Special Proceedings of the Reading Geological Society

Field Trip to Mallorca
14th - 21st September 2002

Contents

Introduction

In September 2002, the Reading Geological Society spent a week on the Spanish island of Mallorca, one of the Balearic islands. The purpose of the trip was to see as much of the geology of the island as possible within the week in a place that members of the society would not normally visit.

This introduction is a general overview of the whole trip. It is intended to describe the activities of the party, the places visited and things done. Following this introduction are reports from the members of the days' excursions.

Throughout 2002 planning proceeded. Dates, excursions and leaders, attendees, travel, accommodation and local transport were all arranged. The visit was organised by Field Secretary Chris Fone who laid on the leaders, the flight, hotel with half-board, and hire cars for the week. Other preparations for the trip were made by Chris Fone, David Ward and David Riley.

The trip was introduced by a lecture on "The Geology of Mallorca" by our president, Dr. Bruce Sellwood of the University of Reading, on 13th May 2002. This talk was based on the work that he and several colleagues had done on the island that resulted in the production of the Geologists' Association Guide, "A Field Excursion Guide to The Island of Mallorca" by H.C. Jenkyns, B.W. Sellwood and L. Pomar.

The small size of the Society meant that it was difficult to get sufficient people to take advantage of group travel rates. After ensuring that everyone from the Society who wanted to go had a place, other local societies were contacted and offered the spare places and this resulted in three more travellers.

Those who attended were:
John and Jo Cocker (Harrow and Hillingdon Geological Society), Chris and Clare Fone, Christine Hooper, Christine and Roger Moore, David Riley, Gilia Slocock (Open University Geological Society), David and Joyce Ward, Roger and Jill York.

We were very fortunate in making contact with Rosa Maria Mateos Ruiz who arranged leaders and itineraries for us and led three of the days herself. We are very grateful to her and the other leaders - Dr. Bernardi Gelabert and Dr. Jordi Gimenez, with assistance from Kelly Jane Wallis - for the effort they put in to make the trip as interesting as it was.

Dr. Rosa Maria Mateos Ruiz (Director, Geological Survey of Mallorca)
Dr. Bernardi Gelabert Ferrer (Lecturer in Structural Geology, Universidas de las Islas Beleares)
Dr. Jordi Gimenez (Lecturer, Universidas de las Islas Beleares)
Kelly Jane Wallis (Australian geology graduate looking for a post in Mallorca and acting as assistant and additional translator on the itineraries)

The result of all this preparation was a very well organised field trip, attended by 13 members and guests, in excellent weather, to an island in the sun with very interesting geology, and which was thoroughly enjoyed by everyone.

Note that photographs are only given attribution when taken by someone other than the author of the report. Note also that some reports refer to figures in the handouts or to the Geologists' Association Guide (mentioned above). Rather than repeat the figure the reference in the report to the other document is retained on the basis that readers will have the handouts and guide.

Planned Itinerary

14th. - Saturday. - Travel out the island.

15th. - Sunday. - Geological history of Mallorca. Dr. Bernardí Gelabert

- Valldemossa. An introduction to the Geology of Mallorca. Morphology and Structure. Geological History.
- From George Sand Urbanisation to Port des Canonge on foot. We are going to see the more ancient materials of Mallorca Island and the Triassic and Jurassic facies as well as the syn-orogenical ones. Historical geology of pre-syn-orogenical phases.

16th. - Monday. – Randa mountains and the reef complex of the SE of Mallorca. Dr. Jordi Giménez

- Randa: Turbiditic facies
- Cabo Blanco and Cala Pi: Messinian reef facies and paleobeaches.

17th. - Tuesday. - Karst Geomorphology. Rosa María Mateos

- Sa Calobra and Torrent de Pareis. Karren landforms and a karstic canyon.
- Lluc Monastery: Karren and exokarstic landforms.
- Visit to the Natural History Museum of Sóller

18th. - Wednesday. - The coastal facies in Serres de Llevant (eastern area of Mallorca). Rosa María Mateos

- Cala Llombards. Messinian Santanyi limestone: mangroves and tidal facies. Stromatolites.
- Cala Figuera: paleodunes with Myotragus Tracks
- Porto Cristo: Caves of Drach visit.

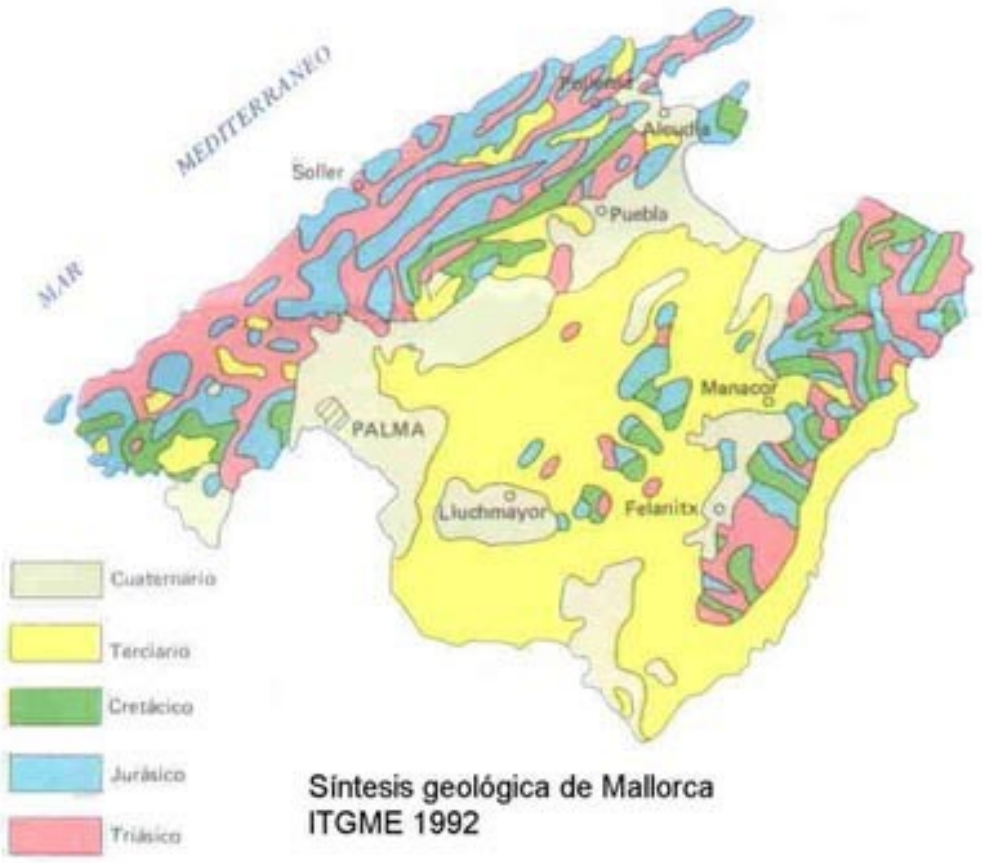
19th. - Thursday. - Landslides geomorphology and hydrogeology of Mallorca. Rosa María Mateos

- Port de Sóller. - Great landslide in the Serra the Tramuntana coast (3 hours on foot)
- Ses Ufanes Font and Campanet Coves?
- Visit to the wet natural area “Albufera de Mallorca”? (depends on the time).

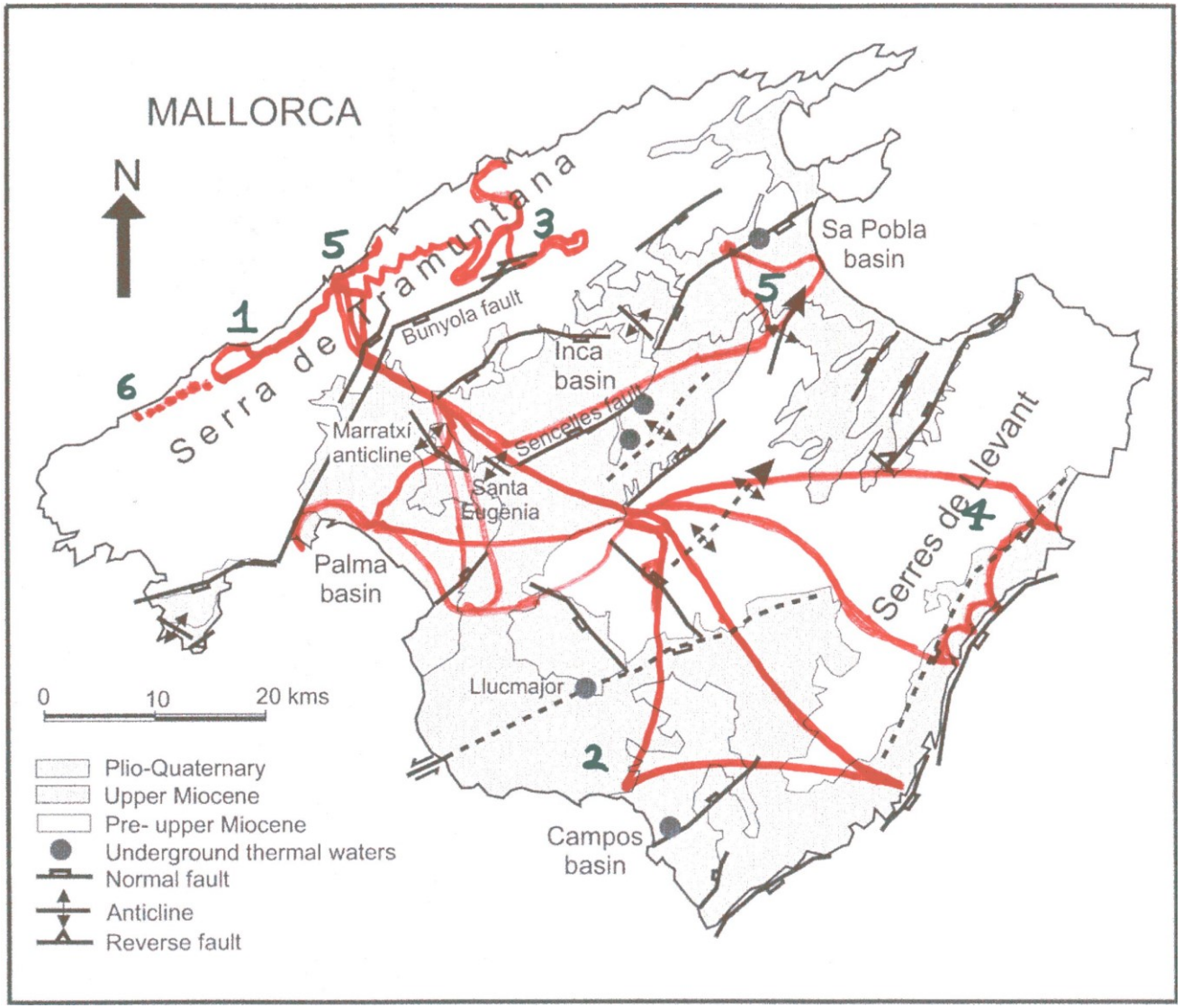
20th. - Friday.-This was to be a free day, when everybody could do as they liked - geology, sightseeing, resting.

21st. - Saturday. - Travel back.

Geological Map of Mallorca



Map of Mallorca


MALLORCA
N
Serra de Tramuntana
1
2
3
4
5
6
Bunyola fault
Inca basin
Sencelles fault
Marratxí anticline
Santa Eugènia
Palma basin
Llucmajor
Campos basin
Sa Pobla basin
Serres de Llevant
0
10
20 kms
Plio-Quaternary
Upper Miocene
Pre- upper Miocene
Underground thermal waters
Normal fault
Anticline
Reverse fault

Members' Reports

Day 0, Saturday 14th Travel out

This day was very relaxed (if air travel can ever be relaxing) with a mid morning start for several members of the party who met at Reading Railway Station to catch the train for Gatwick. Others caught the same train at Wokingham and four others joined at Gatwick. The flight was uneventful and, on arrival at Palma, the formalities and the actual collection of the hire cars (three Citroen Xsara Picassos - quite roomy) were very straightforward. After a 40 minute journey, during which all three drivers managed to take different routes, we all arrived at the Hotel Esplendido in the coastal town of Port de Soller, which is about halfway along the northern coast of Mallorca. Our hotel was on the front overlooking the bay and harbour and separated from the beach by only the road and the tramway. Parking for the cars was found in a free car park just back from the sea, 200 yards back along the road to Soller. The existence of this car park enormously simplified the experience of the drivers for the whole of the week.

We were too late for our evening meal at the hotel, so strolled along the road round the harbour and found a good restaurant for our first evening in Mallorca.

Reported by Roger York

Day 1, Sunday 15th Geological History of Mallorca

Morning

Urbanisation George Sand

We were met, at 09:00 in the hotel lobby, by our leader for the day, Dr. Bernardi Gelabert, and left immediately in the cars for the first site. This was our first experience of the winding roads in this mountainous northern part of Mallorca - it got worse later in the week.

The first stop was at the viewpoint at the tower on a small hill in the Urbanisation George Sand - a very modern housing development of discreet villas 4km to the west-south-west of Valldemossa. We turned right off the road from Valldemossa (C710) into the new development of Urbanizacion de George Sand and headed for the tower. There is a parking area just below and an easy path to the viewing point. From this point an excellent view is obtained of the Sierra Norte (the highest peak of which is Puig Major at 1445m.)

Bernardi described the historical geological development of Mallorca. The island is a Horst and Graben system developed from the Spanish-African thrust, the plates converging to give a series of folded belts. The thrusting is from the south-east to north-west direction. In particular, he described the thrust faults which resulted in the Tramuntana mountains and which produced the landscape in front of us to the north (Plate 1). The divisions can be clearly seen from the vegetation (and are described in figure 1). The Keuper, which is a clayey marl, is tree-covered, the lower Keuper in the valley is agricultural land. The unconformity of Keuper and Lias gives rise to instability and land slippage. 2002 had been particularly wet for Mallorca and had given rise to many land-slips.

Plate 1. Thrust landscape. (Photo RY)

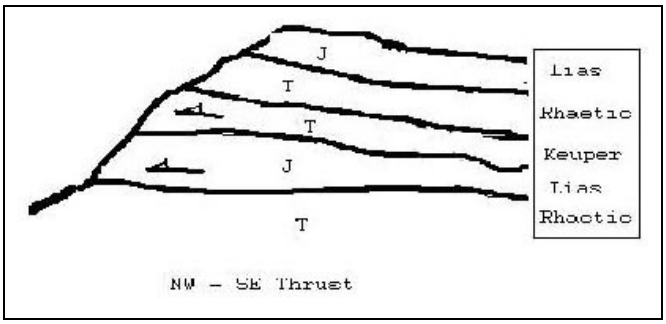


Figure 1. Diagram of the thrust landscape.

Sequence

Jurassic – massive limestone
Rhaetic – boundary
Keuper – shales and basalts

Banyalbufar

We then travelled on to Banyalbufar, a small town further west along the coast.. We turned down the hill into the village and continued left and downhill towards the harbour. There is a small parking area at the end of the village on the left which we managed to squeeze into.

We then continued on down the road on foot, keeping to the left of the harbour bay until the last house was passed. From the flat area we could see across the bay to a recent landslip (caused by the very wet year 2002) in the shales, which is now being stabilized. Looking seaward to the point, the reef rock of the Sant Elm Calcarenite formation can be seen unconformably overlain by the Banyalbufar Turbidite formation.

We proceeded along the platform to the left where there is a well exposed Banyalbufar Turbidite unit (Plate 2). This turbidite is said to be formed at a depth of 2km in a series of steep sided troughs. As the underlying rock is reef rock; a shallow water deposit , this is thought to indicate rapid subsidence during the Lower Miocene (Burdigalian) period. The turbiditic deposits are Middle Miocene (15Ma) The channels have a sharp base and the breccia appears to be graded with ripples where it passes to marls. The lower breccia is pebbles from Muschelkalk.

Plate 2. Banyalbufar Turbidite unit.

Reported by Christine Hooper

Afternoon

After exiting moments getting the cars out of the car park and starting up the steep hill out of the town, we drove a short way back along the road towards Valldemossa to a small car park on a sharp bend of the road. From there we walked along a path towards the coast.

After lunch taken on a grassy viewpoint overlooking the sea (and bought from various shops in Port de Soller that morning) the party retraced their steps almost to the car park and examined the low cliff which formed the east side of the path.

Here, a basalt flow was to be seen within the Keuper Marl. The basalt here was green-grey with minor feldspar and gypsum veins and the upper side of the flow had been cut off by a thrust plane, which had removed the classic “crusty surface” associated with basalts.

The party now walked east along an almost level path which wound in and out of the small bays along this coast. The sea was about 100m below us on the north side, while the southern (cliff)

side consisted of shallow slopes with trees, or much steeper slopes, sometimes vertical or even overhanging the path, with excellent exposures.

Bernardi explained that the rocks exposed were olisthostromes – massive slipped blocks of material, probably transported by sub-sea flows and now left in a chaotic state of blocks, bedded in fine and coarser sediments, some of which appeared to have been uniformly deposited within this mass. The rock from which this cliff formed was the turbidite sequence of the Lias limestone, which had clearly been reworked, first to the turbidite, then to the breccia in front of us.

Individual rock fragments were white, thin-bedded turbiditic material, ranging from sand size up to tens of metres length and separated, in places, by green and brown clays, derived from the Triassic rocks caught up in the slides. This whole mass was well cemented and cut through by thrust planes, most at very shallow angles of not more than 5-10 degrees.

As with most limestones (at least on Mallorca!) caves were to be seen in many places, with stalagmites and stalactites up to 2m long.

We progressed along this path for about 2 miles, with frequent stops to look in detail at the rocks, the trees and the very pleasant views over the sea and along the coasts. At about the two mile mark, a sign post indicated that we should turn north towards Port des Canonge. Here the track began to descend and the lithology began to change. Patches of blue shales appeared in the banks, presumably of the Lias clays. Further down the slope, bedded red and brown sandstones, much shattered, but with still identifiable fining upward sequences were observed and attributed to the Bunter of the Triassic.

At the foot of the path, we emerged onto the rock cut platform behind the beach, which gave us a very good view across a small bay to the low cliffs on the far side. At sea level and standing up about 5m were the red-brown Bunter sandstone with, above it, a uniformly bedded light brown sand – this, Bernardi told us, was a Quaternary deposit of aeolean sand.

After taking in the view, the party set off back the way we had come, but stopped near to the sign post to look along the cliffs to the west (best seen by taking the small path which heads seawards and downhill). The cliffs showed the sequence of rocks we had walked through on the way to the Port and Bernardi pointed out the members. At the top (and in places overhanging the path) was the olisthostrome sequence that had dominated our earlier studies. Below this was a series of thrusted masses of the same material, some showing intact beds of turbidite material, such that the thickness of the bed could be distinguished, which was up to 5 m thick and in some cases, could be seen to be tapering. It was suggested that this taper could be used to predict the direction of flow of sediment when the turbidite was formed.

A steady walk brought the party back to the car park (in the severe bend of the road to the east of Banyalbufar) and so back to the hotel for drinks and dinner – essential to every excellent geological excursion.

It should be noted that this coast is extremely beautiful with very pleasant views of the sea, coastline and cliffs, pleasant woods and virtually no tourists. Many members considered that they might return for walking holidays (but this could have been a diversionary tactic to convince their partners to come back to such interesting geology!)

Reported by David Ward

Day 2, Monday 16th Randa Mountains and the Reef Complex of the SE of Mallorca

Morning

The next day required an earlier start as we had to meet our leader, Dr Jordi Gimenez, in Santa Maria - a town on the main road halfway between Palma and Inca. We decided to travel the shortest route - across country on the secondary roads and miss the main roads into then out of Palma - and this was a very pleasant introduction to a lot of Mallorcan countryside. The journey also introduced us to Bunyola which is a small town with narrow streets (and dense parking) and, apparently, a penchant for civic parties - they had bunting up all week and a model astronaut on the telephone kiosk.

Parking in Santa Maria was not easy but after finding some spaces in the back streets, our chairman and field secretary went to find our leader by the church. He was accompanied by Kelly Jane Wallis, an Australian hydrologist who lives in Mallorca, was about to marry a Mallorcan and who hoped to get a job with the Geological Survey of Mallorca. She was very useful as an interpreter with a considerable geological background and was a very welcome addition to the party on all the remaining days of the trip.

After meeting Jordi in Santa Maria, we drove via Algaida to Randa Mountain and parked in the "Santuari de la Mare de Deu de Cura", a hilltop monastery, about 525m high, with 360º views over this part of Mallorca.

Jordi explained the geological setting – Randa is a horst (upthrown block) of Miocene age rocks, with major fault lines running north-west to south-east at right angles to the major faults of the island and with more minor ones running at about 90º to these. The faults are post Alpine, and cut Middle and Lower Miocene turbidites and calcarenites. These are overlain, on the plain, by gently folded Oligocene sediments.

Directly west of Randa, the town of Llucmajor stands on the plain, which here is a reef platform, not affected by the folding. To the south-east, the mountains of the Serra de Llevante could be seen, while to the northwest, the Serra de Norte was seen in the distance.

Hand specimens appeared from a convenient heap of rock, and Jordi pointed out the features – calcarenites are composed of mm grains of limestone, cemented with calcite, resulting in the surfaces of the grains becoming indistinct. Foraminifera could be made out – 5mm discs of calcite, less than 1mm thick.

Turbidites are here (as almost everything is!) composed of limestone – in section the rock shows a layered structure, with fining upward units – there was some discussion on whether we could actually see this - and the relationship to overlying rocks was again discussed. The problem is that turbidites require deep water for their formation, while the calcarenites are definitely shallow water features and there appears insufficient time to move from one depositional environment to the other. Could their close vicinity at this location be due to calcarenites slumping into the deeper water? A model showing the postulated environment in which the rocks were formed is shown in Fig. 65 in the Geologists' Association Guide, "A Field Excursion Guide to The Island of Mallorca" by H.C. Jenkyns, B.W. Sellwood and L. Pomar.

The party now drove down the mountain to the first turning, to Sant Honorat, and parked at the junction. Where the entrance of the side road to the main had been cut in the bank, the turbidites were exposed and were examined. A sequence of fining upwards, pale brown, 3-10 cm thick beds

with marl partings was seen, the Randa Turbidites. In places, these were separated by beds of conglomerates composed of pebbles up to 5cm diameter, also bedded and therefore part of the turbidite sequence. The cleavage in the turbidites is nearly vertical to bedding and is associated with Alpine activity.

Very close to the road junction, a deposit was seen to fill a small fissure like structure (Plate 3). This was possibly a cave or solution feature, rather than of a tectonic origin. Stalactites and dripstones together with massive calcite were seen in the fissure, which was more than 2m high and 1m wide. Jordi thought that this was probably a Quaternary deposit.

Plate 3. Fissure at the Sant Honorat road junction

A further stop was made at the top of the road at Sant Honorat, where the turbidite sequence now consisted of much finer materials – interpreted as being further from source than the earlier site. The turbidite fans are about the width of Randa Mountain – perhaps 2 – 4km.

A further stop was made at the entrance of the road to “Santuario de N S de Gracia”, a church sitting on a ledge under the side of the mountain. This had achieved fame by being threatened by falling blocks of limestone and was currently closed, following a survey by our leader of later in the week, Dr Rosa Maria Mateos – clearly a formidable lady!

We walked down the road to a barrier, from where we could see the church and were also able to examine the rocks. The particular stability problem here arose because two sets of faults ran at 90^{o} to one another, but each was at 45^{o} to the cliff face, making it very easy for blocks to fall out, especially if rain infiltrated the rock, lubricating the bedding and fault planes.

In the cliff face, we were able to see grey, powdery turbidites with odd pebble patches, indicative of being near surface, overlain by yellow-orange calcarenites. In places these were highly folded (Plate 4**).** Jordi explained that these were slump structures and that alternate hard and soft bands in the deposits enhanced the folding.

Plate 4. Highly folded orange calcarenites.

Reported by David Riley and David Ward

Afternoon

Cap Blanc

Lunch, procured from various shops in Puerto de Soller, was eaten with relish on the cliff top at Cap Blanc, 15km to the south of Randa and on the coast. Here, the Reef Complex of Miocene age makes up the cliffs, which are about 50m high at this point and Jordi explained the sequence from a point just east of the watchtower, where a view to the west showed the section. The entire cliff is contemporaneous - i.e. events forming the base took place at the same time as the highest beds. This comes about because the sequence in the cliff represents the face of a reef, so sedimentation occurred at all depths.

The cliff shows, from the bottom upwards, a white limestone (the reef slope) then brown knobbly beds (the massive coral bed), then a finer bed (the back reef basin) and finally a sandstone with

darker fine grained material in depressions (the Pleistocene sand dunes with palaeosols between the dunes). Jordi explained that sea level changes controlled the development of the sequence. When sea levels rise, corals grow vertically, when it is stable, they grow horizontally (seawards), but if sea level falls, the lagoon disappears and erosion takes place. The reefs are (or would be!) good reservoir rocks for oil, but none is known on the island.

Cala Pi

A short drive to the east brought the party to Cala Pi – a very small village and cove, popular with the tourists, blessed with aquamarine waters, blue skies and temperature of about 28º C.

Jordi pointed out the layered sands, of Pliocene age, resting on the Reef Complex which were seen from the small headland to the east of the cala, after which we descended the steps down the west side of the cala.

The walls of the cala cut through the Reef Complex and we were able to examine them in detail from the steps and by climbing up the slopes behind. It should be said that there seemed to be a severe shortage of bathing garments in this part of the island – the RGS in boots, shorts and tee shirts were much overdressed!

The sequence seen in the walls, from the top down, was an orange sediment filling the upper surface of the coral reef (the lagoon filling, now soil), then a white, knobbly rock with many solution and other cavities (the reef limestone with coral, gastropod and bivalve moulds). The whole was draped with dripstone, travertine and stalactites, which cemented the rock into a solid mass. Jordi explained that the subsequent rise of sea level had brought in Mg ions, which partially replace the Ca ions in the calcite, altering it to dolomite.

The corals were spectacular – cavities up to 8 –10cm diameter with very intricate structures on the inside (outside of the coral!) and beside the steps at beach level, corals of 0.6m diameter with individual polyps of 4-5mm were preserved.

We discussed the colour of the lagoon fill – a very bright orange – and Jordi proposed that it was Saharan dust, blown in from the south.

Cala Pi –small cove 0.5km east of centre

A narrow path between houses led down to a low headland, where the Reef material was partially covered with a fragmental, cemented, coarse (1-2mm) limestone grit, the fragments being clearly parts of bivalves. This was the Pliocene Beach, which had circular holes up to 2m diameter and 0.5m deep – Roman extractions of cylinders for columns! Interestingly, on looking at the inside of the walls of the cylinders, we could see that weathering had cut into the softer layers, indicating that the rock was not the ideal building stone – but someone said it would take a nice polish!

A quarry on the east side of the cove showed a modern quarry also in the Pliocene grit, which enabled us to examine the rock in section.

Two very anomalous structures were pointed out to us in the grit - each was 25cm deep and about the same diameter at the top, both tapering downwards. The material in this “cone” was the same as the surrounding sediment, but whereas the surrounding sediment was clearly bedded, that in

the cone was aligned sub- perpendicularly. We were told that Prof. Pomar had considered them to be root structures of anemones, but several of us had trouble with this interpretation.

The party now thanked Jordi for an excellent day, made their way back to the hotel and undertook the next serious ceremony of the day - “Grand Cerveza” before dinner.

Reported by David Ward

Day 3, Tuesday 17th Karst Geomorphology

Morning

(References to the handout in the text refer to the handout for the day entitled "EL EXOKARST DE LA SERRA DE TRAMUNTANA DE MALLORCA". The handout is not reproduced - it is assumed that members have a copy.)

Santuari de Monestir de Lluc

The day started with a drive through the Tramuntana from Port de Soller to the Santuari de Monestir de Lluc, situated mid-way between Soller and Pollenca, about 6km from the northwest coast. The monastery (470m above sea level) is a popular tourist stop but is surrounded by wonderful countryside and walks that few others seemed to inhabit. It had been a place of pilgrimage since the 13th century, famous for a wooden statue of the Virgin Mary.

Clot d'Albarca

We met our leader for the next three days, Dr Rosa Maria Mateos Ruiz, and Kelly Wallis, at the monastery and were led up a path initially to a viewpoint to enable an overview of the geomorphology to be examined. Rosa explained the chemistry of the Karst environment was a consequence or reversal of a simple chemical formula,

$$\mathbf{H_2O + CO_2 + CaCO_3 \leftrightarrow Ca^{++} + 2HCO_3^-}$$

Dissolution Precipitation

Although the day was hot and the sky was clear Rosa explained that the rainfall in the Lluc area was about 2000mm/year, whereas in the east it was only 400mm/year. This is comparable with our Lake District levels and we all started regretting that we hadn't brought our wet-weather gear with us.

The view from our stop-point however was magnificent. It covered the Clot d'Albarca, a large, oval karstic depression about 1km by 1.5km surrounded on all sides by a raised but primarily flat area (see Fig 2 of handout). Higher mountains were visible on the horizon to the west. The ground depression was being farmed extensively with a reddish soil being quite visible.

Rosa explained that the base of the Clot d'Albarca was the top of the Keuper and the surrounding rocks were the Lias limestone. The formation of the depression has been attributed to an assembly of dolines that have formed over the relatively impermeable clays of the Keuper and eventually have dissolved into a complete regional depression. There are a significant number of these features in this area of the Tramuntana (see Fig 3 of handout). This assembly of dolines is called a Polje.

There is no surface water in the Clot d'Albarca as streams leading to the sea have now captured it but we were reminded of the Cuber reservoir that we passed on the way to Lluc which apparently is a Polje not yet captured by any streams. The stream exiting the Clot d'Albarca travels west and joins with other streams that we would follow later in the day.

Terra de Ses Ollies

Our main walk of the day would take us to the Karren karstic area to the east of the Clot d'Albarca, called the Terra de Ses Ollies.

Karren landforms are primarily formed subsurface. Soil derived CO_2 from the decomposition of contained organic matter has the concentration 20X that of atmospheric CO_2. The amount of CO_2 that can be absorbed by groundwater and create the chemical acids behind the limestone dissolution is significantly enhanced by increased pressure and low temperatures (this phenomena was checked-out each evening when examining the gas condition in the local San Miguel lager beer). The pressure derives from the groundwater depth and much of the dissolution on Mallorca originates from the last ice age when temperatures were of course much lower than current. Rates of dissolution are estimated to be 1-2 cm/10^3 years.

The karren landform shape originates under the soil and becomes fully or partially exposed as the soil is washed or eroded away. It was planned that examination of these exposures would comprise the remainder of the morning as part of a walk following a path through the Terra de Ses Ollies. The micro-karren landforms are beautiful shaped vertical rills in the surface of the exposed limestone. It was suggested by Rosa that the rills originated by dissolution from localised subsurface water flow areas on the surface of the base limestone, which increased the depth and width of the 'U' shaped grooves over time. The vertical groove edges eventually overlap adjacent grooves and form the sharp edged rills characteristic of the micro-karren landform. Various versions of these canal-shaped rills were examined with a common feature being a dense area of small rills on the upper surfaces of the landform with larger, less numerous canals below (see Fig 7 of handout).

Other surface shapes were solution pits, clints and gripes, dry stream beds.

The macro-karren landform also originates from subsurface water flow but with greater velocities cutting deep grooves in the base limestone surface, often a number of meters wide and over 6m depth. The soil has subsequently been eroded exposing the upper limestone features of these 'V' shaped sectional grooves (see Fig 8 of handout). In some instances the upper shapes can be loosely interpreted as carved animals and we visited the famous Camel, Elephant, Tortoise, and Duck although some of the group preferred alternative descriptions more consistent with reptiles of the Jurassic period.

The whole region is world famous for its Karst structures and is visited and studied by many geologists from all over the world. The Lias in Mallorca is primarily a brecciated limestone, re-calcified, and with an extremely high level of chemical $CaCO_3$ purity, and is thus subject to quicker dissolution rates. The cause of the brecciation was already a hot discussion within the RGS group, but the two local theories were this was either a fossilised series of turbiditic structures or the result of a meteor impact!

Es Pixarelles

By 11.30 am we had climbed up the path to another viewpoint, about 500m above sea-level. Here we could see the karst landscape stretching over a raised flat area east of the Clot d'Albarca, called Es Pixarelles. Beyond this, in a north-westerly direction, were a small range of peaks stretching across much of the horizon (the sea was beyond this ridge). Just below the range of peaks a horizontal line, comprising a forested area clearly stood out from the landscape above and below it. Rosa explained the NW directional thrust characteristic of the Tramuntana and Mallorca. Our view direction was in the line of thrust and the forested line we could see in the distance was a thrust plane where the Keuper had been exposed with what has been documented

as Limestone 1 below and Limestone 2 above. This plane of Keuper could be traced for tens of kilometres along the line of the Tramuntanas. The natural height of the Keuper formation was lower (as evidenced by the base of the Clot d'Albarca depression) and to the south-east of Lluc. What we were looking at was thus the edge of a knapp structure, eroded to expose this second higher Keuper line.

We then walked down into the Es Pixarelles area to look at more evidence of the karren landforms. Much was very similar to that already seen but a number of oval patches of flat soil slightly below the normal surface were attributed to a collapsed doline cavern. The lack of vegetation on the flat patches caused much discussion. The soil in the area is referred to as Terra Rossa and consists of clays and sediments that remain after dissolution of the limestone. The silica in it has been determined as loess originally from the Sahara. One theory suggested as the root cause of the poor vegetation in some areas was perhaps because of a massive difference in the chemistry of the soil which did not suit the normal lime-loving preference of most of the seeded vegetation.

Evidence of the damage by man that had accelerated the erosional exposure of the karren landform was visible in the form of ancient charcoal manufacturing pits called, Corralas de Carbon. These round structures, maybe hundreds of years old, originated from peasants chopping down the local Holm Oak and converting the wood to charcoal for sale elsewhere on the Island.

Lunch was taken in a shaded grove in the middle of the Es Pixarelles. It was a welcome, tranquil interlude before a 1.5 hour walk back to the Monastery, initially in the hot sun through Es Pixarelles and then through the shaded path of the Clot d'Albarca.

Afternoon

Mirador de S'Entreforc (Gorg Blau and De Pareis)

We then drove in convoy from Lluc to Sa Calobra stopping on route at a Mirador about 1km west of the village of Escorca (590m). This gave a wonderful view from the roadside of the confluence of two streams leading into the Torrent de Pareis, the main river flowing down into Sa Calobra. The stream from the east was the Torrent de Lluc, emptying the Clot d'Albarca, and from the SW a steep gorge contained the Torrent des Gorg Blau, originating from the Cuber reservoir (see Fig 6 of handout). Both streams had little or no visible water flowing, but this was due to a relatively dry period had during the previous few weeks.

The confluence of the streams was the start of the Torrent de Pareis and a very steep sided gorge that followed a natural fault in the Lias limestone in a north-westerly direction down to the sea. The sides are a 200m near vertical drop and from the Mirador this was only visible as a dark vertical shadow in the surrounding steep sided mountains (Plate 5).

Rosa explained that it was only possible for experienced climbers to descend through the gorge and the route was very dangerous with a number of fatalities each year in attempts to reach Sa Calobra.

Although little flow was visible in the streams it was obvious from the amount of debris and erosion that there were periods when highly energetic flows occurred. Rosa explained that emitting from a spring on the coast, about 2km south-west of Sa Cordoba, there was an average annual measured flow of 15,000,000 m^3. This valuable water resource was lost to an Island in desperate need of water for an annual influx of 10 M tourists/annum and there was an ambitious

plan to capture the giant spring flow and pipe it along the coast to Porte de Soller and then through to Palma.

Plate 5. The inland start of the Torrent de Pareis from the Mirador (Photo DR)

Torrent de Pareis, Sa Calobra (see Locality 7, GA Field Excursion Guide to the Isle of Mallorca)

Sa Calobra is a small but very popular tourist village on the coast and is reached by driving down a narrow winding road, trying to avoid large coaches fighting their way back up after the requisite 1-hour stop. We parked the cars and walked to the river exit which required going through a narrow man-made but ill-lit tunnel. Interestingly the tunnel followed a natural fault in the cliff edge exiting in an impressive steep-sided canyon. A small shingle storm beach was the focus of most tourists but the RGS couldn't take their eyes off the canyon walls!

Rosa explained that the canyon follows a natural fault in the Lias limestone that rests on Keuper marls close to sea level. The depth of the canyon followed the natural water table which itself was controlled by sea level. Erosion of the fault and the deepening of the canyon reflected a drop in sea level to its present day height. The near vertical canyon walls were about 200m high with a 50m width although further inland they reached 300m and in places the walls were only 5m apart. There is a view that the canyon may have been a large cave system in places that had subsequently collapsed. At the time of the visit the river had only a shallow depth (paddling height) with a slow velocity but from the size of rolled blocks it was evident that much higher levels and energy were commonplace. Rosa estimated the canyon was about 10/15 k years.

Karstic cave systems, close to the sea, follow a route very close to the water level, the erosion being exaggerated by the mixing of fresh and salt water. High in the walls of the canyon were exposed cave exits, apparently overhanging the canyon. Rosa explained that these cave systems reflected a time when the sea-level was much higher and, of course, the canyon shallower; they were thus a historical record of past conditions.

We then walked up canyon base floor (rather overdressed in comparison to the beach natives), examining the different levels of cave systems exiting into the vertical walls and marvelling at the forces that had been able to cut such an impressive feature.

Plate 6. The end of the Torrent de Pareis at Sa Calobra. (Photo DR)

Soller Geological Museum

We rapidly drove back to Soller for our last stop of the day, the Soller Museum, which houses the most impressive geological record on the Island together with a surrounding gardens that could occupy a visitor for many quiet hours.

The curator welcomed us to the museum and explained that much of the collection and impressive library were the derived from a 20th century local micropalaeontologist, Guillem Colom. Marriage to a wealthy woman had enabled him to devote much of his life to geological research. He had recorded 300 new species of foraminifera and written over 300 related papers. The museum also included a tribute to a French palaeontologist, Paul Fallot, who had taught Guillem Colom in his early years.

The most famous item in the museum collection was fossilised bones of a very small goat, Myotragus, discovered in 1909, which was unique to the Balearics and lived on the Island in Quaternary times.

Another large display was a replica of a sea elephant, Halianassa Cuvieri, suspended from the ceiling with its original bones in a case beneath. This was found in the north of Mallorca and dated from the Miocene period.

The collection also shows clearly how vegetation altered through climatic changes, so affecting types of animals during the Palaeozoic, Triassic, Jurassic, and Cretaceous periods. One case shows plants present in Mallorca, one being Burdigalia, found in the lower Miocene. Further cases were still being worked on with a large collection of stored material.

Reported by Chris and Clare Fone

Day 4, Wednesday 18th The Coastal Facies in Serres de Llevant (Eastern area of Mallorca

Morning

The Santanyi Limestone

The forecasts were poor, but the morning was beautiful, and we had time to admire the morning glories at our meeting place, C'an Penasso at the Bunyola turn-off on the main Soller-Palma road. We set off to Palma, marvelling at the outside of the cathedral on our way to Porto Pi (pi means a lighthouse), on the west side of the promontory, just south of the royal family's summer house.

Here the reef complex, of Tortonian (Miocene) age (20-15 Ma) outcrops on the cliff. Above it lies the Santanyi limestone of a shallow platform facies, which is interpreted as a mangrove tidal flat. The nearby mountains would have supplied sediment, so there is a continental facies of fans overlying the limestones: these are the Bonanova marls, for which this is the type locality. This whole sequence is regressive, representing a fall in sea level, as shown by the marine foraminifera at the bottom and the terrestrial sediment at the top.

Closer inspection was possible part way down the cliff. The stromatolite facies of the Santanyi limestone was spectacular, with domes of laminate structure overlying masses of thrombolite structure, which is less organised, more knobbly. The domes were separated by channels, up to 2m wide, now filled with sediment which showed ripple structures. Some domes have been measured as large as 15m wide and 4m high. Those we saw were smaller, still massive, but decreasing in size to about 1m in width towards the top of the sequence as the water became shallower and salinity increased. The top of the stromatolite sequence is an erosion surface. Then there are well laminated calcarenites, about 1m in thickness, and then a heavily bioturbated bed with calcite lined tubes about 1-2cm thick. Pomar, the authority on this whole formation, thinks that the tubes are the burrows of polychaete worms, poliquetos in Spanish. Such worms characterise deeper water, yet he refers to the rock as dolomitized.

On the other side of the road there is a road cutting which exposes the Bonanova marls. They consist of beds of creamy pinkish clays 40-50cm thick and pebble bands about 10-30cm thick. The pebbles are almost all of limestone and are well rounded, up to 15cm in diameter. The beds have an apparent dip southwards of 12^{o}-15^{o}. To the south they are cut by a high angled normal fault with substantial fault breccia, and this brings down the Santanyi limestone. At the top there is a red palaeosol and then the aeolianite dunes which we later saw elsewhere.

All the rocks of the Porto Pi outcrops show joints and cracks with tufa and some brecciation. Many of the marls are more or less pink in colour, reflecting the amount of iron contributed to the environment.

We piled ourselves back into the cars, and set off through Palma again, and right across the southern part of the island to Cala Llombards (Llombarts on some maps), near Santanyi in the south east corner of Mallorca. The cliff top is covered with villas, and we had to pick our way through the residential roads to find the path which lies between numbers 12 and 14 on the Carrer des Ferrers, the road nearest the cliff top and parallel to it. The path leads to the Mirador d'es Pontas (Es Pontas on some maps), a look-out point which gives a good view over the coast and sea, and then there are steps down which allow close inspection of the golden Santanyi limestone.

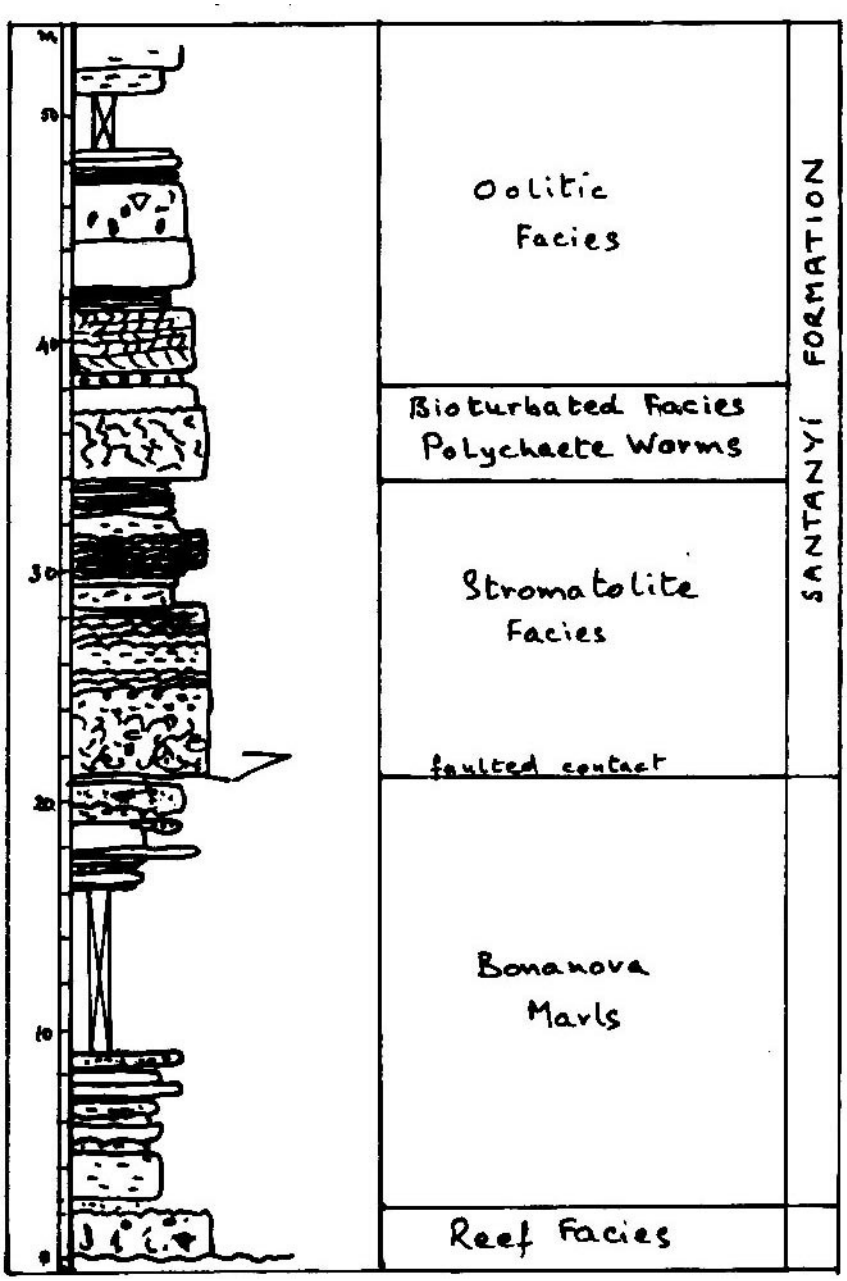


Figure 2. Reconstructed section to show the relationships between the Santanyi Formation, the Bonanova Marls and the Reef Complex (after Fornos and Pomar 1983).

Plate 7. Large Stromatolite mound with eroded top

Plate 8. Breccia and black calcite infill in Santanyi Limestone

Here there are no Bonanova Marls; the reef complex presents as a wave-cut platform, and is then directly overlain by shallow marine marls with a high degree of bioturbation. Many rootlets are visible and bivalve fossils, including pectinids. These seven beds, separated by layers of fine grained lime mud, with a total of about 3m thickness, are interpreted as a mangrove swamp.

Above them are about 3.5m of muddy beds which are increasingly stromatolitic, starting with cryptalgal laminates and finishing with strongly laminated structures and finally thrombolites. Between beds there are finely laminated tidal flat deposits of lime mud, some showing little eddies. The top of this sequence is an erosion surface.

The third unit of the Santanyi limestone is the one for which it is famous, the intertidal oolitic beds with asymmetrical ripples in both directions, so that in section there is a herring bone pattern. These are sometimes called climbing ripples or flaser beds. The oolitic 'sands' are picked out visually by the tiny mud layers which settled over them; i.e. as the general direction of sediment transport was inland, at small scale there is fining upwards. There are about 4m of these beds, and as sea level was rising, at the larger scale the sequence is coarsening upwards.

The beds are interrupted at one point by a collapse structure, 2-3m high, where a karstic cave had developed early on, and the sediments above, as yet unconsolidated, fell into it. Above it the strongly laminated stromatolite bed is undisturbed. The hole in the rocks reminded us that we were hungry, so we went back to the cars and found our way down to the beach. There was a good swell in the sea that day, so our swim was vigorous and added to the enjoyment of lunch.

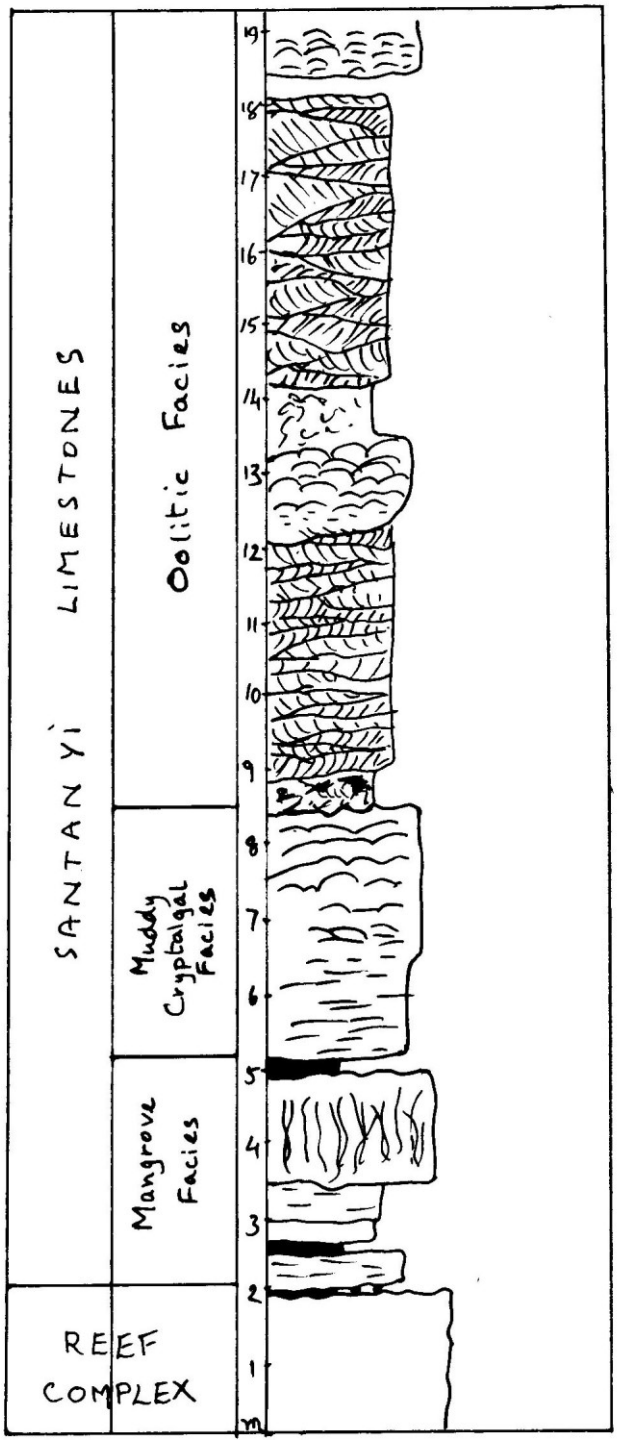


Figure 3. Reconstructed section of the Santanyi Limestone at Mirador d'es Pontas (after Fornos and Pomar 1983)

Plate 9. Dr. Rosa Ruiz in front of the Mangrove Swamp bed, Santanyi Limestone

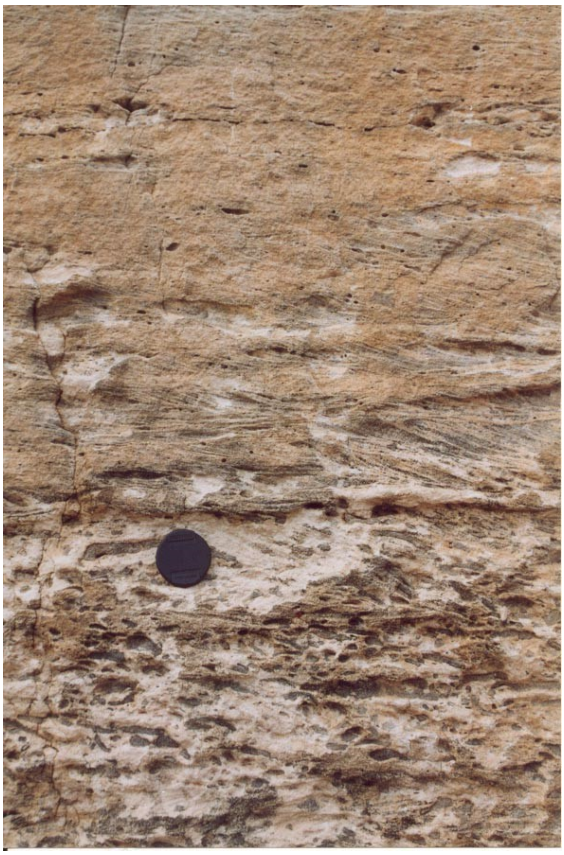


Plate 10. Climbing ripples in oolitic beds, Santanyi Limestone

Plate 11. Laminated Stromatolite bed, Santanyi Limestone

Plate 12. Karstic syn-sedimentary collapse structure, Santanyi Limestone

Reported by Gilia Slocock

Afternoon

Cala Llombards

After lunch and a swim (for some) we walked along the inlet to observe the collapse in the cliff opposite. The underlying Reef Complex developed Karst features particularly caves. When the cave roof collapsed the sediments above it i.e. the Mangrove Unit of the Santanyi Limestones, being still plastic, slumped forming a wide V shape above the former hollow (see figure 4). These Miocene syn-sedimentary structures are common all along this coast.

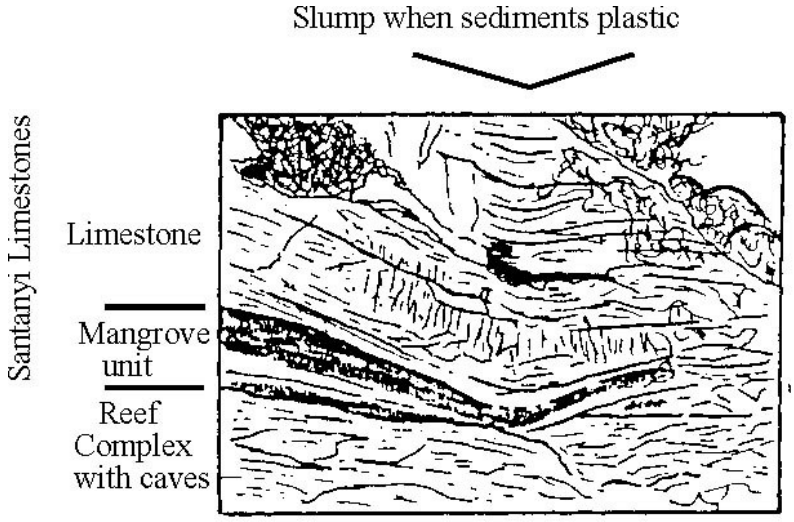


Figure 4. Cala Llombards Collapse.

But if the cave roof in the Reef Complex collapsed in post-Miocene times when the Santanyi Limestones were more consolidated these rocks became broken and filled up the cave in the Reef Complex with breccia. (See figure 5.)

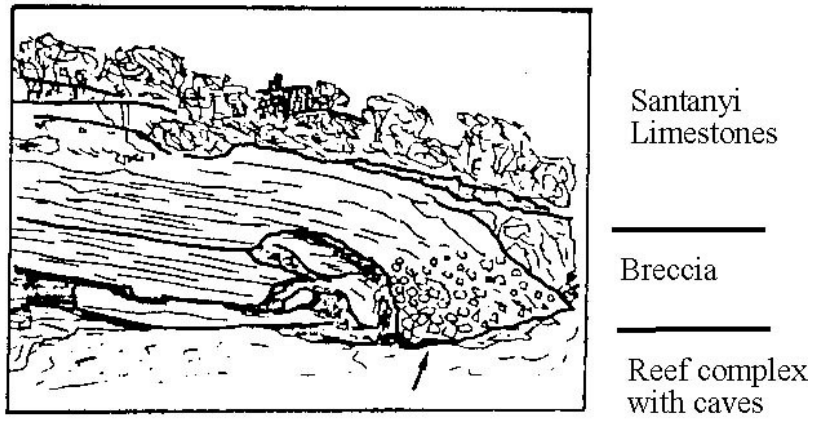


Figure 5. Collapse elsewhere along the coast where the Sediments were more consolidated.

S'Amarador

Here Aeolian sand dunes were formed against a cliff of Santanyi Limestone. These palaeodunes were mined for construction stone by the Romans and toolmarks are still visible. This working exposed the cross-section of the dunes which clearly show their shape during their evolution. Rocks - called rolling stones - from the Santanyi limestone fell from the cliffs down onto the dunes during their growth and are incorporated within the body of the dunes. Excavations have exposed tracks of Myotragus, the extinct goat of Mallorca.

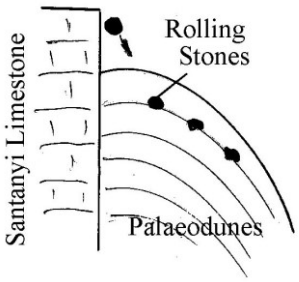


Figure 6. Palaeodune structure and "Rolling Stones".

Cuevas del Drach

These are fine examples of an underground Karst system. Caves form in the phreatic zone where the calcium carbonate is dissolved in the presence of water and carbon dioxide. Here the sea is relatively close so in the Drach Caves the water table inside the limestone is controlled by sea level.

Not only are some caves formed horizontally but at the seawater/freshwater interface more solution of the limestone occurs to produce a cave system at a steep angle. Inside the Drach caves we could see the huge caverns and also empty spaces falling steeply away from the path.

When the water table drops stalactites and stalagmites are formed, small spiky ones, huge columns and flow features. But on the present-day saltwater lakes there could be seen 'rafts' of lime deposits developing (precipitating on a nucleus) from the sides of the lakes and also on the stalactites that are dipping into the water. Looking carefully at all the stalactites above our heads we could see that some of them had small horizontal calcite protuberances. Sometimes there are several small 'ridges' up the side of a stalactite. In others the smooth shape had developed a huge fat bulge of precipitated calcium carbonate. All of these protuberances were precipitated when the sea-level was at that point on the stalactite. Using dating methods on the stalactites and the relative positions of these protuberances researchers have worked out the fluctuations of sea-level in the past 2 to 3 million years.

The caves are very beautiful and awe-inspiring and - "the visitor who has walked through this subterranean paradise, knows very well that the strange scenery of silences he has contemplated has created in his mind such a personal view, that from then on the beauty of these petrifactions will be an intimate part of his innermost emotional treasure, indescribable as a happy dream, majestic and unattainable as a page of music formed in the ether between heaven and hell" - Rafael Ferrer Massanet, *Cavern of the Dragon* (Manacore, 1983)

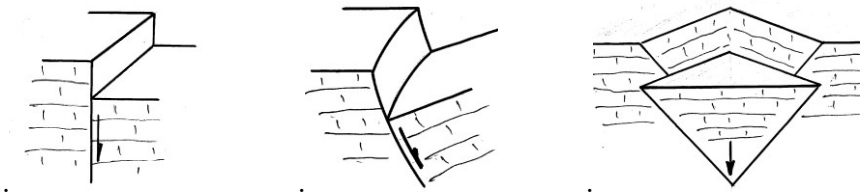
Reported by John and Jo Crocker

Day 5, Thursday 19th Landslides Geomorphology and Hydrogeology of Mallorca

Morning

On this, the last day of formal geology, we met Rosa and Kelly at the car park in Porte de Soller and drove a short distance out of the town to the north-east. This was a hair-raising drive up a very steep, very narrow road with interconnecting zig-zag bends which were so sharp that the drivers sometimes had to reverse to get round them. This road lead to a car park half way up the hill from which a very rough, unmade road continued upwards.

The aim of this morning's excursion was to examine the huge Bálitx landslide, north east of Port de Sóller. This landslide is of the wedge type (see box for landslide varieties} because two major faults form an acute angle down which the rock slides. The path was parallel to the north east slip plane in the Jurassic Lias.



1. Planar - here the slip plane is vertical and the displacement is like a normal fault
2. Rotational - the slip plane is curved so that the falling block rotates
3. Wedge (or Cuña in Spanish) - there are two slip planes so that the displaced rock is wedge-shaped

Figure 7. Types of Landslides.

After a short walk it was possible to look down to the coast and see a promontory of the Muschelkalk which underlies the whole area (this is seen more easily from the sea on the boat trip between Port de Sóller and Sa Calibre) covered by Miocene Turbidite (Plate 13). A diagram explaining the landslip was shown to us by the leader (Plate 14). This showed that the Lias broke off as large blocks and then slid down the underlying Keuper rather like icebergs calving. The blocks of Lias are now separated by rubble debris. It was easy to recognise the similarity of the diagram with the surrounding landscape (Plate 15). Much of the area was covered in debris, many of these rocks being several metres in diameter. The debris between fallen blocks can be used as a date indicator for the landslip if organic material is incorporated in it. The island of S'Illetta just off the coast may in fact be a fallen block.

Further along, the walk passed isolated houses (some of which seemed abandoned) surrounded by ancient olive groves - some trees may have been 600 years old. An example of a water storage building was pointed out - the houses would have depended on rain as their water supply. At the furthest extent of the walk there was a fissure field in which the fissures in the ground were about a metre wide, 20 or more metres long and of unknown depth - perhaps as much as 100m. It was obvious that the whole area was unstable. From this point it was possible to see the other slip plane of the landslip which runs almost due north.

Before returning down the path for lunch many of the party sampled the ripe figs growing on an abandoned tree. The party returned a short way back along the track to the shade of the olive grove for lunch. To my amazement, during lunch an old Renault car came out from behind one of the houses and drove down the path we had come up. How the driver didn't manage to break the car's suspension or hole the bottom of it as it zig-zagged down the pot-holed rough track I have no idea.

The cause of the landslip and its date are unknown. Possible causes could be either increased lubrication by water in the past or perhaps earthquakes. There is no evidence of seismic activity in the area. The earthquake zone at present is on the fault zone between the Tramuntana highlands and the plain.

Plate 13. Promontory of Muschelkalk with Miocene Turbidite (pale area) cover. A boulder of debris can be seen in the foreground.

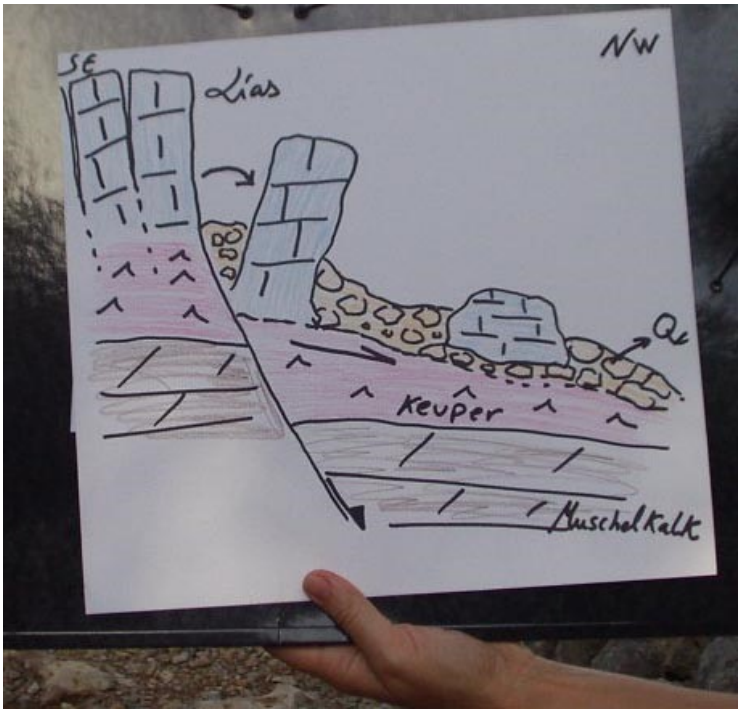


Plate 14. Diagram of the slipping of Lias on the underlying Keuper which is underlain by Muschelkalk. The fallen, sliding blocks are supported by debris.

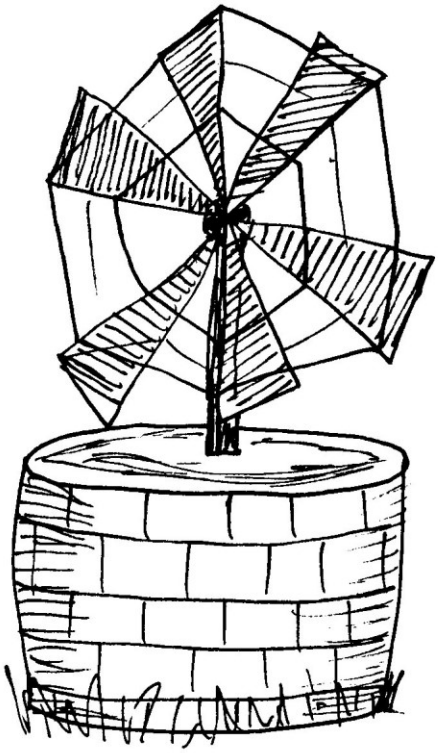
Plate 15. An upright block of Lias similar to that shown in Plate 14 and the rough ground of fallen rocks in the foreground.

Reported by John and Jo Crocker

Afternoon

Hydogeology

The population of Mallorca is 600,000 and 350,000 live around Palma. Every year 10 million tourists visit the island. Tourism and agriculture make heavy demands on the water resources of the island. Rainfall can be up to 400mm a year on the plains and 1100mm in the mountains, comparable with South East England, which falls mainly in the autumn and winter. Mallorca has no main rivers, just streams from mountain springs which flow after heavy rain.



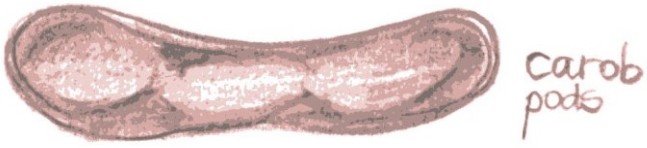
Typical well

The limestone rocks absorb the rains and act as aquifers. There are 25,000 licensed wells sunk into the ground, driven by windmill pumps, and a similar number of illegal wells. The rate of water extraction is leading to seawater soaking into the ground as water levels drop. Intensive farming techniques are also concentrating very high levels of nitrates and other agrochemicals in the water supply. The attached paper from the proceedings of the 13th Salt-water Intrusion meeting held in Cagliari, Italy, in 1994 refers to the area we visited, Sa Pobla and S'Albufera.

Springs or "ullals" from the limestone overflow after heavy rainfall and contribute to the brackish marshlands of S'Albufera. The main spring Ses Ufanes near Campanet and S'Albufera have been made national parks and are now environmentally protected.

The group visited the site of the Ses Ufanes spring and drove to the coast across the Sa Pobla basin to the wetlands near Alcudia.

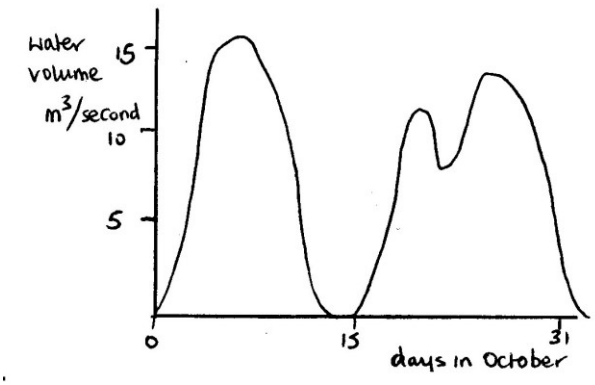
Sa Pobla is an intensively farmed area of Mallorca with olives, sheep, goats and carob on the higher ground and mixed arable and animal farming and market gardening on the on the plains.



The karstic cave system in the Lias rocks is above the normal water table. Rainfall is collected over an area of 42 square kilometres in this area of the Sierra de Tramuntana. It flows though the interconnecting caves and porous rocks. The Lias limestone is the aquifer; the lower Rhaetic limestones are semi-permeable, not so porous and usually below the water table. See figure 10 for cross section through the area. Below (figure 8) is a photograph of core samples drilled from both rocks. The lower Rhaetic limestone is seen to be more dense and made from finer particles.

Figure 8. Core samples from Lias limestone and Lower Rhaetic limestone.

After heavy rain the aquifer fills up and overflows in dramatic fashion at Ses Ufanes. Within 20 minutes water flow can be 11 cubic metres per second. The water engulfs the forest at that point and flows into the San Miguel stream flowing over impermeable cretaceous rocks to the marshes round S'Albufera.



The permeable surface is 42sq.km Area =
1100mm av. rainfall p.a.
Av. Spring flow 15 million cubic m.p.a.
Maximum annual flow measured has been
35 million cubic metres
Max. flow at one time = 70 cu.m./sec -
Usual flow 11 cu m / sec
Lasts for 2-3 days.
2001 dry year, no overflow
2002 up to 19 Sept., wet year
10 overflows so far.

Figure 9. Typical October water volumes.

The forest is monitored with many boreholes recording water table levels and water quality. The original boreholes took cores of 45cm diameter, exceptionally large. A machine was developed locally to do this and now the columns are much sought after to decorate local buildings. The group can be seen looking at an old well above the spring and the site of the spring. Note the size of the boulders in the streambed moved by the water flows. The forest floor is flooded by rushing torrents immediately after heavy rain, which dry up in a few days.

Plate 16. The spring site

The water quality is very good but the irregular huge volumes mean no scheme to control it has yet been devised. Ses Ufanes is the only spring from the whole Lias aquifer along the 12km fault running from NW - SE at the base of this area of the Tramuntana. (See diagram section figure 10)

The dams and reservoirs at Gorg Blau between Soller and Lluc in the mountains, hold 10 million cubic metres for Palma. Ses Ufanes water volumes average 15 million cubic metres a year so represent an important resource of good quality water. Various schemes have been proposed to pipe the water to Palma or to replenish the Sa Pobla aquifer, which has up to ten times (500milligrams per litre) the recommended level of nitrates from intensive farming.

Plate 17. The well above the spring

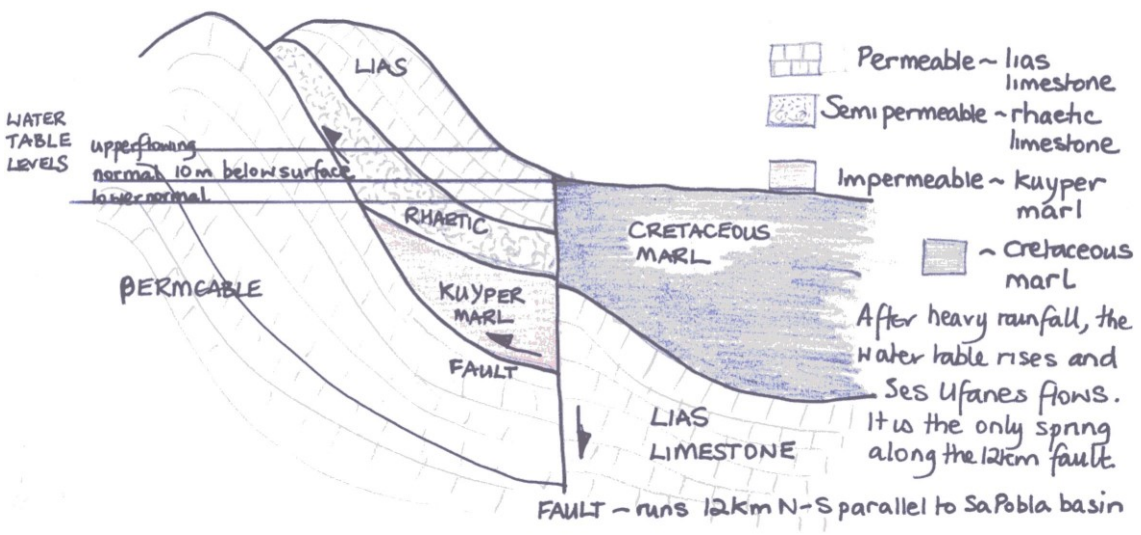


Figure 10. Geology of Ses Ufanes area.

Plate 18. Looking west towards the forest round the spring.

Water costs to domestic users, farming and business are subsidised by the government from tourist taxes. It cost 2 euros per cubic metre to desalinate water from the aquifers. Residents pay 45 euros per month (£7) for their water supply. 95% of the water supply comes from ground water and only 5% from the reservoirs.

The danger from increasing salinity from seawater and pollution from sewage and farming caused by overexploitation of the basin aquifer resources is serious. The basin aquifers are the Pliocene coral reefs. So Pobla farmers sink wells into the upper Pliocene calcarenites and Palma is tapping the lower reef calcarenites.

S'Albufera

'Albufera' derives from the Arabic word for wet. The area is a national park and has a visitors' centre, hides and walking and cycling paths. No cars are allowed in and it is protected from drainage and development. The coastal strip is densely built on with many hotels and apartments.

The wetlands lie behind the belt of coastal sand dunes. They are fed by the San Miguel stream and other springs which arise from the reef aquifers. It is not possible to visit them because they are below ground level. See the geological cross section below, figure 11.

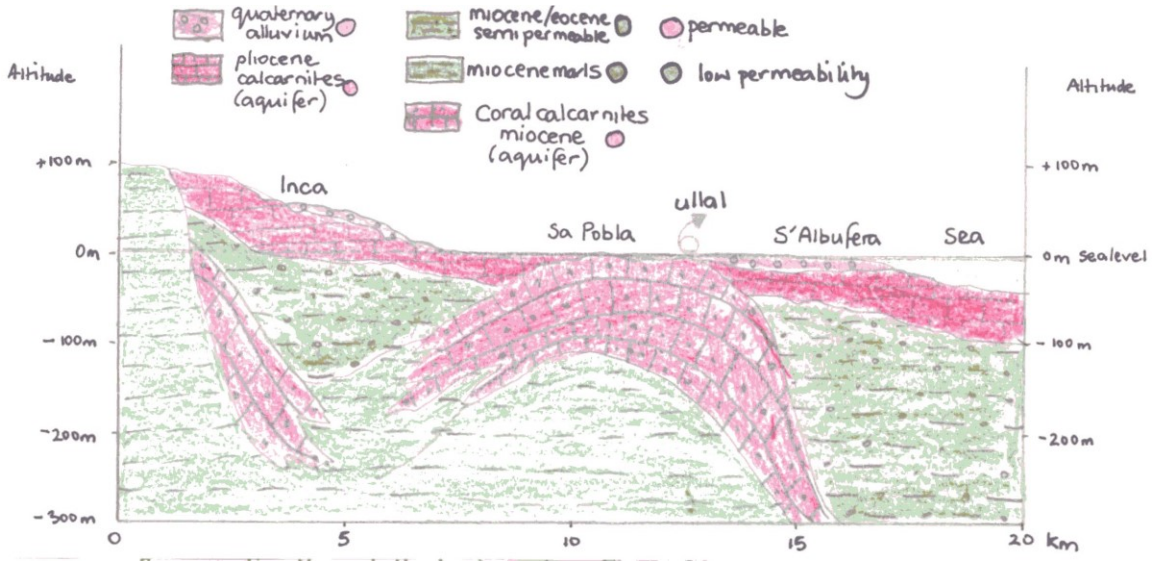


Figure 11. Cross-section through the basin geology.

The wetlands are a mixture of deep freshwater and shallower brackish marshes. It is an important wildlife area for migrating birds. During our brief trip, we saw a variety of insects including dragonflies and scarlet damselflies and surprisingly few mosquitoes. Hides have been created to view the birds and we saw Marsh Harriers, Mallards, Shoveller ducks, gailines, egrets, storks, pigeons and seagulls. In contrast we had seen very few birds throughout the week except for a colony of black storks nesting on the coastal cliffs near Banyalbufar and very few seagulls. Reeds fringe the deep water and bamboo and oak surround the visitors' centre.

Plate 19. The marshes of S'Albufera from one of the hides.

Plate 20. End of the last excursion. David thanking Rosa.

The day and the whole field trip ended here with David Ward's vote of thanks to Rosa and Kelly summarising the many highlights of the trip. It is not known how much Rosa understood but Kelly promised to translate. We were very grateful for the excellently arranged visits and for what we had done and seen. The event was marked by the cutting and distribution of a fruit cake , baked in England by Joyce Ward, an event which was much appreciated by Rosa who was given an extra piece for her son. After this we all returned to Porte de Soller

Reported by Christine Moore

Day 6, Friday 20th Rest Day

Friday was the free day with no geology trip planned and everyone able to choose what they wanted to do. Some went to Palma, some went on a geological walk, some went on a train, some went on a tram ride and some went on a boat trip. One popular choice was the walk round the west of the bay up to the lighthouse.

The tram went from the eastern end of the harbour at Porte de Soller, round the bay then up the valley to Soller and through the town to near the railway station. A lot of us took this trip although it could be quite crowded on some trams. (There was the main tram car and also an open-sided coach which, I assume, was attached for the holiday season.) Soller was a bustling town with cafes, the church and the tram at the main square and streets off it with quite a number of small interesting shops - all very nice.

The favourite seemed to be a boat ride from Porte de Soller along the coast to Sa Calobra. This was extremely pleasant with warmth and a breeze and a good view of the coast side of the landslip we had walked across the day before. It was possible to see all the features from the different viewpoint. The trip there took about 45 minutes and the boats sailed on the hour each way (not every hour). Many people took the opportunity to stay for an hour then catch the next boat back. A report from John Crocker with photographs from David Riley on the boat trip follows.

Boat trip along the coast from Port de Soller to Sa Calobra

As we rounded the northern headland of Port de Soller we could see the building of new apartments on the top of the high cliff right above the precipitous drop into the sea and also above the very recent small land slide which had taken away the road with it.

Sailing around the southern headland of the major landslip seen on Thursday, the Muschelkalk and overlying Miocene Turbidites were easily seen. In fact the darker Muschelkalk layers a few metres high seemed to form the base of all the cliffs here.

The wedge land slip is not as clean nor clear as Rosa’s diagram. The upper strata of the Jurassic Lias of the fault (and the ‘needle’ looking much larger from the sea) were clearly visible but the actual landslip is broken up and has smaller landslides on it with rotational slips at sea-level. Some of the house (by the olive grove where we lunched on Thursday) and the car travelling down the track were glimpsed through the trees.

Plate 21. View of the landslide and another aspect of the high block (centre of the picture) which we had seen during our coastal walk the previous morning. (Photo DR)

Further north of the main island another smaller one is developing as the cliff although only just attached to the land at sea-level has red-coloured debris in the crack behind it.
The second landslip was easily seen but much steeper than the other and with fewer minor landslips. But it does have one long stone avalanche track extending from the top of the mountain to the bottom.

The headlands of Lias limestone showed up the underground Karst features and the holey nature of the rock. Huge caverns, small caves, tunnels and hollows with many caves at sea-level all helped us to appreciate the water system of the flash floods at the Ses Ufanes Spring.

Plate 22. The numerous caverns (solution features) gave the limestone rock a honeycomb structure. (Photo DR)

Arriving at Sa Calobra the boat sailed very close to the shore to allow us to see the deep fault and chasm through the Tramuntana mountains.

Reported by John and Jo Crocker

Day 7, Saturday 21st Travel back

Since we did not have to leave for the airport until 16:00, and the hotel was very happy for us to keep our rooms until 12:00 and provide storage facilities, showers and other essentials after we vacated our rooms, we all had the chance of doing some of the activities we had not done on the Friday.

Port de Soller

One activity (or, rather, inactivity) was indulged by one couple who, at 10:00, after breakfast, sat out on the esplanade in the sun for about a hour reading, writing, looking…..then moved a few yards to a seat in the shade for about an hour…..then moved a few yards to a seat outside a café for a drink, again for about an hour. It was becoming cloudy and near lunch time so they moved to a table under the café's awning where they sat then lunched while viewing the downpour which lasted about half an hour (the only rain of the week apart from a pitiful shower on Wednesday afternoon). They were then joined by another member of the party and enjoyed some conversation. After all this it was nearing 15:00 so they returned to the hotel to get ready to leave for the airport.

Palma

From the 14th century Bellver Castle on the top of a hill just west of Palma, the view encompasses not only the town itself but also the magnificent Sierra Norte, the Palma Basin and further to the east, the line of the cliffs of the Llucmajor Reef Complex. Inside the fort is a museum of the history of the island with the final paragraph stating “When statistics suddenly burst on the scene, coming to form a part of both Mallorcans’ lives and those of the island’s immigrants, the city inevitable had to lay its hands on all available land. The city had not lived so intensely and so much in unison with the rest of the world for centuries. Whilst the reality may remind us of a kind of Tower of Babel, it is also true that the city’s inhabitants are well aware of the story of that beautiful utopia and can find the lesson to be learned from it” - Guillem Frontera, Guillem Rosello-Bordoy, Guillem Soler, *Palma* (Ajuntament de Palma, 1988)