the coastal platform, progress to the light coloured thin cover on top of the rocks that make up the cliffs ***(Fig. 4.4c).***

Fig. 4.4a,b,c *Walk down to coastal platform. Where the path splits, go to the left until you reach the light coloured layer in Fig. 4.3c.*

- The Arucas outcrop is a coastal abrasion platform. Pliocene shells are found on Fataga lavas. The platform is ca. on 350,000 year old and the Arucas volcano (cinder cone in background) is ca 125,000 years old. Patella is the main fossil in the raised marine sediments ***(Figs. 4.5a-c, 4.6a,b).***

Fig. 4.5a,b,c *Pliocene shell beds and marine boulders on uplifted Arucas platform (~45 m asl).*

Fig. 4.6a *Photograph of part of Arucas platform.*

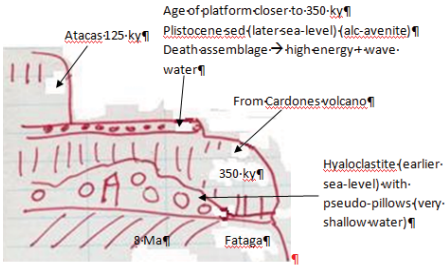


Fig. 4.6b *Sketch of outcrop in Fig. 4.6a.*

- Here, at an elevation of approximately 45-50 m, the Pleistocene marine sediment is not only made up of shell debris from Patella, but also larger remnants of bivalves and gastropods are seen frequently (mussels and snails). The rock is not fossilized and the animal remains are effectively still carbonate in their composition (not lithified!).
- Locally insect burrows in the upper part of the marine deposit are observed (bees, wasps, hornets), suggesting a fair bit of time between the younger lavas and platform formation.
- The wider implication of these sea creatures is that they underline the concept of uplift discussed at STOP 4.1. The evidence seen at this location would support an uplift of 45 to 50 m since the Pleistocene. If this information is taken at face value, it would imply an acceleration of uplift in the more recent geological record, as compared to e.g. 90 m since the Pliocene (STOP 4.1).
- If correct, then the recent volcanic activity in NE Gran Canaria may after all be a more dominant factor than flexural tilt of oceanic crust. However, sea level was higher in the Pleistocene, making this estimate a little tricky.
- If you have a packed lunch this may be a good spot for a picnic!
- **Note:** At the time of writing (2010), the headwall of the bay displayed a major arcuate fracture that de-stabilizes a sliver of rock ca. 5 m wide ***(Figs. 4.7a,b).*** DO NOT STEP ON THE HEADWALL!

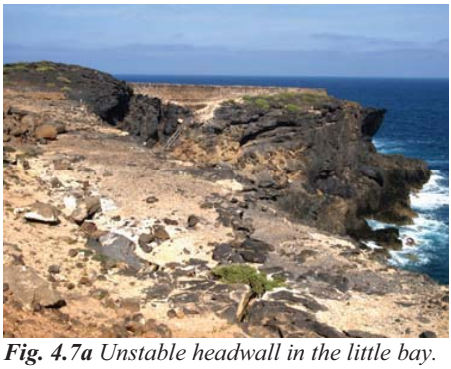


Fig. 4.7a *Unstable headwall in the little bay.*

Fig. 4.7b *Steep fracture that detaches a major sliver of the headwall. Do NOT step on it! You are ca. 50 m above sealevel.*

- This fracture is symptomatic of intense coastal erosion that undercuts steep rock cliffs in the North and North West of the island. Once this rock falls, it will likely cause a bit of a splash, and will probably damage the few small shelters in the bay by creating a mini-tsunami.
- Return to car and continue on GC-2 towards *Gáldar* (towards West).

Note GC-2 (blue) turns into GC-2 (red) at some point along this stretch.

- Note the steep cliffs and the strong waves here in the North. This area is very popular with surfers, and Björn Dunkerbeck, the multiple surf-world-champion, runs a surfing school here on the coast.
- The North of Gran Canaria also grows a lot of bananas as this is the weather side of the island and bananas need a lot of water. Perhaps not the most sensible crop on an archipelago that continuously suffers from water shortage, but bananas provide a regular income for the local farmer communities.
- After a while "Pico de Gáldar" appears in the distance.
- Canarians call this cone lovingly 'Little Teide'. It is a Pleistocene (ca. 1.2 My old) pyroclastic cone as well that experienced several small to medium-scale landslides prior to erection of the village that now creeps up the slopes.
- After a few more kilometers on GC-2, a thick succession of (Pliocene to Peistocene) Roque Nublo and post Roque Nublo lavas is exposed in the cliffs above the road. The road climbs up and you will drive through a series of small tunnels.
- As soon as the road descends into the next valley you can pull into a bus stop on the right or the petrol station to the left to view Pico Gáldar in its full beauty ***(Figs. 4.8a,b).***

Fig. 4.8a,b *Pico Galdar pyroclastic cone in the very NW of Gran Canaria. Note the steep slopes and the spoon-shaped embayments marking the sites major landslides from this edifice.*

STOP 4.4 Distant View of Pico de Gáldar

Location:
[N28° 0.8' 41.2" W15° 36' 44.0"]

- Note angle of the slope is ca. 33 to 35º, which is approximately the angle of repose for stable accumulation of granular material such as sand. This indicates that this cone's architecture is prone to flank failures. Also, note the spoon-shaped collapse scars on both sides of the cone.
- Although *Pico de Gáldar* is unlikely to erupt again, it still represents a considerable landslide hazard for the village at its base.

- Return to car and continue on GC-2 towards *Agaete*.
  Note: GC-2 is blue again now.
- When driving past *Pico de Gáldar*, note the onion-skin appearance of the layers excavated by the landslides and the houses built within these scars ***(Figs. 4.9a,b).***

Fig. 4.9a,b *Onion-skin appearance of pyroclastic layers within the spoon-like scars of Pico de Gáldar.*

- After another 10 kilometers or so on GC-2, when descending into the next valley and given that the weather is good, you will get some nice views of *Tenerife* on your right, dominated by *Pico Teide* in its centre. *Teide* is over 3700 m high and the tallest peak in Spain. Its name is probably derived from the aboriginal language of the Canaries, meaning "white peak" as it often has a snow cover on its top. Can you see its white cap?

- Just before *Agaete* port you will be able to see the concave coastline of NW-Gran Canaria (bite in apple), which is believed to have sourced a major Miocene landslide ***(Fig. 4.10a,b).***

4.10a *First view of North-West coast of Gran Canaria.*

4.10b *Large North-West embayment (bite in the apple), that has formed from a giant landslide event in the Miocene.*

- When entering *Agaete* go across the 1st roundabout with direction toward the cemetery. Go uphill for ca. 300 metres, pass the cemetery and park at the sign for *Playa la Caleta*.

STOP 4.5 Playa La Caleta – Tsunami Deposits

Location:
[N28° 0.6' 20.0" W15° 42' 17.3"]

- Walk toward North West from the parking space, along a dirt track for 5 minutes until you see the coast ***(Fig. 4.11).*** Turn right onto a terrace, where you will find a marine conglomerate. This rests on 1.8My old lava ***(Figs. 4.12a-d).***

Fig. 4.11 *Turn right at coastal cliff and do not go down the stairs.*

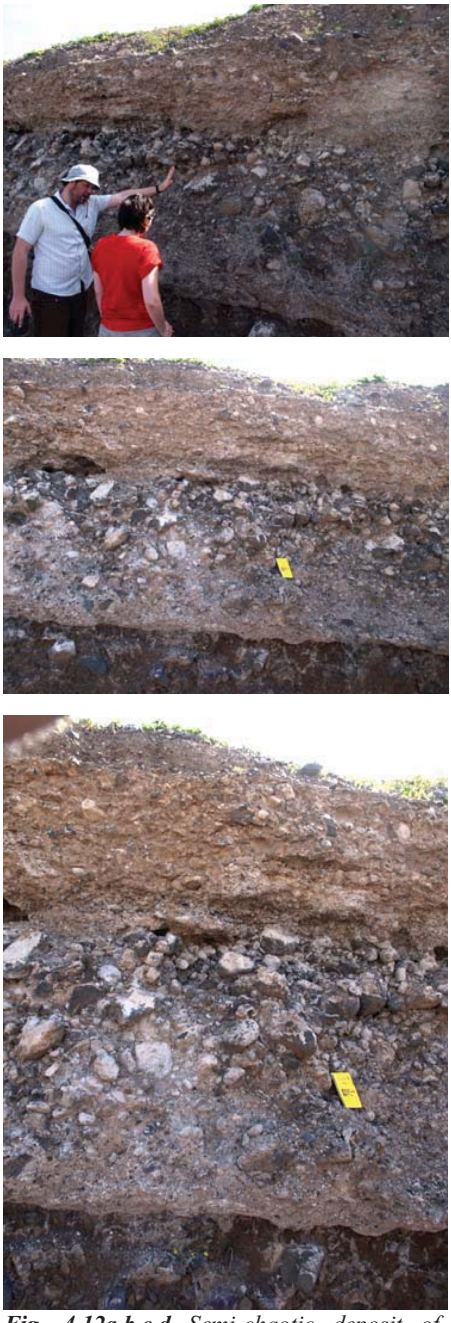


Fig. 4.12a,b,c,d *Semi-chaotic deposit of beach pebbles and marine debris resting on 1.8 My old lava. Note, the bottom and top facies of the sedimentary deposit are believed to represent the successive in- and outflow of a giant tsunami wave.*

- Rounded and angular boulders occur together in this unit with marine shells. This is a high-energy deposit believed to originate from a giant wave created by a tsunami from a collapse on Tenerife (the *Güímar* collapse).
- The landslide scar of *Güímar* is ca. 80 km away from Gran Canaria and occurred some 830,000 years ago. These deposits can be found up to an elevation of 160 m above sea-level and there it looks very similar, suggesting a wave, rather than stable water column that rushed to 160 m above sea level. Locally a soil is underlying the tsunami deposit, supporting that it is not a "regular" marine layer. Two distinct facies are visible, believed to represent the initial in- and later back-flow of the giant wave.

- Go back to car and continue to *San Nicolás* (GC-200, green).
- For that drive towards port, but turn left before entering the port area (i.e. enter GC-200 green).

Set km-counter to zero now.

- After ca. 0.7 kilometers on GC-200, right in the 1st major bend after the turn off, you will encounter again the conglomerate deposits from earlier that are believed to be tsunami deposits. These here are from the same event and can be found throughout Barranco Agaete ***(Figs. 4.13a-c).***

Fig. 4.13a,b,c *In first major bend on GC-200, you will encounter the tsunami deposit again.*

- Drive further uphill through shield basalts that somewhat surprisingly dip toward the island's centre. Geophysical evidence suggests that a positive gravity anomaly exist offshore Agaete and a separate volcanic edifice may have existed here, adding substantial weight to the crust and thus promoting landslides. The inward dipping lavas may thus have originated from a long-lost volcanic centre.
- About 2.5 km after *Agaete* (on GC-200) you will see massive Miocene Mogán and Fataga pyroclastic flows on top of the shield basalts.
- Note the strong alteration in the basalt when passing. Zeolithes, calcite, chalcedony, amygdales and gypsum are frequently found in these rocks.
- After about 4 kilometers on GC-200, a major unconformity of Roque Nublo group lavas resting on shield basalts will appear in front of you ***(Figs. 4.14a,b).***

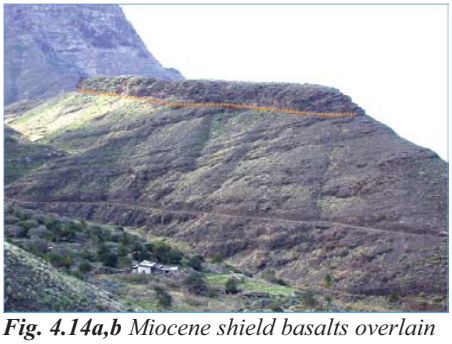


Fig. 4.14a,b *Miocene shield basalts overlain by Pliocene (Roque Nublo) lavas.*

- The Roque Nublo rocks show a seaward dip whereas the shield basalts still dip towards the islands centre.
- Drive to the hill with the unconformity and park in a little lay-by. Just after the little lay-by, note a massive phonolitic dyke in the road section. Take a stroll up to the unconformity if you want to stretch your legs.

STOP 4.6 Roque Nublo Unconformity – Shield Basalt

Location:
[N28° 05' 06.3" W15° 42' 19.6"]

- Continue on GC-200 and after another 600 metres you will see an erosional remnant of a dyke sticking out of a cliff like a wall ***(Figs. 4.15a,b).***
- After 8 km on GC-200, around a steep bend, you get a nice view of the wild and rugged coastline of North-west Gran Canaria.

Fig. 4.15a *Prominent dyke remnant along GC-200.*

Fig. 4.15b*Weathering resistant phonolitic dyke that stands out like a wall (dyke=wall in Scottish).*

Location:
[N28° 04' 30.7" W15° 42' 54.4"]

- Note parking is limited here so a stop is optional. Just around the bend you can see another big Fataga phonolite dyke in vertical section.
- Continue on GC-200. Basalt flows and younger dykes of mostly late Miocene (Fataga) age are now passing by.
- At about 10.5 km after *Agaete* (i.e. GC-200) we will get to the El Risco landslide ***(Figs. 4.16a,b)***.
- You need to park around a bend where you will find an open space to your left. From here you need to walk back on the road to inspect the head of the slide and down the dirt-track opposite to the parking space for the toe of the slide ***(Fig. 4.17)***.

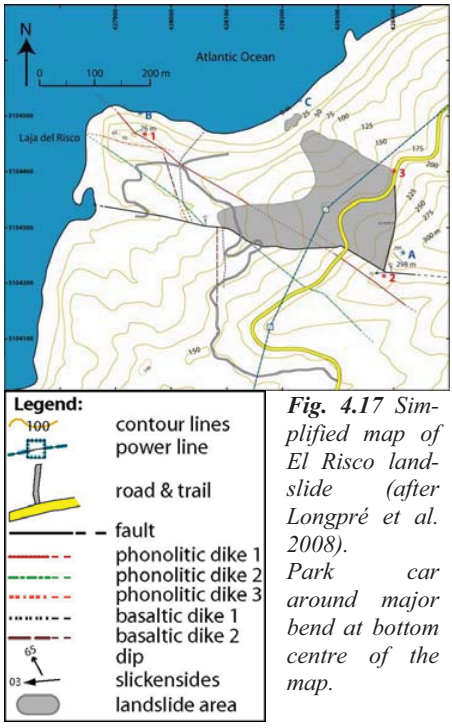


Fig. 4.17 *Simplified map of El Risco landslide (after Longpré et al. 2008). Park car around major bend at bottom centre of the map.*

Fig. 4.16a,b *El Risco landslide approached from the North. Note the large detached mass of material and the steep overhanging headwall (from Longpré et al., 2008).*

STOP 4.7 El Risco Landslide

Location:
[N28º 03' 46.4" W15º 43' 42.6"]

- Let's do the head first. Walk back on the road around one the major bend and approach the gully that separates the stable from the unstable rock mass ***(Fig. 4.18a)***. On the way you will have passed two major phonolite dykes that cut through the shield basalts here ***(Fig. 4.18b).***
- The gully at the landslide follows a radial fault (to the caldera), and a lithified fault breccia is visible up on the slope above the road. The head-wall of the slide, in turn, is a concentric open scarp

(Figs. 4.19a,b). *Continue along the road around the landslide* ***(Fig. 4.19a)****.*

Fig. 4.18a *Walk back towards the slumped rocks (centre and left in photo).*

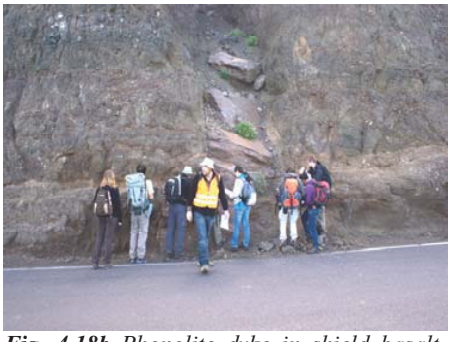


Fig. 4.18b *Phonolite dyke in shield basalt near El Risco.*

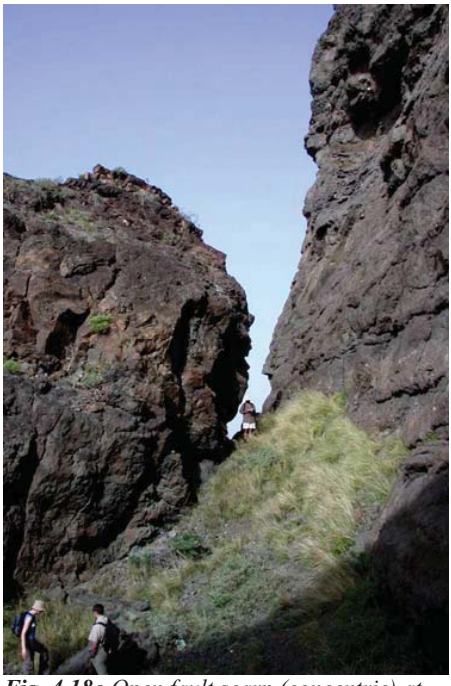


Fig. 4.18c *Open fault scarp (concentric) at El Risco (head of slide) if you are ok with a little scramble.*

Fig. 4.19a *Tilted and slumped shield basalts at El Risco landslide along GC-200.*

Fig. 4.19b *El Risco, head of slide along road GC-200.*

- To view the toe of the landslide, walk back to car and then down the dirt track opposite the car parking site. Pass a Fataga phonolite dyke on the way and walk out – along the dyke – onto the nose that sticks into the sea ***(Fig. 4.20a-b).*** Turn back and view the landslide from below ***(Figs. 4.21a-e)***.

Fig. 4.20a,b *Walk down to the nose that sticks out into the sea. Note the massive phonolite dyke running along the length of the nose.*

Fig. 4.21a *El Risco landslide viewed from the West.*

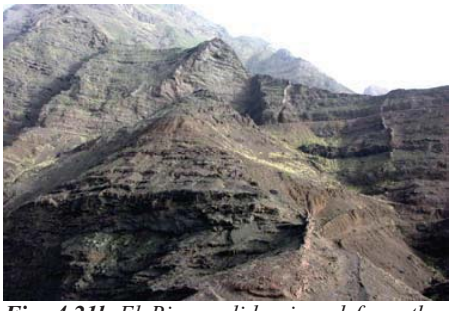


Fig. 4.21b *El Risco; slide viewed from the West.*

Fig.4.21c *Landslide deposit shaded in (4.21b,c from Longpré et al., 2008).*

Fig. 4.21d *A significant gully in hillside is the expression of the older, likely Miocene, radial fault that forms the southern landslide limits.*

Fig. 4.21e *Aerial photograph of El Risco landslide and nose with landslide area shaded (from Longpré et al., 2008).*

- Return to car and continue until village of *El Risco*. Right at the main road is a small coffee shop with outside seating. This is a superb lunch spot with an excellent inspection opportunity of another Fataga dyke ***(Figs. 4.22a,b).***

STOP 4.8 Village of El Risco

Location:
[N28° 04' 30.7" W15° 42' 54.4"]

- Look back down the road toward *Agaete* to admire a phonolitic dyke, cutting shield basalts, while enjoying a break. Unlike most of the other phonolitic dykes, this one is concentric and not radial to the caldera, which is slightly uncommon.

Fig. 4.22a *Fataga-aged phonolite dyke intrusions into Miocene basalts, El Risco village, NW Gran Canaria.*

Fig. 4.22b *El Risco village offers a splendid lunch opportunity and a nice Fataga dyke of concentric orientation.*

- Leave *El Risco* village and follow GC-200 uphill toward *San Nicolás*. The road becomes reasonably narrow and bendy soon with a steep drop to your right for several kilometers. **Ideally an experienced driver should do this leg.**
- At 16 km, 2-2.5 km after *El Risco* village, the road leads through the transition between intra-caldera breccias and pyroclastics and the shield basalts. The felsic pyroclastic units and the sedimentary breccias often display vivid alteration colours in a very similar style to those at Los Azulejos inspected on DAY 2, although this can be difficult to see if vegetation is thick.
- After 16 km on GC-200, drive through a small tunnel and look back to the port of *Agaete*. You will note the overall curved coastline, the Miocene giant landslide, but also the shallow-inwards dipping caldera margin becomes very clear from here.
- Note plenty of radial phonolitic dykes and other intrusions on the way. Continue on GC-200, but please drive carefully.
- At 21 km, the first ignimbrites of the Mogán succession can be seen to overlie shield basalts. At 21.5 km (*Andean Verde*), a stop might be taken. Stop at lay-by just on top of the ridge for a picnic or just for the view ***(Fig. 4.23).***

Fig. 4.23 *Parking for STOP 4.9; Andean Verde. Please drive carefully here.*

STOP 4.9 Andean Verde, the NW-Coast

- Climb up the small rock ridge behind the lay-by for some spectacular views of the coast and Tenerife on a good day ***(Figs. 4.24a,b)***, but again please be careful!

Fig. 4.24a,b *Andean Verde lay-by.*

- If you look around in a calm manner you might see one of the large Canary lizards that are sometimes sunbathing around here ***(Fig. 4.24c)***. However, straying dogs have also been reported from this location and you may need to offer a bite of food to buy your peace.
- Behind you, a stack of Mogán-ignimbrites is resting on top of shield basalts *(Andean Verde)*.
- Looking towards the South, i.e. towards *San Nicolás*, numerous white covers of tomato plantations are creeping up the valley ***(Fig. 4.25a,b).***

Fig. 4.24c *Canary lizard bathing in the sun.*

Fig. 4.25a,b *St Nicolás approached from the North. Note the number of tomato plantation that creep up the valley bottom and flanks.*

- This valley is somewhat exceptional on Gran Canaria as it is the only major barranco that is concentric to the caldera, rather than radial. Interestingly, it follows the margin of the Miocene Caldera with its hydrothermal alteration cells and a link is rather possible.

- Continue journey down to *San Nicolás*. Note Pl ignimbrite to your right hand side a few 100 m after the *Andean Verde* lay-by.
- At 25 km after *Agaete*, a quick stop at *Mirador Del Balcon* to admire the coastline might be worth your while on a good day ***(Fig. 4.26).***

Fig. 4.26 *View onto the Northern cliffs from Mirador de Balcon.*

STOP 4.10 Mirador de Balcon, NW-Coast

Location:
[N28º 06' 27.3" W15º 42' 16.7"]
(64 m asl)

- Continue downhill towards San Nicolás..
- At 28 km, on some of open hills to your left, reports of high proportions of sea shells and beach pebbles are known, probably where today's green-houses extend up the valley ***(Fig. 4.27)***. One may risk a speculation on potential tsunami deposits, with a wave originating from some of the neighbouring island (e.g. *Güímar* on Tenerife again), which would have the energy to transport beach sediment inland for several kilometers and to altitudes of several 100 m above sea level.

Fig. 4.27 *Open hills in Barranco La Aldea in part covered with green houses. From these hills unusual marine shells and beach pebbles have been reported.*

- At 30 km after *Agaete*, you will meet a fork. Follow GC-173 (yellow) to visit *San Nicolás* harbour and beach, which offers a number of very pleasant seafood restaurants and bars. Otherwise, continue to the left on GC-200 (green) to return to *Maspalomas.*
- From the outskirts of *San Nicolás*, one can see Roque Nublo monolith in the centre of the island when looking up *Barranco La Aldea* of course if weather permits.

- At ~35 km after *Agaete* and now already in the outskirts of *San Nicolás*, turn right towards *Mogán*, still on GC-200 (green) and complete the round trip. This leg was previously used (DAY 2) and you will find that you are already slightly familiar with the route by now.

Fig. 4.28 *NW-coast of Gran Canaria at sunset.*

End of DAY 4

DAY 5 – Traversing the Island South to North

Highlights

- Traverse of the Island from South to North.
- Driving through highland lakes within Miocene intra-caldera facies and Roque Nublo deposits.
- Ayacata and Tejeda Mountain villages and Roque de Betaiga.
- Cruz de Tejeda and recent (Holocene) volcanism.
- Eruptive vents, cinder cones and lapilli beds.
- Decent into lush valleys on North-side, where lots of water is present.
- Barranco Loreal; Remnants of former agricultural glory are seen.
- Meet coastal highway and return via Las Palmas to the South.

Start of DAY 5

- Drive from *Maspalomas* to *Arguineguín*, either on motorway GC-1 (blue) or along the coastal road GC-500 (green). See e.g. start of DAY 2.
- When in *Arguineguín*, drive to the entrance of Barranco de Arguineguín and drive inland on GC-505 (yellow) toward *Cercados Espino* and *Soria* (see morning of DAY 1).
- Follow GC-505 and pass Fataga ignimbrites and pumiceous deposits on either side of Barranco de Arguineguín. Remember these units dip toward the sea, so we are driving into older units the further we progress inland along the flat valley bottom.
- You will pass *Mogán* ignimbrite units soon, and after a while you pass STOP 1.7.
- Continue further inland and soon you will find dark coloured shield basalts to your left and right that make up the barranco walls on your altitude level. Pinnacles of Roque Nublo deposits, however, stick out on the higher slopes.
- Just before the village of *Cercado Espino*, follow GC-505 (left), i.e. sign for *Soria* (see also DAY 1-morning).
- After the village of *La Filipina* (km 14 on GC-505 road sign), the road will climb from the shield basalts units through the Mogán group and into the Fataga succession. Some spectacular features are exposed in these road cuts for you to inspect ***(Fig. 5.1).***
- Continue uphill to the plateau that was STOP 1.6 ***(Figs. 5.2, 5.3a,b).***

Fig. 5.1 *Basal vitrophyre of Mogán ignimbrite in Barranco Arguineguín.*

STOP 5.1 Barranco Fataga – Overview Miocene Succession

Location:
[N27° 53' 08" W15° 40' 39.5"]

Fig 5.2 *Miocene succession in Barranco Arguineguín.*

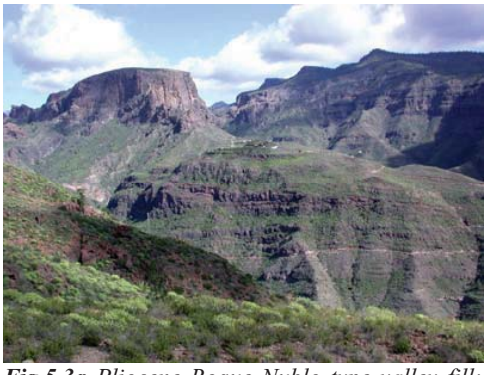


Fig.5.3a *Pliocene Roque Nublo type valley fill; Upper Barranco Arguineguín.*

Fig.5.3b *Behind your parking spot towers Mt. Tauro, which is made of Fataga deposits all the way from her to its very top.*

- Enjoy the view and stretch your legs if you like. For geological details see DAY 1, STOP 1.6.
- Continue uphill on GC-505 (yellow).
- After a short drive only, you will enter the small village *Barancillo de San Andres,* in which you will meet a road fork.
- At the fork, follow signs for *Tejeda* and *San Bartolome* (GC-605 yellow).
- The road now climbs steeply and gets narrow very fast, but you will pass some beautifully columnar jointed Fataga units on the way. The major mountain on your left is *Mt. Tauro*, made up entirely of Miocene rocks. Please drive carefully!
- Once you are over the narrow and bendy ascent and on the flat again, you will soon drive through some beautiful highland landscape ***(Fig. 5.4).***
- Soon you will also drive no longer through Fataga deposits, but within Roque Nublo strata that rests unconformably on the Fataga units now underneath our current altitude level.
- The Roque Nublo deposits here are part of a series of Roque Nublo debris avalanche deposits (breccias). They are characterised by fragments of mainly mafic rock in a rather chaotic arrangement. Locally more coherent domains exist.

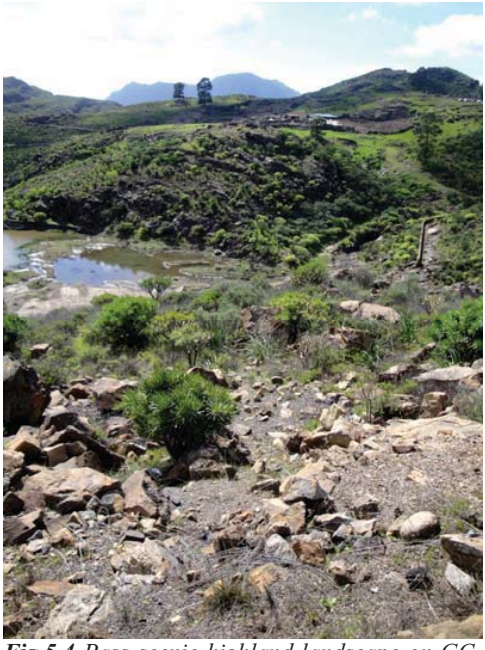


Fig.5.4 *Pass scenic highland landscape on GC-605.*

- Right after the first lake, the road goes slightly downhill. Park here somewhere for STOP 5.2, but note parking opportunities are limited here.

STOP 5.2 Roque Nublo Dyke in Roque Nublo Breccia

Location:
[N27° 54’ 27.9” W15° 41’ 12.6”]

- Here, two larger phonolitic dykes can be seen. If you look around, you realise that the dyke itself must be part of a larger dislodged block that was previously intruded. The dyke is therefore not *in-situ*. It is 'allochtonous', i.e. not form this place.
- If you have a good eye and a bit of luck, some 'mantle nodules' (i.e. peridotite xenoliths) have been reported from this section of the Roque Nublo breccias! ¡buena suerte!
- To the right (West) you can get a nice overview of the Miocene caldera margin in Upper Barranco Mogán. A small road goes off a little further should you want to go and have a look.

- Continue to drive inland with Roque Nublo breccias to your right.
- Soon you will meet another fork. Continue toward *Tejeda* and *San Bartolome* (GC-605, yellow), which is uphill and to your right in this case. To inspect the caldera margin you would have to go left and downhill. Continue towards *Tejeda.*
- Pass more Roque Nublo breccias and note, that after a while, the rocks become more coherent and several lava flows with top and bottom breccias appear in road sections.
- Drive by sign for *Cruz de San Antonio* ***(Fig. 5.5)***, with splendid highland landscapes that will unfold before you (given its not cloudy today).
- Continue to drive inland (approximately northward).

Fig.5.5 *Cruz de San Antonio road-sign.*

- The rocks along the road are now fresh-looking Roque Nublo basalt flows and you may take a quick stop to enjoy the views and inspect the exposures, e.g. around:

<u>Location:</u>
[N27° 55' 32.7" W15° 41' 0.0"]

- Continue on GC-605 inland. Pass several small to medium-sized highland lakes on your right and note that just before km 11 on the GC-605 road sign you will encounter Roque Nublo breccias again for a short while before you drive within basalt flows once more. Note, however, the freshness of these flows is rapidly diminishing as you drive further inland.
- At around km 8 on GC-605 road sign, you will note a drastic change in the rock type exposed as you have just made your way into the late Miocene cone-sheet swarm that lies beneath the Roque Nublo cover in this now more central part of the island (compare to STOP 2.7).
- Continue inland. The boundary between the Miocene cone sheets and the Roque Nublo deposits is now undulating along the road and you will see a bit of both coming and going for a short while.

- Soon, however, you will drive fully in hydrothermally altered cone-sheet units for several kilometers once more. Note, the majority of them dip towards the centre of the island (approximately toward the North). This makes sense as we are now approaching the central highlands from the south.
- At the end of GC-605, you will encounter the unconformity between the Miocene cone-sheet swarm and the overlying dark and massive Roque Nublo breccias once more now, forming the pronounced cliffs in front of you, e.g. at:

  Location:
  [N27° 57' 25" W15° 36' 42.5"]

- Continue into the village of *Ayacata* for a short refreshment stop (i.e. turn right on to GC-60 red).
- In *Ayacata*, park outside the little coffee shop that we had used on DAY 3, only that we approached it from the other side this time (see STOP 3.2 / STOP 3.3).

STOP 5.3 Ayacata Village – Cone Sheet-Roque Nublo Unconformity

Location:
[N27° 57' 30" W15° 36' 40"]

- You can now consider doing the Roque Nublo hike (~ 1 hour) if you have not managed to do it on DAY 3 (e.g. because of weather or time constraints). If you choose this option, continue uphill on GC-600 (green) towards *San Mateo* for ca. 10 minutes and fall back on instructions for STOP 3.4 ***(Fig. 5.6a).***
- If you just want to stretch your legs for a few minutes or have coffee only, consider STOP 3.2, which is only a few steps away from your current parking place ***(Fig. 5.6b).***

Fig. 5.6a *Consider doing the Roque Nublo hike if you have not done so on DAY 3.*

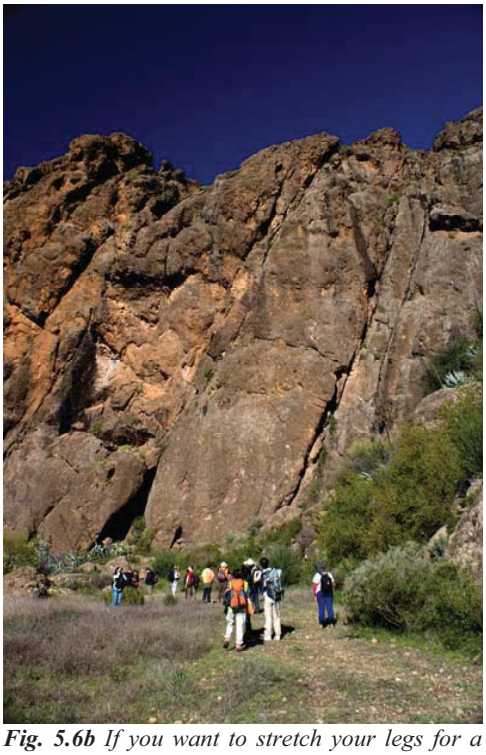


Fig. 5.6b *If you want to stretch your legs for a minute, there is a nice outcrop just South-West of Ayacata village.*

- To continue the N-S traverse of the island, however, drive out of the village the way you came, but now join GC-60 (red) towards *Tejeda*, i.e. go right at the fork just outside *Ayacata* village.
- Now you will drive along some steep cliffs of Roque Nublo breccia to your right hand side.
- Above you and to your right are still Roque Nublo-type rocks, but below you are the Miocene intra-caldera cone sheets with their much lighter colours.
- The road descends for a while and around km 9 on GC-60 road-sign you will find yourself next to cone-sheets of the Miocene epoch again. Note the dip of the cone-sheets has changed once more by now, reflecting that our position relative to the focal point of the Miocene cone-sheet swarm has also changed since earlier in the day.
- After approximately km 8 on the GC-60 road-sign, you will once more traverse "the unconformity" and Roque Nublo-lavas will appear to your right for about one km, followed by Roque Nublo pyroclastics and breccias.
- Yet a little further, you will encounter a major fork. To the left is *Roque Bentayga* (GC-607 and GC-67, yellow), another erosional remnant of the Roque Nublo period, similar to the Roque Nublo monolith itself. If time permits, have a look and take a short drive to there (10 min.) to stretch your legs for a while ***(Figs. 5.7a-c).*** Stunning views are the reward. A short hike there is warmly recommended. Note, however, the entrance road is closed higher up on Sundays.

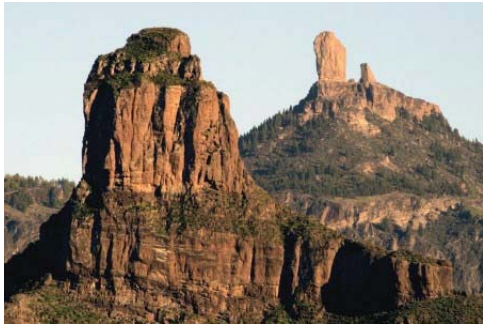


Fig. 5.7a *Roque Bentayga with Roque Nublo in background. ©Canary Tourist Board*

Fig. 5.7b *Parking at food of Roque Bentayga.*

Fig. 5.7c *Looking back to Roque Bentayga from Tejeda village. Note the inclined base on which the monoliths sits, suggesting it to be part of a former valley-fill deposit.*

- Otherwise, continue towards *Tejeda* on GC-60 (red). Roque Nublo lavas and pyroclastics on your right pass once more into the Miocene intra-caldera rocks as the road descends toward *Tejeda* (between km 6 -5 on GC-60 road-sign). This underlines the irregular

topography of the Miocene-Pliocene unconformity as you now see Roque Nublo deposits 'below' the altitude-level of some of the Miocene cone-sheet rocks we passed only a few kilometers earlier on GC-60.

- A little further, several rock faces can be seen to have protective measures implemented, e.g. shot-crete and protective wire fencing ***(Fig. 5.8),*** reflecting the crumbly and unstable nature of the exposed hydrothermally over-printed Miocene rocks in the central parts of the island.

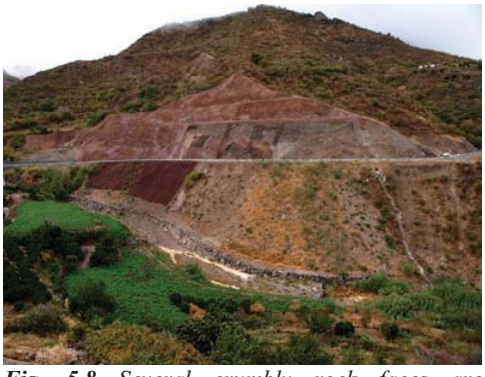


Fig. 5.8 *Several crumbly rock faces are stabilised using a shot-crete cover near Tejeda. Not too attractive for the geologist, but practical for the road engineer.*

- In *Tejeda* village ***(Fig. 5.7c)***, you have several options for refreshments and there is also a petrol station in the centre of the village in case you are running low on fuel. Please check!
- Right at the petrol station, you will meet another fork. Choose the right hand turn towards *Las Palmas* and *Artenara* (Stay on GC-60, red).
- After *Tejeda* village, continue to follow signs for GC-60 (uphill) and turn left after a short while, but still following GC-60 to *Las Palmas* and *Artenara*. Signs for *Cruz de Tejeda* should appear now as well.
- After less than 0.5 km, you will meet a roundabout. Drive uphill, now following signs for *Cruz de Tejeda* on GC-15 (red). Follow GC-15 uphill for a while.
- At the next fork, go left so that you stay on GC-15 (red). Now you are in Roque Nublo-Group rocks once more.
- When coming into *Cruz de Tejeda*, a major tourist attraction, please drive carefully, as many people may be walking on the streets outside the cafés and souvenir shops. Have a break yourself if you feel like.
- Just after the white building with towers on your left, a small road (GC-150-green) goes off to your left hand side. Follow GC-150 (green) towards *Pinos de Galdar*.
- Follow GC-150 (green) uphill and continue for approximately 4 km through Roque Nublo strata.
- Once the road descends again, you will soon encounter Holocene scoria and lava deposits on your left (ca. km 9 on GC-150 road-sign). These are very reddish (oxidized) from contact with air in a hot condition and are locally seen to overlie weathered Roque Nublo deposits ***(Fig. 5.9)***.
- The Holocene scoria deposits were erupted from a series of vents and cones around *'Montañon Negro'*. As the name implies, black scoria and lavas of fresh appearance are found here in the area too. An inspection is possible a few kilometers further.
- A little further, Holocene feeder intrusion cuts and was locally fritting, the surrounding scoria ***(Fig.5.10)***.

Fig.5.9 *Reddish Holocene scoria along GC-150.*

Fig.5.10 *Holocene sheet-intrusion in scoria.*

STOP 5.4 Holocene Intrusion into Scoria

Location:
[N28° 01' 29" W15° 36' 36.7"]

- Although strongly weathered, pyroxene and feldspar, plus altered olivine can still be recognized in the intrusion ***(Fig. 5.11)***.

Fig.5.11 *Note 'fritting' of scoria next to the intrusion margin.*

- Continue on GC-150 for another short while, before you stop to inspect fresh scoria and lapilli deposits.
- Park car near bend from which a long stonewall goes uphill to the cinder cone ***(Fig. 5.12; 5.13).***

Fig. 5.12 *Parking site for STOP 5.5.*

Fig. 5.13 *Walk along stone wall to about half way up the hill, then walk sharp left.*

Fig. 5.14 *View Teide on a good day on the Western horizon.*

STOP 5.5 Montañon Negro – Fresh Lapilli Deposits

Location:
[N28° 01' 32" W15° 36' 42.7"]

- Follow the stone wall perhaps half way up and then walk to the left to make your way to the fresh exposures on the NW face of *Montañon Negro* ***(Figs. 5.15a-c).*** Note it can be slippery when walking on lapilli. The cone is approximately 2500-3000 years old, i.e. geologically very young. Note the whitish xenoliths!
- Return to car and continue on GC-150.
- Continue on GC-150 and after km 11 on GC-150 road sign, you will leave the forest. Layers of dark (fresh) scoria and lapilli will be visible in good weather and the cinder cone will appear on your right hand side again. You are now fully in the Holocene eruptives that cover large areas of N and NE Gran Canaria.
- After another 1 or 2 km, you might be rewarded with a stunning view of Teide volcano on Tenerife – at least on a good day ***(Fig. 5.14)***. Soon you will meet a fork with GC-21.
- Right at the fork of GC-150 (green) to GC 21 (red) is a small lay-by and viewpoint with a small parking space.

Figs. 5.15a,b,c *Fresh lapilli exposures at Montañon Negro.*

STOP 5.6 Pinos del Galdar, Holocene Crater

Location:
[N28° 02' 19.1" W15° 37' 06.9"]

- From here you can get a bird-eye view of the Holocene (3000 years) "Pinos del Galdar" crater below you ***(Fig. 5.16)***. The crater is virtually the same age as *Montañon Negro* cinder cone.

Fig. 5.16 *Pinos del Galdar Crater viewed from STOP 5.6.*

- Continue on GC-21 towards *Valleseco* and *Las Palmas*. Very soon you will meet another T-junction.
- You have two options here. Both are very nice drives:
  A) A shorter drive is the one via *Las Palmas* which passes Holocene lavas (right hand turn) and **B)** a somewhat longer one (left hand turn) passes the Holocene crater again and takes you through the lush northern valleys.

Return option A) "aa lava"

- If you want to follow GC-21 towards *Las Palmas*, continue here.
- After km 3 on the GC-21 road sign, you will drive by a Holocene lava field to your right. This makes a very useful stop and is usually shady in the afternoon ***(Figs. 5.17a-c).***

STOP 5.7 Holocene "aa" Lava Flows

Location:
[N28° 02' 6.5" W15° 36' 23.5"]

Fig. 5.17a,b,c *Holocene lavas along GC-21. Holocene lavas here are approx. 3000-5000 years old and vegetation is slowly recovering the resurfaced ground.*

- Here, bottom and top breccias of several lava flows are superbly exposed, displaying more massive flow centres, the typical architecture of viscous "aa" or "blocky" lavas. Unfortunately, the rocks are not the freshest ones on the island and have seen significant low-temperature hydrous alteration. Remember, this is the wet side of the island and these lavas have presumably seen a lot of rain.
- These lavas are part of the eruptives of *Montañon Negro* again that you visited earlier and are hence also ~3000 years old. Walk down the small paved street for a few hundred meters until a 'hornito' becomes visible. Frome here the valley-filling nature of the lava becomes apparent. The top surface of the flow looks very rubble and looks almost unmodified apart from the plants that slowly conquer the lava surface of this flow.
- After the Holocene lavas, the road rapidly brings you to lower altitudes and back into the underlying post-Roque Nublo and Roque Nublo sequences. Continue on GC-21 (red) towards *Valleseco*, *Teror* and *Las Palmas*.
- Soon, you will be able to see *La Isleta*, the volcanic arm of the island to the NE of Las Palmas (in the far distance).
- Continue on GC-21 downhill toward *Las Palmas.* A cultural stop in *Teror* is recommended if there is enough time ***(Fig. 5.18).***

Fig. 5.18 *Scenic Teror!*

- You will note that Gran Canaria is more lushes here on the Atlantic weather side due to (considerably higher rainfall!). This gives rise to a series of springs in this part of the island. The spring water is bottled and available to you in all supermarkets on the island (e.g. Aqua Teror, Firgas, El Toscal, etc). Chance is that the bottled water you have in the car with you is from here somewhere!
- Further downhill, join GC-3 (blue) and follow signs for *Las Palmas*, *Telde* and *aeropuerto*.
- Consider a visit to Las Palmas especially the old town 'Vegueta' ***(Figs. 5.19a,b).***
- GC-3 eventually brings you to the North-South motorway GC-1 (blue). Follow the motorway GC-1 with direction South (Sur) towards *Telde, aeropuerto, Play del Ingles* and *Maspalomas*.
- From here it will be about 40 minutes back to *Maspalomas*.

Fig. 5.19a *Las Palmas, Cairasco Square with Literary Cabinet in the background. Enjoy the sizzling late afternoon of Las Palmas before returning back South.*

Fig. 5.19b *Las Palmas, Santa Ana Cathedral, in the heart of the old town was the first church of the Canaries. Note, Santa Ana is largely constructed from Fataga ignimbrite material.*

Return option B)
Holocene Crater Route

- After ca. 1 kilometer on GC-21 (red) with direction *Valleseco* and *Las Palmas*, you can turn left into GC-70-(red). Follow GC-70 towards *Moya* and *Galdar*.
- After only about one km on GC-70 (red), the larger Holocene *Pinos del Galdar* crater opens up on your left again. This site is worth a photo stop but please be careful here; traffic can be heavy and the lay-by is of the slim type.

STOP 5.8 Pinos del Galdar – Holocene Crater (3000 years)

Location:
[N28° 02' 24.4" W15° 36' 56.4"]

- Beautiful exposures of crater rim facies are seen here. The deposits overall are oxidised, compatible with a near vent facies deposit where the combination of heat and air contact are allowing rapid uptake of oxygen, producing a rust-like colour.
- Continue downhill on GC-70 towards *Galdar*. On your right stunning views of *La Isleta* opens up, the volcanism North-East of *Las Palmas.*
- You will also pass more scoria and lapilli deposits and about 1 km after the crater stop, a Holocene dyke of considerable thickness cuts through the scoria layers.
- Locally, the underlying post-Roque Nublo and Roque Nublo rocks (Pleistocene) appear beneath the scoria deposits when you descend further on GC-70. You can spot them easily by their weathered nature and brownish to greyish colours.
- Continue downhill through more Pleistocene post-Roque Nublo-deposits.
- When you reach the village of *Fontanales* (the 'fountains', indicating an area with plenty of fresh water), join GC-75 (red) towards *Moya*.
- Continue downhill on GC-75, with many more Roque Nublo road cuts along the way.
- You are now driving through *Barranco Loreal* the site of large-scale bay leaf cultivation of past centuries ***(Fig 5.20)***.

See if you can spot some plants along the way. Maybe have a stop for a minute at some point as beautiful smells spread over this barranco at the right time of the year.

Fig. *5.20* *Bay leaf cultivation of former days is still leaving a mark; Barranco Loreal.*

- When reaching *Moya*, continue to follow GC-75 (red) towards *Firgas* and *Las Palmas*. This involves two major turns in *Moya*, but you can simply follow road signs towards *Firgas* and *Las Palmas*.
- After *Moya*, continue on GC-75 (red) now with direction *Las Palmas.* Do not follow the small (green) road to the right for *Firgas* village that appears after a few kilometers.
- Descend further through Pliocene Roque Nublo lavas and breccias until after the small settlement of *El Drago*, you will start to encounter Miocene extra-caldera Fataga units that comprise ignimbrites, pumice layers, lavas and debris deposits.

Note, you have just been going back in geological time if you will (i.e. from the Pliocene in to the Miocene).

- Continue on GC-75 downhill until you meet GC-2 (red), which you should join with direction towards *Arucas* and *Las Palmas*.
- A few km after you have joined GC-2 (red), it will become a proper motorway (then GC-2-blue) that will take you to GC-23 and GC-110 and from there back on to GC-1 to the South (all blue), i.e. follow signs for *Telde, aeropuerto* and *Maspalomas.*
- Once you made it to the northern coastal area, the South-North traverse of the entire island is complete - and with it a drive through the entire exposed rock successions of the island too. Chance is that it will be late when you return ***(Fig. 5.21)***.

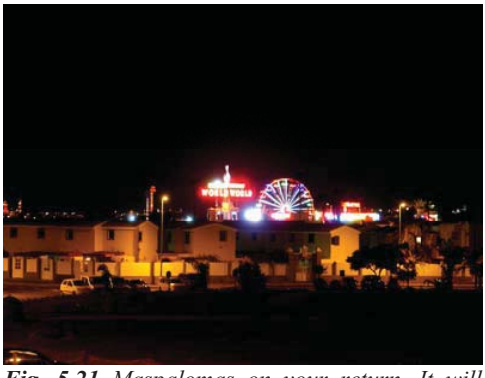


Fig. 5.21 *Maspalomas on your return. It will likely be late today.*

End of DAY 5

EXERCISE 1 – Ignimbrite Logging in Barranco Ayagaures

Exercise 1 is a classical geological recording method best placed between DAY 1 and DAY 2 or between DAY 2 and DAY 3. The exercise will take place in a Grand Canyon-like landscape that has only dirt-track roads. Please check if your hired car is insured on dirt-tracks! Note there is no opportunity to buy food or water for most of the day, so please bring lunch and plenty of water.

Start of EXERCISE 1

▪ Drive onto GC-503 (yellow) towards *Montaña La Data* or take GC-504 to *Ayagaures*. Both ways will take you to *Ayagaures* village from where the dirt track for the exercise starts. I recommend you use GC-503 for the nicer views.

▪ Once you have made it onto the plateau at km 6 on GC-503, you will start to see some splendid housing in front of you. This is for example where the conductor Justus Franz has his 'little finca' as he calls it. He claims the Canary climate keeps his fingers warm and elastic for playing the piano.

▪ Continue to drive through this type of residential area while passing Fataga-aged pyroclastic deposits and sedimentary rocks (debris flows and avalanches) on the way; e.g. at km 8 on GC-503 road sign. Nice obsidian is known in some of these sedimentary units.

▪ Once you have left of the residential area, the road progresses horizontally along a steep hillside and you can get a first glimpse of the massive Fataga-aged ignimbrite package to your left.

▪ A few minutes further on GC-503, you will pass a larger lay-by on the right hand side in a sharp bend ***(Fig. E1.1)***.

Fig. E1.1 *STOP E1.1; Overview of Barranco Ayagaures and the Fataga succession.*

STOP E1.1 Overview of Ayagaures Village and Fataga Succession

Location:
[N27° 50' 07.3" W15° 36' 06.6"]
(485 m asl)

▪ At the 'mirador', you will have a spectacular view on to the Fataga ignimbrite succession to the North and North-East. Looking north, you will see a major dam in the foreground and caldera margin rocks in the background ***(Figs. E1.2a,b)***. Descend down to *Ayagaures* village and drive over the dam you just saw.

▪ Once over the dam, drive uphill on a good but bendy dirt-track. When you reach the highest point on the ridge (i.e. before descending again), park the car on your right hand side in the large lay-by ***(Figs. E1.3a,b)***.

Figs. E1.2a,b *Inspecting the Fataga succession and Ayagaures village. Note the dam down in the village, our next destination.*

Figs. E1.3a,b *Parking for STOP E1.2.*

STOP E1.2 Start of Exercise

Location (parking):
[N27° 50' 7.35" W15° 36' 6.62"]
(440 m asl)

▪ Walk down the dirt track for about 700 meters. While walking, note the top of the first sequence you encounter is the Ayagaures ignimbrite. It is very thick. Once in the next unit below, count ignimbrites using vitro-phyres.

▪ Walk further here downhill, while counting units, for about ten minutes until you reach a dark green lava flow ***(Fig. E1.4)***.

Location (lava flow):
[N27° 50' 33.9" W15° 36' 5.2"]

▪ The lava flow itself is massive and dark green in colour ***(Fig. E1.4)*** and not very rich in crystals at all. Little tension gashes now filled with white secondary phas-es are common and relate to the pattern of flow during final lava emplacement.

Fig. E1.4 *Greenish lava flow at the base of our log-section.*

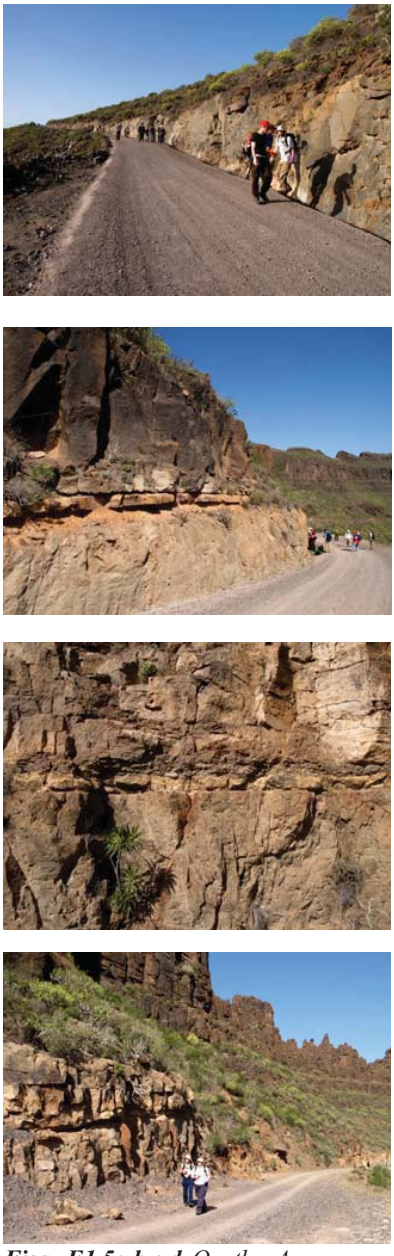
▪ The overlying debris avalanche deposit is characterized by up to man-sized blocks of basalt, trachyte and phonolite and the concept of domains of clasts due to progressive dis-integration of large blocks during transport of such mass-movements can be quite well visualized here. Some of the blocks are so large that they may locally be taken for a new unit.

▪ Devise your log-table now. What is the information you are looking for? Percentage of lithic clasts, crystal content, percentage of fiamme, percentage of ash matrix, steep-ness of fiamme, flow directions etc., etc., etc.

▪ What else can be recorded? How do you measure altitude? With a GPS, sure, but how else?

▪ You cannot log the whole succession in cm-steps. If you take a reading at approxi-mately every five 'altimeters' you will be having lunch on top of the hill at the cars ... so keep moving while taking the readings.

▪ From the lava flow you can start the log-section. Make your way up the hill again ***(Figs. E1.5a-d)***, noticing unit thickness crystal percentages, lithology and if present lithic clasts as well as fiamme abundance, fiamme length and fiamme aspect ratio (length : height).



Figs. E1.5a,b,c,d *On the Ayagaures log.*

▪ Also note the dip of e.g. young scree deposits as you may find that same contacts and boundaries occur again before and after younger scree, which means you can simply go there and pick up the logging from such a marker horizon or boundary.

▪ Your overall stratigraphy should comprise 5 ignimbrites, one debris avalanche deposit and one massive lava flow (top part) when going from youngest to oldest.

▪ The first ignimbrite after the debris avalanche deposit shows several flow unites (3-4) and is about 6-7m thick ***(Fig. E1.6)***. The next ignimbrite is somewhat thicker, with good welding in the bottom part.

Fig. E1.6 *First ignimbrite on your log is overlying a debris avalanche deposit.*

▪ Around here, a concentric 120˚ striking fault is visible in the hillside opposing the outcrop ***(Figs. E1.7a,b)***. The North side is thrown down by about 10-20 m.

Figs. E1.7a,b *Hillside opposite the log-section. Note concentric fault running through the hill with a downthrow of the side closer to you.*

▪ Up stratigraphy, the next ignimbrite shows dense welding at its base, but with fiamme that appear to dip opposite direction from the vitrophyre, i.e. the vitrophyre dips toward the sea, whereas the fiamme dip toward the Island's centre. This is probably a depositional feature where accumulating particles pile up in an imbricate fashion due to the push from behind and above due to continuing flow above the depositional interface.

▪ You may encounter some research drill holes in the rocks here that were done for investigating magnetic polarity e.g. for an age determination or to see if units have been moved or rotated on a large scale (say by island uplift). These units here, however, are in their original position for all we know.

▪ A little higher up, another ca. ten meter thick ignimbrite occurs, again the fiamme dip opposite to the direction of flow, which is in this section is shown by the orientation of the vitrophyres that dip towards the South. The final ignimbrite is a very thick unit and is named the *Ayagaures* ignimbrite, a prolific marker unit for the Fataga succession. It has more than ten individual flow units and a classic reddish ash top is preserved too.

▪ Back at car, you may want to have lunch now and take a rest while enjoying the views ***(Fig. E1.8)***.

Fig. E1.8 *View from lunch spot looking roughly East.*

▪ After lunch, drive on along the dirt track, aiming for a section two barrancos further. There, we will pick up the lava flow again after the second major coastward bend ***(Figs. 1.9a-c)***.

Fig. E1.9a *Last valley (coast-ward bend) before STOP E1.3.*

Figs. E1.9b,c *Parking for STOP E1.3. Park car near crest and walk downhill again.*

STOP E1.3 The Other Side!

Drive up to crest of the road and park car there ***(Figs. E.1.9a-c)***.

Location (parking):
[N27° 50' 36.22" W15° 35' 13.52"]

▪ Walk back downhill until you meet the top of the dark green lava flow at an elevation of ~450 m ***(Fig. E1.10)*** at

Location:
[N27° 50' 52.86" W15° 35' 13.54"]

Fig. E1.10 *Greenish-dark lava flow at start of afternoon section.*

▪ Start logging up to the car using the methods applied on the other side of the valley earlier in the day. Note that you are approximately on the same horizontal level than you were on in the morning on the other side of the barranco.

▪ Start counting the units: one lava, one debris avalanche deposit, one ignimbrite, the second ignimbrite etc., etc. and work your way backup to the car. It may not be necessary to record all details again on this side, more the overall succession, but if you are keen, it offers a very good opportunity to practice.

▪ Note a thin band of beige coloured loosely consolidated material ***(Figs. E1.11a,b)*** on the way at ca.

Location (thin beige band): [N27° 50' 52.79" W15° 35' 13.57"]

Figs. E1.11a,b *Note beige-coloured band along the way. What could this be?*

▪ After the second ignimbrite, a little ignimbrite occurs that weathers very intensely. No vitrophyre is visible, and hence in part it may have been of air fall origin. A palaeosol at its top suggests that it was a thin unconsolidated tuff that swiftly weathered in the rain, developing a soil on its top surface. Note that the vitrophyres are now dipping toward the East (implying deposition was on a slope again).

▪ This is followed by ignimbrite 'P3', a massive deposit with spectacular green fiamme and clear flow units visible

Location (ignimbrite 'P3'): [N27° 50' 45.18" W15° 35' 14.48"]

▪ Towards its top of the outcrop a possible degassing structure is visible. Up the track, after a bit of recent scree, another vitrophyre occurs, but this time it is dipping towards the centre of the island ***(Fig. E1.12)***.

Fig. E1.12 *Another vitrophere? Wait, this one is somewhat strange ... What is going on?*

▪ This is probably also the little unconsolidated ignimbrite from earlier again. In fact, you just have been going down in stratigraphy for the last ten meters or so although you have been going uphill! Below the inclined vitrophyre and ignimbrite, you can see an old, heavily weathered, fractured lava ***(Fig. E1.13)***.

▪ This is really an old topographic high that got overrun by the eruptions and cannot be taken into account for your stratigraphic column. If you look up to your left, however, you can see the vitrophyre of the Ayagaures ignimbrite, where technically, the log could be continued, but please do not attempt to climb up there.

Fig. E1.13 *Older Miocene rocks appear under the logged ignimbrite succession, suggesting a plaeotopography despite the apparently flat nature of the deposits.*

▪ Interestingly, this implies that underneath the current landscape there is another, older landscape that is also of Miocene age. This enforces the concept about valleys here being formed, filled, and formed again in repetitive fashion.

▪ Thus, a hidden canyon-like landscape underlies this "flat" Fataga-ignimbrite blanket. If this was not recognized by e.g. a field geologist, drastic flaws in stratigraphic correlation are possible! You can now attempt your correlation of units across the barranco!

▪ If you have used the same scale for both logs, and use the basalt flows as a lower tie point, you should be able to make a sensible correlation. Does it fit? You may find that one ignimbrite is missing?

▪ Also consider, what do the individual bits of information tell us (crystal content, lithic percentage, fiamme orientation etc.). Some of these data tell us about eruption dynamics (flow-units), others, in turn, about transport features (e.g. fiamme orientation) and yet others about pre-eruptive magma chamber processes (e.g. crystal content). There is a lot of information in your data. See how far you can push your interpretations!

▪ Continue on dirt-track to go back to *Maspalomas* or to join the route for the Roque Nublo day. After about 15-20 minutes on the dirt track, you will pass a major rock fall with individual blocks of up to car-size in a large block field that fans out at the foot of the hill ***(Fig. E1.14).***

Fig. E1.14 *Recent block field resulting from large-scale rock fall.*

▪ Another 10 minutes further in a bend, a short while before the dirt track joins the road again and just after a little bridge, a band of light coloured rock appears. This is a pyroclastic deposit possible of airfall origin that may be worth inspection despite its somewhat weathered nature.

▪ Once you meet the road again (GC-60 red), turn right to return

to Maspalomas and left to join the Roque Nublo day (direction *Fataga/San Bartolomé*). If you go to the right you will soon be climbing up a steep hillside road that leads up to a larger view point *(Mirador Degollada de las Yeguas)* at the top of the ridge at km 41.5 on GC-60.

STOP E1.4 Mirador Degollada de Las Yegus

▪ From here you can look back onto the Fataga pyroclastic succession and enjoy the views up Barranco Fataga, especially after having spent a full day's work on these exceptional pyroclastic deposits ***(Fig. E1.15)***.

▪ Continue downhill on GC-60 and return to *Maspalomas*.

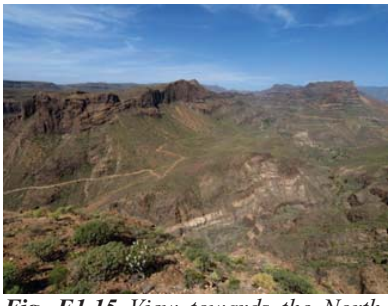


Fig. E1.15 *View towards the North from Mirador Degollada de Las Yeguas – the full beauty of the Fataga succession unfolds before you.*

End of EXERCISE 1

EXERCISE 2 – Montaña Cedro: Faults in Volcanic Rocks

This exercise is best taken after DAY 2 and after EXERCISE 1. Make sure you have hiking gear, lunch and water for a full day with you. The goal is to inspect an extra-caldera fault system near Montaña Cedro in Western Gran Canaria and record the individual units, their relative positions and their thickness. This will allow us to reconstruct the lifecycle of this fault system in detail and will give you some further insights information on the Miocene caldera as a whole.

Start of EXERCISE 2

▪ Drive towards St. Nicolás from the South.

▪ Turn left up to the graveyard just before St. Nicolás village and pass a graveyard on a little road to your right. Then drive steeply up the hill.

▪ Turn right into flat dirt track pretty high up on the hill. Drive along the flat track for ~3 km on same altitude and park the car at a little water reservoir that also marks the end of the track.

Location (parking):
[N27° 58' 54.35" W15° 48' 27.57"]

▪ You will find yourself in shield basalts. A small footpath leads on from the water station to the West and South-West. It splits very soon after the car parking place, and you should take the higher one!

▪ After a short while you will see the Gui Gui-Horgozales unconformity on your right in the hill side (to the West). This marks the boundary of an old landslide in the shield basalts into which more shield basalt rocks were erupted.

▪ Hike further up the footpath ***(Fig. E2.1)***. Note a fair number of basaltic dykes in the shield basalt rocks around here. Remember the concept of radial and concentric structures! Are these dominantly radial or concentric to the central caldera?

Fig. E2.1 *Hike up the valley until it narrows. Stay on the trail if possible as otherwise you might end up doing extra kilometres.*

▪ If you are lucky you will find my favourite vesicle on the hiking trail ***(Fig. E2.2)***.

▪ If you look around, a larger number of 'P1' boulders are scattered around the hillside. View 'P1' on the other side of the valley on approximately your altitude level. It is obviously above your altitude on this side of the valley, so is it a depositional or fault offset?

Fig. E2.2 *This is my favourite vesicle. Watch out on the hike, you might find it along the way.*

▪ Hike up until you are in the ignimbrites ***(Fig. E2.3)***. Walk uphill until the trail gets rather narrow, bendy and steep. Start your log here: Start on East side and log all ignimbrites on both sides of the valley (record also altitude!).

Fig. E2.3 *Ignimbrite 'Vi' with columnar jointing on your left along the trail. Continue uphill for a little longer until the path gets narrow, bendy and steep. Start your log here.*

▪ Several of the familiar Mogán ignimbrites occur here once more. You can use their real labels or give them descriptive names by yourself ***(Fig. E2.4)***.

Fig. E2.4 *Mogán-age ignimbrite 'X' on the Eastern side of the steep gully.*

▪ Note the little beige-coloured tuff-band above ignimbrite 'B' when entering the flat bit of the path after the narrow bendy section of the trail ***(Fig. E2.5).*** This has been termed 'HC' on my log ***(Fig. E2.8)***. Note the small-scale faulting that is frequent in this band.

Fig. E2.5 *Thin, beige-coloured and slightly faulted tuff-band near lunch-spot.*

▪ Note also the fault breccia on the the horizontal bit of the path.
Around the next bend, a little open area with a small cave next to it provides a terrific spot for lunch ***(Figs. E2.6a-c)***!

Location (lunch):
[N27° 58' 00.40" W15° 48' 56.69"]

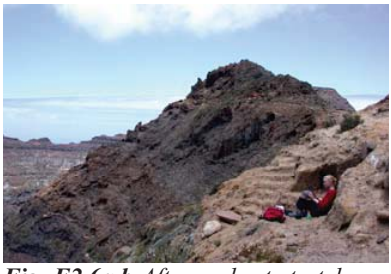


Fig. E2.6a,b *After a short stretch on the flat bit of the trail, you will encounter a little plateau which is a superb spot for lunch.*

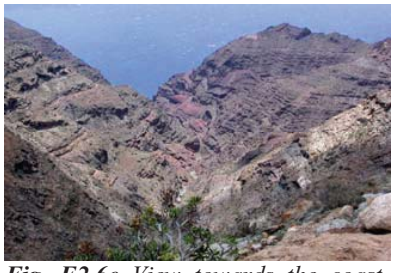


Fig. E2.6c *View towards the coast from your lunch spot.*

▪ After lunch, view the actual fault zone on the back of the hill ***(Fig. E2.7)***, which is only a few hundred meters further along the trail.

Location (fault core):
[N27° 57' 51.9" W15° 48' 53.66"]

▪ At the fault exposure, you will see a sharp boundary between ignimbrite 'X' on the East-side and a fault core of various clasts (including green Fataga ones), but especially basaltic ones from overlying 'T4' basalt. A few metres further to the West (beyond the fault core) there is ignimbrite 'C', marking a considerable displacement. The Fataga boulders in the fault core imply that the fault was active at least into early Fataga time.

▪ Climb up to the East side of the fault and find ignimbrites 'A' and 'B'. These are offset by about 190 m relative to the Western side of the fault!

▪ Part of the events may be summarized as in ***Fig. E2.8*** and a little cartoon sequence of fault evolution is provided in ***Fig. E2.9***.

▪ Essentially, the fault must have moved in opposing directions early and late in its history to accommodate all the offsets measured!

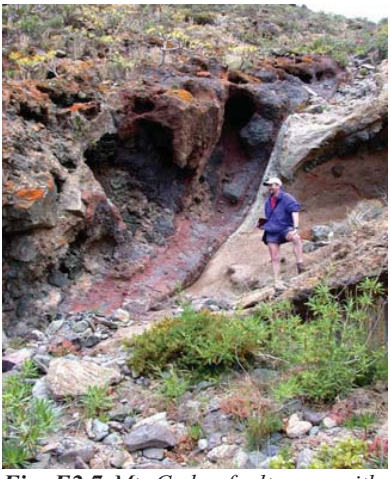


Fig. E2.7 *Mt. Cedro fault zone with ignimbrite 'X' (right) and 'T4' basalt (from above) in the fault core.*

▪ Enjoy the views and hike back to the cars. Note the return hike will take you between one and one and a half hours. Please leave sufficient time as you don't want to hike down on the trail in darkness.

End of EXERCISE 2

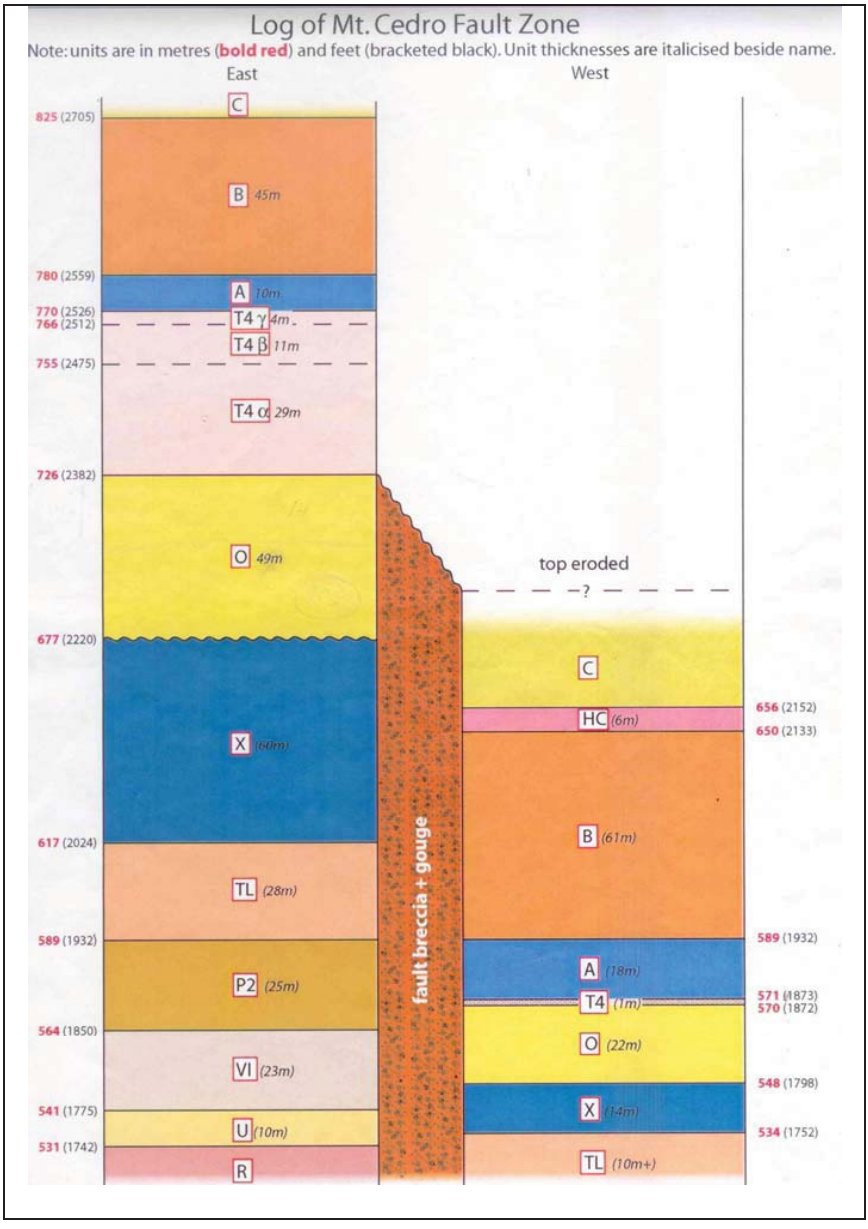
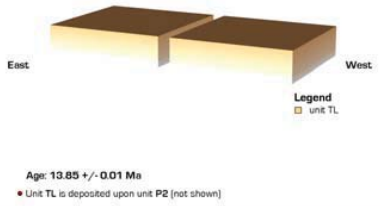
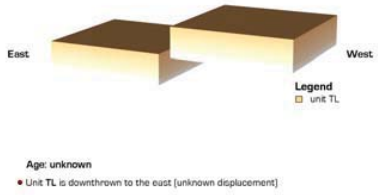
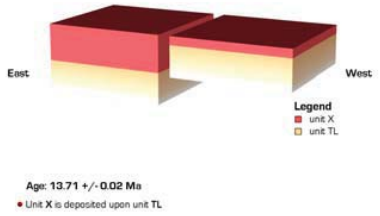
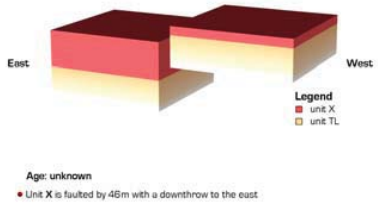
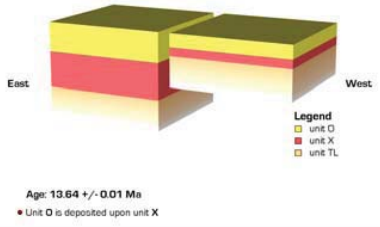
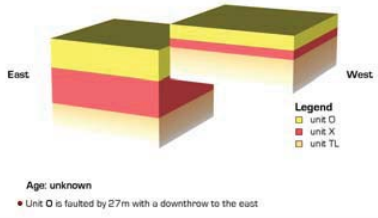
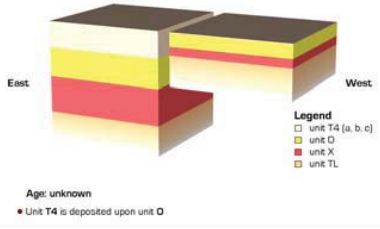
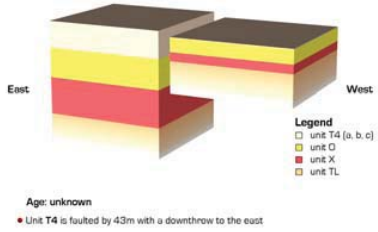


Fig. E2.8 *A possible solution for the Montaña Cedro fault log. (© V.R. Troll 2006, but opinions and observations can always change … Let's see what you have seen!)*

Depositional Events	Faulting Events
 *Step 1a*	 *Step 1b*
 *Step 2a*	 *Step 2b*
 *Step 3a*	 *Step 3b*
 *Step 4a*	 *Step 4b*

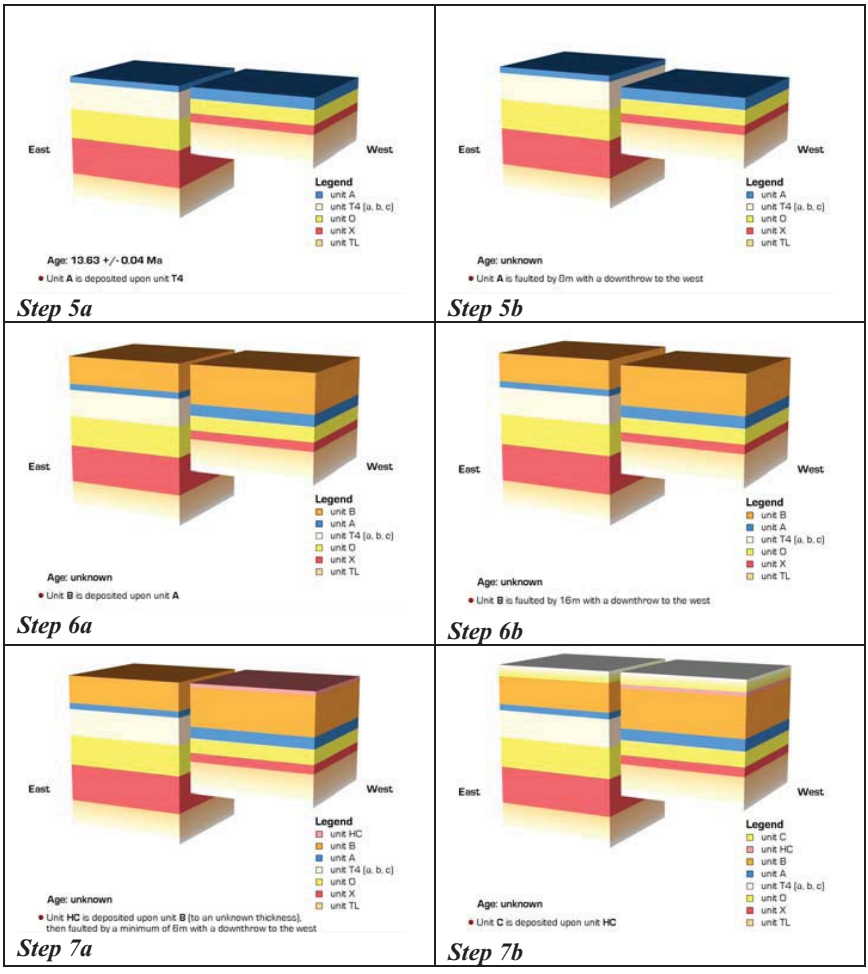


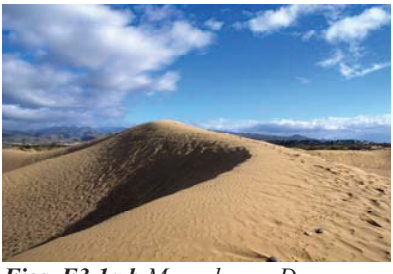
Fig. E2.9 *Cartoon sequence of fault evolution. Note that this history is necessarily incomplete due to e.g. exposure, but nevertheless allows a fair bit of reconstruction (© V.R. Troll).*

EXERCISE 3 – Maspalomas Dunes: The Origin of Beach Sand

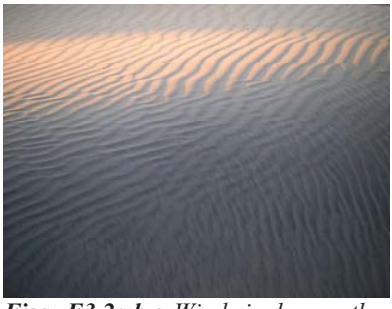
This is a useful exercise for the last day of your trip when you are off on e.g. an afternoon flight. This exercise will offer some light geological entertainment with a zip of holiday flavour. Please bring a hand-lens and a compass (plus notebook) to the field site.

Start of Exercise 3

▪ Make your way to Maspalomas dunes, they are widely visible already from far ***(Figs. E3.1a,b, E3.2a-c)***, but note that parking can be an issue. Consider using the 'beach shuttle' that picks up passengers along a number of places in *Maspalomas* and *Playa del Ingles*.



Figs. E3.1a,b *Maspalomas Dunes.*



Figs. E3.2a,b,c *Wind-ripples on the Maspalomas Dunes.*

STOP E3.1 The Origin of the Dunes

▪ Where do the dunes in Maspalomas come from? Rather special conditions are needed to 'pile up' such an amount of sand. Several theories may be delivered. It could be volcanic detritus, or blown in from Africa (the Sahara?). Alternatively, wind and waves could have just piled up local marine debris at this place. And then, of course, any combination of the above may apply.

▪ To unravel the origin of the famous Maspalomas dunes, a somewhat different beach experience might be required. We shall set out to acquire a suite of useful geological data.

▪ Measure dip and strike of the dunes! How do they move about? Inspect mineralogy. Are the minerals local or foreign ones? What is below the dunes? On what are the dunes travelling? What is coming from where? Analyse trade winds (Passat) using satellite images (see below).

STOP E3.2 The Origin of Maspalomas Sand

▪ Most beaches are made of sand, but sand can be made up of many different types of grains. From these grains you can infer where they came from, and how they made their way to the beach. Every grain of sand has its own story and hence its own history. Each grain is a tiny world in itself!

A. What is in your Sand?
Look carefully at your sand with the magnifier/hand lense. Tick the things you think are in your sand.

☐ Bits of rocks
☐ Mineral grains
☐ Pieces of shell
☐ Pieces of coral
☐ Pieces of glass
☐ Other things:

.....

B. What Colour is your Sand?

Again, look closely with your magnifier. The colours of your sand grains can tell you what rocks, minerals or other particles your sand is made of. Check the colours you see in your sand.

- ☐ Clear or frosty transparent white grains (quartz).
- ☐ White, beige to transparent (usually feldspar).
- ☐ Shiny black (magnetite or basalt fragments). Test for magnetite with a magnet!
- ☐ Gold, silver or brown (usually mica).
- ☐ Green (olivine).
- ☐ Black (pyroxene or amphibole).
- ☐ Bright white, pink or milky colour (probably pieces of shell or coral).

C. Where do you think your sand grains *originally* came from?

Do you find any quartz grains? There are no free magmatic quartz crystals in the volcanic rocks from the island. They must come from some continental mountains (Africa?).

How do these grains get from the mountains to the beach? Erosion and wind transport of sand plumes from Sahara is a likely answer ***(Fig. E3.3)***.

You will find numerous shell fragments that are from local marine debris. The black and green sand is from the lavas (pyroxene, olivine and basalt clasts), i.e. it is derived from the island. So is the whitish feldspar.

Fig. E3.3 *Satellite image showing sand and dust plumes carried by East to West winds from Africa to the Canary Islands and beyond. ©NASA*

▪ So, although pyroxene and feldspar are present and derived from the island, quartz grains are alien to the island, thus probably a wind-blown contribution from Africa. Sahara sand blows up to Ireland! Dust on cars in Western Europe is often from the Sahara, demonstrating how distant a travel some dust grains might experience.

D. How big are your sand grains?

What sizes do you find in your sample?

Particles from 0.06millimeters (mm) to 2.0mm are considered "sand". Particles larger than 2.0mm are considered "gra-vel". Do you have mostly sand or gravel? Right at the beach are also boulders and larger pepples and less sand and gravel. What does this mean?

E. Grain Shape
Draw a picture of one or two of your sand grains. Are they very rounded or rather more angular? When sand first breaks off from rock, shells or coral it is usually very pointy and rough (angular). As time goes by, the sand grain tumbles in the ocean or a river, getting smoother and rounder. Smooth round grains are the ones that have seen the most transport. Do different types of grains show different degrees of angularity?

Wind can break up sand particles and make them more round, smooth and all grains about the same size. Is your sand from a windy beach or a beach with little wind?

F. What does the Beach rest on?
You will need to find a "window" onto the substrate below the dunes ***(Figs. E3.4a,b)***. In these places you can actually see through onto an older and hardened sand layer. This means there is an old sand platform present and the new dunes travel on an older beach.

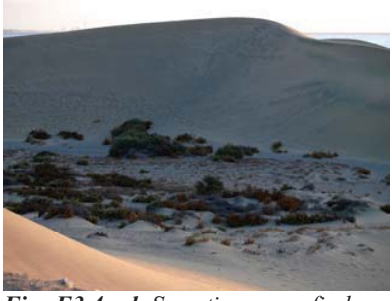


Fig. E3.4a, b *Sometimes one finds a "window through the dune cover".*

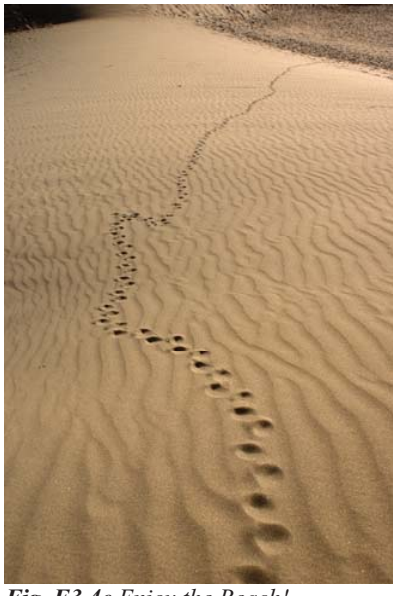


Fig. E3.4c *Enjoy the Beach!*

End of EXERCISE 3

Acknowledgements

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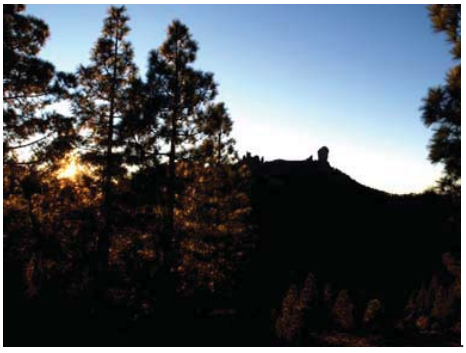
Glossary



Aa lava: A basaltic lava that is characterised by a jagged blocky surface. The term originates from the Polynesian language of Hawaii.

Alkali basalt: *basalt* with a lower amount of silica and higher amounts of sodium and potassium relative to average (tholeiitic) basalts. Alkali basalt is often found containing phenocrysts of *olivine*, *augite* and *plagioclase*.

Alkaline suite: a *magma* evolution series (alkali basalt → trachyte → phonolite) that yields compositions increasingly rich in alkali elements such as sodium and potassium (See also *differentiation*).

Amphibole: (rock-*forming mineral)* Amphiboles are made up of double silicate chains and a variety of metal elements including calcium, magnesium, iron, sodium and aluminium. It contains OH (water) and occurs in intermediate stages of the discontinuous series of *Bowen*.

Andesite: igneous rock that contains slightly more silica than basalt but less than rhyolite. Andesite contains about the same amount of silica as trachyte, but at lower concentrations of alkali elements. Contains plagioclase feldspar, pyroxene and amphibole. Named after the most common rock of the Andes.

Ash (volcanic *tephra*): fine rock particles less than 2mm in size ejected from a volcanic vent, often blown high up into the atmosphere. When ash settles its forms an 'ash-fall' deposit.

Biotite: dark brown mica (*rock-forming mineral*). Similar in structure to muscovite, except much darker in colour. Colour ranges from dark brown or greenish-black to black. It contains iron (Fe) instead of potassium (K). It often appears six-sided when present in its own crystal shape (pseudohexagonal).

Bomb: ballisticaly transported volcanic ejecta (*tephra*) >65mm (6.5cm) across.

Bowen's reaction series: gives the order in which minerals crystallise from *magma* as it cools. Bowen's series is divided in two branches; the discontinuous series, containing *olivine*, *pyroxene*, *amphibole* and *biotite*, and the continuous series, which has *calcium-rich plagioclase* at the top and *sodium rich plagioclase* at the bottom. *Quartz*, *white mica* and *potassium-rich feldspar* are at the very bottom of Bowen's reaction series, i.e. these are the final minerals to crystallise as a *magma* cools.

Breccia: rock made up of irregular, angular fragments in a finer-granied matrix. There are several forms of breccia: sedimentary, volcanic and impact breccias, all of which imply some form of dynamic motion as part of rock formation.

Calcite: (rock-forming mineral) calcium carbonate ($CaCO_3$), can be precipitated from sea water or aqueous solutions. It is a major constituent of calcareous sedimentary rocks, fossils, and of hydrothermal vein and crack fillings.

Caldera: a roughly circular depression of commonly more than 1km in diameter, often more than 10km in diameter, which formed by the collapse of a *magma chamber* roof into an emptying *magma chamber*. This frequently results in explosive eruptions leading to intra- and extra-caldera ignimbrite (ash-flow) deposits.

Cinder cone (also known as scoria cone or spatter cone): a volcanic cone built up of basaltic ejecta and pyroclastic material, generally moderately to poorly consolidated with straight slopes at an angle of about 30°. These are often the result of a single eruptive episode (monogenetic).

Clinopyroxene: (*rock-forming mineral*), rich in iron and magnesium, pyroxene is usually black and prismatic and belongs to the group of single-chain-silicates. Pyroxene comes second in *Bowen's* discontinuous series (after *olivine*).

Cone sheet: a *dyke* intrusion or swarm of dyke intrusions with the shape of an inverted cone, i.e. the intrusions dip 'inwards', toward a common centre.

Conglomerate: a coarse-grained rock with rounded clasts greater than 2mm in size in a finer-grained matrix. The roundness of clasts implies considerable transport of clasts before lithification.

Dacite: a silica-rich igneous rock with a composition (tholeiiti) in between *andesite* and *rhyolite*. Dacite belongs to the sub-alkaline series.

Debris avalanche: a rapid gravity-driven mass movement of mixed debris, similar to a landslide except it is usually made up of more than one type of debris.

Debris avalanche deposit: The result of a *debris avalanche*.

(Magmatic) Differentiation: A suite of processes which produce a series of daughter magmas from one parental *magma*. There are several mechanisms affecting differentiation (e.g. *magma mixing*, assimilation), but it is most commonly assumed to work through *fractional crystallisation* (i.e. the progressive change of a magma's composition due to the successive removal of mineral species). See also *Bowen's reaction series*.

Dyke: Solidified fracture fill of *magma* that when intruding propogates vertically or sub-vertically through fractures in the crust and volcanic edifice.

Feldspar: (*rock-forming mineral*) the most common mineral in the Earth's crust. Feldspar comes in several forms including potassium feldspar (K-feldspar) and plagioclase Feldspar (Ca-feldspar). All feldspars have a complex silicate framework structure. The continuous series of *Bowen's reaction series* evolves from plagioclase to K-feldspar. This frequently causes feldspar to show internal zoning that reflect successive growth stages (like tree rings if you will).

Felsic: light coloured igneous rocks that containing a high proportion of feldspar, muscovite and quartz are referred to as felsic (felsic = feldspar and silica!).

Fractional crystallization: process which causes a change in the overall chemistry of a *magma* by removing crystals of more silica-poor composition. Crystals are formed at different temperatures and then sequentially separated due to settling or other processes as the *magma* cools.

Gabbro (rock-type): a medium-dark, coarse grained igneous rock, containing *pyroxene*, *plagioclase* and sometimes *olivine*, chemically similar to *basalt,* but formed at a greater depth (slow cooling), allowing for the growth of larger minerals.

Graben: a depressed section of crust between two bounding faults creating an elongate basin. A graben is caused by extensional stresses in the crust.

Hornito: A small rootless spatter cone that forms on the surface of a basaltic lava flow (usually pahoehoe). A hornito develops when lava is forced up through an opening in the cooled surface of a flow and then accumulates

around the opening. Typically, hornitos are steep sided and form conspicuous pinnacles or stacks. They are "rootless" because they are fed by lava from the underlying flow instead of from a deeper magma conduit.

Hot spot: an abnormally hot part of the Earth's *mantle* that results in a buoyant plume of material that rises to the surface. Some 100km below the surface, the material begins to melt from decompression. Rising *magma* (the melt) then feeds eruptions on the Earth surface. Hot spots are assumed to underlay ocean islands.

Hyaloclasite: an aggregated rock composed of small fragments of volcanic material, generated by the explosive reaction of hot *lava* with cold water, often found in shield successions of ocean islands where lava enters the sea or where submarine facies grade into non-marine units.

Hydrothermal alteration: Chemical change in rocks and minerals caused by the interaction with hydrothermal solutions (hot-waters). This is a common phenomenon in volcanic areas were groundwater becomes heated from magmatic activity.

Ignimbrite (deposit): a poorly sorted pyroclastic rock body formed by deposition from a ash and pumice-rich pyroclastic flow. Ignimbrites (i.e. ignimbrite deposits) are often sheet-like or fill valleys and tend to "flatten" the existing topography.

Lahar: mudflow rich in volcanic material, generated by e.g. heavy rainfall or the melting of surface ice by an eruption or by high heat flow from a volcano in general. Lahars can be hot!

Landslide: rapid mass movement of Earth materials downhill, resulting in a *debris avalanche* or *debris flow deposit*.

Lava: molten rock that flows on the surface of the Earth and was expelled by a volcano during eruption. Very viscous lavas are termed *'aa' lava*, whereas very runny lava is called *'pahoehoe' lava* following local Hawaiian terminology. Geologists often use the term 'lava' also frequently for solidified lava flows.

Maar: a volcanic crater, often occupied by a lake or filled with sediment, surrounded by a ring of tuffaceous deposits, caused by the violent explosion of *magma* in contact with ground water. This often leads to high proportions of country-rock fragments in initial maar deposits.
Mafic: *magma*, rock or minerals which contain abundant magnesium and iron. E.g. any igneous rock that contains appreciable proportions of ferro-

magnesian minerals like *olivine* and *pyroxene* coupled with low concentrations of *feldspar* and *quartz* (mafic = magnesium and iron).

Magma: liquid rock at high temperature below the Earth's surface, containing crystals, liquids and dissolved volatiles that turn to gas bubbles when pressure is released (e.g. on ascent).

Magma chamber: zone where rising magma comes in equilibrium with the surrounding rocks and stalls temporarily. Often this may take the form of a sponge-like mush of solid minerals and liquid magma. Magma chambers can reach several kilometers in width and are the locations of *magma mixing* and *differentiation* of magma.

Magma mixing: is the process by which two *magmas* intermingle and hybridise to form a magma of a composition somewhere between the two original magmas. Note, perfect blending of two magmas, however, is very rare and incomplete mixing frequently observed.

Mantle: zone lying above the Earth's core and below the Earth's crust, approximately 2300km thick, and probably similar in composition to *garnet peridotite*. It represents 84% of the Earths volume and 68% of its mass. Melting of the mantle at different depths and to different degrees produces different types of *magma* (see e.g. *alkaline series*, *tholeiitic series*)

MORB (Mid-Ocean Ridge-type Basalt): a general term for the *tholeiitic basalts series* along the mid-oceanic spreading centres (ridges). Tholeiitic rocks can, however, occur on oceanic islands too.

Muscovite: (*rock-forming mineral,* belongs to Mica-group), forms thin flaky sheets, ranges from colourless to very pale green or light brown, with a pearly sheen. It incooperates K instead of Fe (biotite, black) or Mg (phlogopite, brown).

Oceanic crust: composed of primarily *mafic* basaltic and gabbroic rocks (*MORB-type*), covering some 60% of the Earth's surface. Oceanic crust is about 6-8km thick and has an average density of about 3.2 to 3.3g/cm^3 (see also *mafic* and *basalt*). A layer of pillow basalts intermingled with sediment grades downward through feeder-dykes into what once was the ridge magma-chamber, the *gabbros*.

Olivine: (*rock-forming mineral*), usually olivine is green in colour and found in silica-poor igneous rocks that are *mafic* (i.e. rich in Mg and Fe) *basalts* and *gabbros*.
Phlogopite: belongs to mica-group of minerals, similar to *biotite* and *muscovite,* but contains magnesium. Brown to dark golden in colour, with glassy

or pearly luster. It is frequently found in the *felsic* volcanic rocks of the Canary Islands.

Pahoehoe: type of lava flow with smooth ropy surface texture, as opposed to the sharp blocky texture of *aa lava*. The term originates from the Polynesian language spoken in Hawaii.

Peridotite: dense, ultra-*mafic* coarse-grained rock, containing *olivine* and *pyroxenes,* with or without garnet and has a very low silica content. Peridotite appears to be the dominant rock of the Earth's *mantle* and produces a basaltic *magma* on partial melting. Peridotite fragments from the mantle do occur sometimes in ocean island lavas (mantle modules or xenoliths).

Phonolite: a fine-grained, medium to light, grey to green coloured igneous rock of evolved alkaline composition. It is the highest differention product of the *alkaline magma series*. Phonolite is found on many ocean islands, but also in continental regions subjected to anorogenic upwarping and rifting. Phonolite makes a distinctive sound when struck, hence the name.

Pillow lava: type of lava flow that forms underwater. It has a glassy rind surrounding a coarser centre. Its bulbous pillow- and tube-like shapes are caused by the chilling of *magma* against water, causing a rim of solid crust to facilitate further *magma* flow inside these tubes. These tubes often stack up in piles and when cut a high angle, appear like a 'stack of pillows'.

Plagioclase (**feldspar**) (rock forming mineral!): silicate mineral rich in calcium and aluminium, also contains sodium. Plagioclase feldspar is the most common mineral in the Earth's crust and is frequently found in mafic and intermediate igneous rocks of both, plutonic and volcanic character. Ca-rich plagioclase forms the start of *Bowen's continuous reaction series*.

Plinian eruption: an explosive volcanic eruption of pyroclastic ejecta characterised by a plume of ash rising high into the atmosphere due to a high gas content. Named after Pliny's the Younger's description of the AD79 eruption of Mount Vesuvius, which killed his uncle Pliny the Elder.

Pyroclastic Flow: a flow of hot volcanic ash, gas and rock fragments (tephra), driven by gravity or propelled by a blast down the flank of an erupting volcano. Pyroclastic flows can travel at up to 500km/h and can be up to 600°C in temperature at distances of up to 10km away from their vent. The result is often an *ignimbrite deposit.*

Pyroxene: (*rock-forming mineral*) Prismatic black mineral that is rich in iron and magnesium. It has a single chain silicate structure. Pyroxene comes

2nd in Bowen's discontinuous reactionseries. Occurs as Clino- and Ortho-pyroxene.

Quartz: (*rock-forming mineral)*, commonly colourless or white but can be found in a wide range of colours depending on its composition (e.g. blue chalcedony or red carneol and jasper). If crystalline, crystals are usually six sided prisms terminated by a six-faced pyramid. Quartz has a complicated framework structure and is last in Bowen's reaction series. Note however, primary (igneous) quartz is not present on Gran Canaria. Secondary (hydro-thermal) quartz is common, however (e.g. vein and vesicle fills, etc.).

Rheomorphic flow: post-depositional flow of hot material (e.g. an *ignim-brite deposit*), leading to spectacular fold and thrust structures in e.g. some Mogán ignimbrites in Southern Gran Canaria.

Rhyolite: a fine grained, usually light coloured, igneous rock that is very high in silica content (> 70%), often containing *feldspar* (*K-feldspar* and possibly *plagioclase)*, *amphibole*, *botite* and possibly *quartz*. Rhyolite is the extreme differentiation product of *basalt*, or the melting product of crustal rocks such a silica-rich sediments.

Rift zone (volcanic): Volcanic rift zones are marked by the alignment of *cinder cones* and other vent types at the surface and by a concentration of *dykes* at depth. Volcanic rift zones usually take the form of long and narrow ridges in the Canary Islands.

Rock-forming minerals: the most common minerals that make up 95% of all rocks in the Earth's crust and *mantle*. The main rock forming minerals relevant to magmatic rocks are silicates, and are subdivided into two groups the *mafic* and *felsic* ones. The mafic ones are *pyroxene, amphibole, biotite, olivine* and *calcite*. The felsic ones in turn are *quartz, potassium K-feldspar, plagioclase feldspar* and *muscovite.*

Scoria: pebble to fist sized basaltic ejecta with rough texture and gas bubble holes. Scoria usually forms from *lava* fountains, eruptive clouds, or by the grinding and crunching of materials by an advancing but cooling lava flow.

Scoria cone: (see cinder cone)

Shield volcano: volcanic landform with shallow slopes, often crowned by a pit crater or caldera (e.g. Hawaii).

Sill: a tabular igneous intrusion with contact surfaces that are semi-concordant with the bedding or layering of to the intruded rock.

Spatter cone: small volcanic cone built from *tephra* blown out as clots of relatively fluid basaltic lava (Similar to *cinder* or *scoria cones*).

Strombolian eruption: type of eruption in which pockets of gas episodically burst at the top of a basaltic *magma* column, throwing *tephra* into the air. Common in *cinder cone* eruptions.

Syenite: a coarse-grained felsic intrusive igneous rock of the same general composition as *trachyte*, but slow cooling at depth has allowed the growth of larger crystals. Syenite is found as discrete intrusions in the stable continental crust and in the cores of some ocean island volcanoes such as Gran Canaria.

Tephra: any particle or fragment, of any size, ejected from a volcano.

Tholeiite: fine-grained igneous rock. Type of basalt. Common component of the ocean floor (see *MORB*).

Tholeiitic series: an evolutionary series (*basalt* → dacite → *rhyolite*) of *magma* that yields lava increasingly rich in silicate (see *differentiation*) and is the most common series present at Mid Ocean Ridge settings (see *MORB*).

Trachyte: intermediate igneous (volcanic) rock of alkaline affinity. Silica concentrations are similar to andesite, but sodium and potassium are higher. Trachyte generally derives from alkaline basalt *magma* by *differentiation* and occurs frequently in hot spot settings. Trachyte is the volcanic equivalent of S*yenite*.

Viscosity: resistance to flow of a liquid or (e.g. *magma*), which is principally a function of composition and temperature.

Vitrophere: a glassy volcanic rock that may or may not contain larger crystals (phenocrysts) embedded in the glassy groundmass. A vitrophyre is formed when molten rock (magma) cools and solidifies on contact with a cold substrate.

Volatile: a substance that melts or vaporises at a medium to low temperature. For example gas dissolved in *magma* is released as a free gas-phase when the pressure on the *magma* is reduced.

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Notes

DAY 1 – Miocene Rocks of Gran Canaria:
Shield Basalts and Ignimbrites

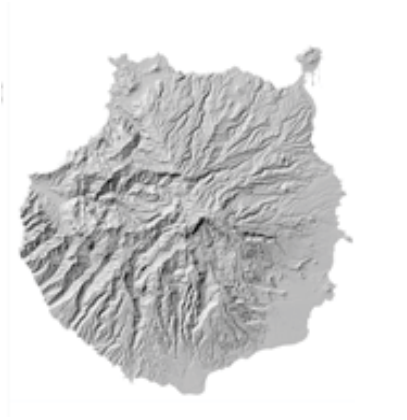
Notes

DAY 2 – The Miocene Tejeda Caldera

Notes

DAY 3 – Roque Nublo Volcano and Recent Volcanism:
(Las Palmas Volcanic Vield)

Notes



DAY 4 – Coastal Geology and Destruction of Oceanic Islands

Notes

DAY 5 – Traversing the Island South to North

Notes

EXERCISE 1 – Ignimbrite Logging
in Barranco Ayagaures

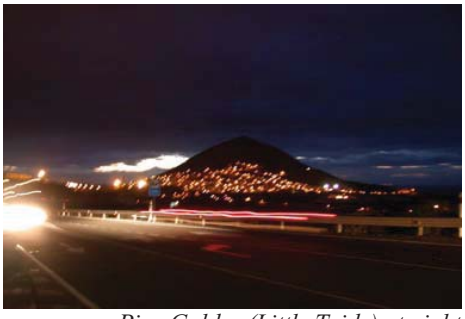
Notes

EXERCISE 2 – Montaña Cedro:
Faults in Volcanic Rocks

Notes

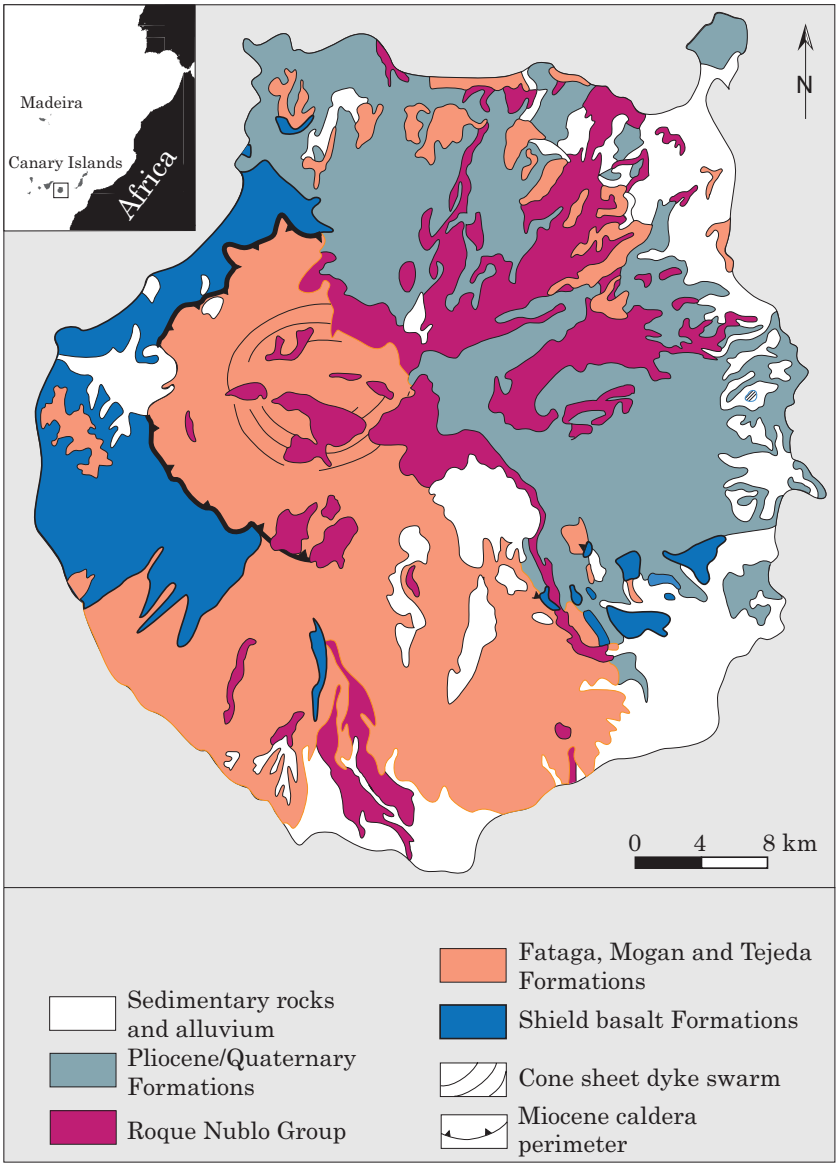
EXERCISE 3 – Maspalomas Dunes:
The Origin of Beach Sand

Appendix

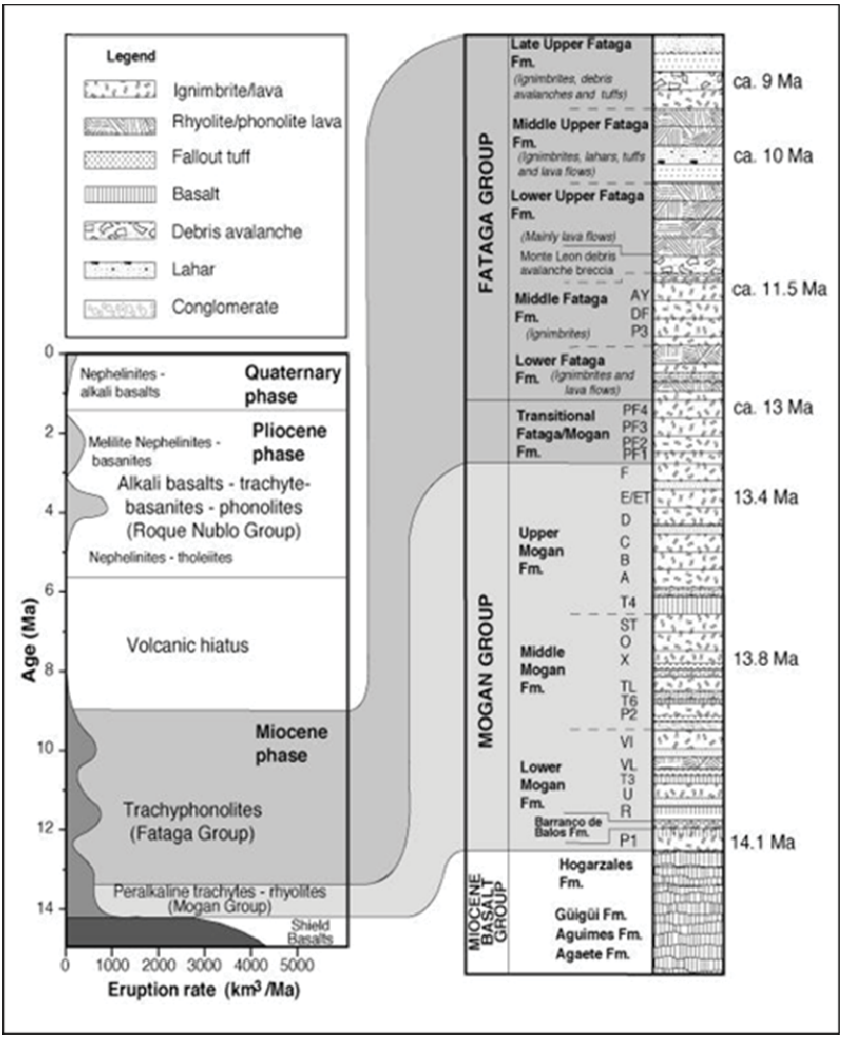


Pico Galdar (Little Teide) at night

Appendix 1 *Topography and road map of Gran Canaria (Image © Google Inc., 2012).*



Appendix 2 *Simplified geological map of Gran Canaria based on IGME, 1992 (Courtesy of N. Urbanski).*



Appendix 3 *Stratigraphy of the Miocene ignimbrite succession on Gran Canaria (from Sumita and Schmincke 1998).*