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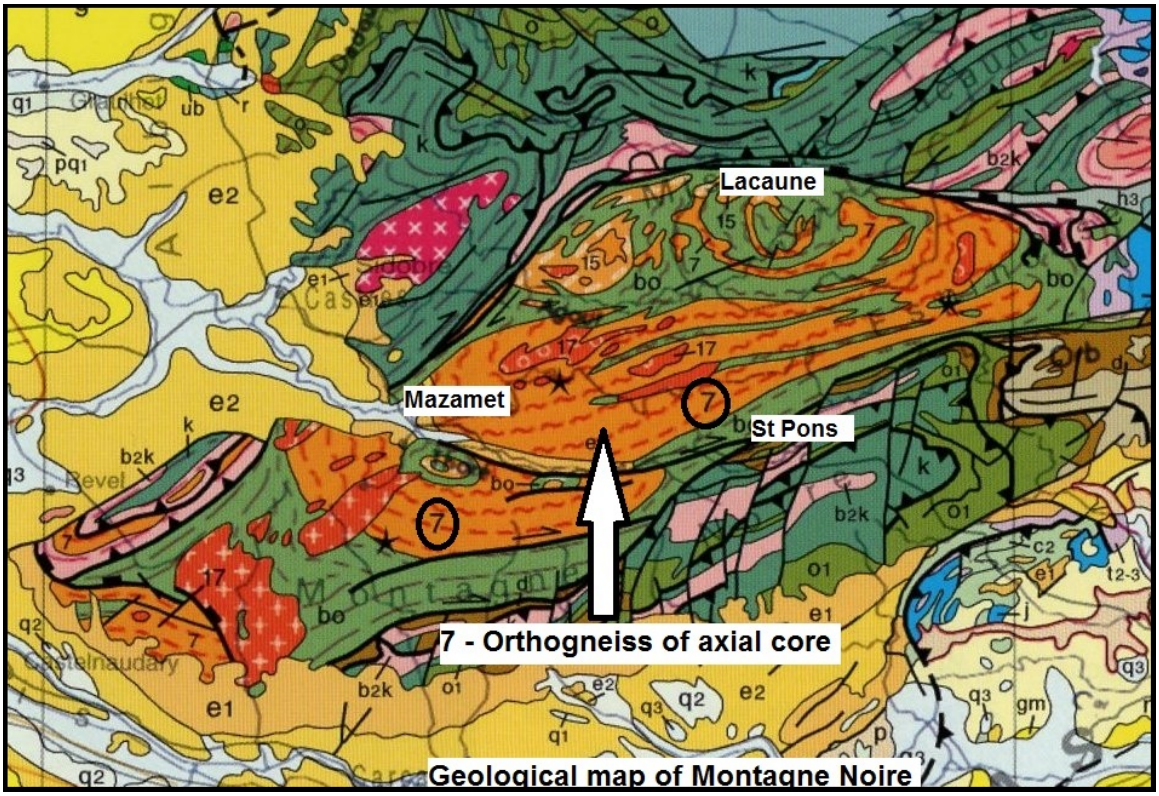
# Special Report of the Reading Geological Society

# Field Trip to Montagne Noire

# GEOLOGY OF THE MONTAGNE NOIRE AND THE PARC NATUREL REGIONAL DU HAUT LANGUEDOC

## 16th – 22nd September 2018



# Contents

# Introduction

This field trip was organised by David Ward and Carole Gregory who organised the flights, coach travel and hotels for the whole week to achieve a most successful outcome enjoyed by all.

Our leader for the week was Dr. Hilary Downes who is Professor of Geochemistry at Birkbeck College, specialising igneous rocks and with an interest in metamorphic rocks, and who has previously given us lectures as well as leading the visit to the Auvergne. Hilary provided a description of the geology of the area, of the individual sites to be visited, and of some specific aspects of metamorphism that we may not have come across before (“**Reading Geological Society field trip to Southern France, September 2018**”). Carole arranged for this to be printed and distributed before the trip which gave us an opportunity to be prepared for where we were going and what we would see. It was an essential guide and reference during the week and is referred to in the text as the ‘Guide’. It is not copied here as it is assumed that each member has their own copy.

This special proceeding has separate sections for each half-day, each section being written by a different member of the party. Photographs are provided by the reporters of each half-day unless stated otherwise. They, and any figures, are numbered sequentially, separately, in each half-day account. Sites were not all visited in the order given in the guide and so the actual stops are numbered sequentially within the day with the associated Guide STOP numbers given as well. The stops are also described with a brief name and the latitude and longitude given in decimal degrees. Where relevant, the Birkbeck standard notation for dip and strike is used. This has 2 digits for the dip and 3 digits for the strike, separated by /, no º symbol, and may be given 2/3 or 3/2.

**Attendees:** John Banks, Barbara Barrett, Alex Booer, Ailsa Davies, Ben Dixon, Hilary Downes (leader), Christina Fisher, Carole Gregory, Helen James, Hilary Jensen, Roger Lloyd, Bob Rall, Ted Smith, David Ward, Roger York. Thanks are due to all for making the week so enjoyable, for writing-up the half-days for this report and especially to David and Carole for organising it.

# Summary of the Geology

The objective of this field trip was to study the rock formations of Montagne Noire - the metamorphic and magmatic rocks emplaced during Palaeozoic times. The area under study is part of an active collision zone that forms the Variscan and Hercynian orogenic belt which began folding in the Late Devonian and continued into the Carboniferous. The high degree of deformation of igneous granitic intrusions, metamorphosed rocks outcrops, and the deformation of Palaeozoic sediments can be seen. Younger sedimentary rock deposits of Cretaceous and Eocene age showing slight deformation during the Pyrenean Orogeny, and the effect of the Pyrenean Orogeny on granites of Hercynian orogeny can also be seen.

The area under study is the southern side of an area known as the Montagne Noire. The Montagne Noire forms part of the southern end of the Massif Central. The central part of Montagne Noire is classified as an Axial Zone trending in an ENE-WSW direction which has a highly metamorphosed core complex, composed of Early Palaeozoic gneisses that have been migmatised with localized intrusions of anatectic granites. The Montagne Noire complex shows structural orogenic crustal shortening and thickening, combined with later orogenic crustal thinning. The crustal shortening and thickening has produced nappe folds on the southern flank of the Montagne Noire dome. To the south are the Pyrenees Mountains that were folded during Tertiary times by the Pyrenean Orogeny. The opening of the Atlantic caused the opening of the Bay of Biscay and the Iberian peninsular rotating and colliding with France. The crustal folding causing crustal shorting and faulting and their effects can be seen in the quarries to be visited.

The detail of the geology of the area is well described in Hilary's Guide and is not further repeated here. But each day had a different theme with the party, on the first day looking at the different metamorphic and igneous rocks in a traverse across the Montagne Noire metamorphic core complex (the Axial Zone), and, on the second day, doing a similar traverse but looking at the metamorphosed Palaeozoic sedimentary cover. The third day was spent walking from south-east to north-west through the southern half of the Caroux Dome. This was in the Gorges d'Heric – a very popular local holiday attraction. We walked through a cross-section through the gneisses and granites of the Caroux dome, from the nearly vertical strata at the start to the horizontal, deformed strata in the middle of the dome.

On the fourth day we went south-east off the Axial Zone and visited Lower Palaeozoic rocks, viewed the Eocene unconformity and visited the Eocene limestone gorge in the ancient, and historic, village of Minerve.

The fifth day was spent in the Nore Massif, part of the Montagne Noire south of Mazamet (but separated by a Hercynian fault) where we saw older rocks thrust over younger and the last day was spent in the Sidobre area, north of Mazamet, where we saw the Sidobre granite (also separate from the Axial zone) and the outcrops resulting from the weathering, a granite quarry, and the museum of mining (Espacemuseologique).

# Half-day Reports

**Day 1, Monday 17th September – morning**
***A traverse across the Montagne Noire metamorphic core complex (part 1 – the metamorphic and igneous rocks)***

The geological aim of the day was to traverse across the Montagne Noire metamorphic core complex studying the metamorphic and igneous rocks.

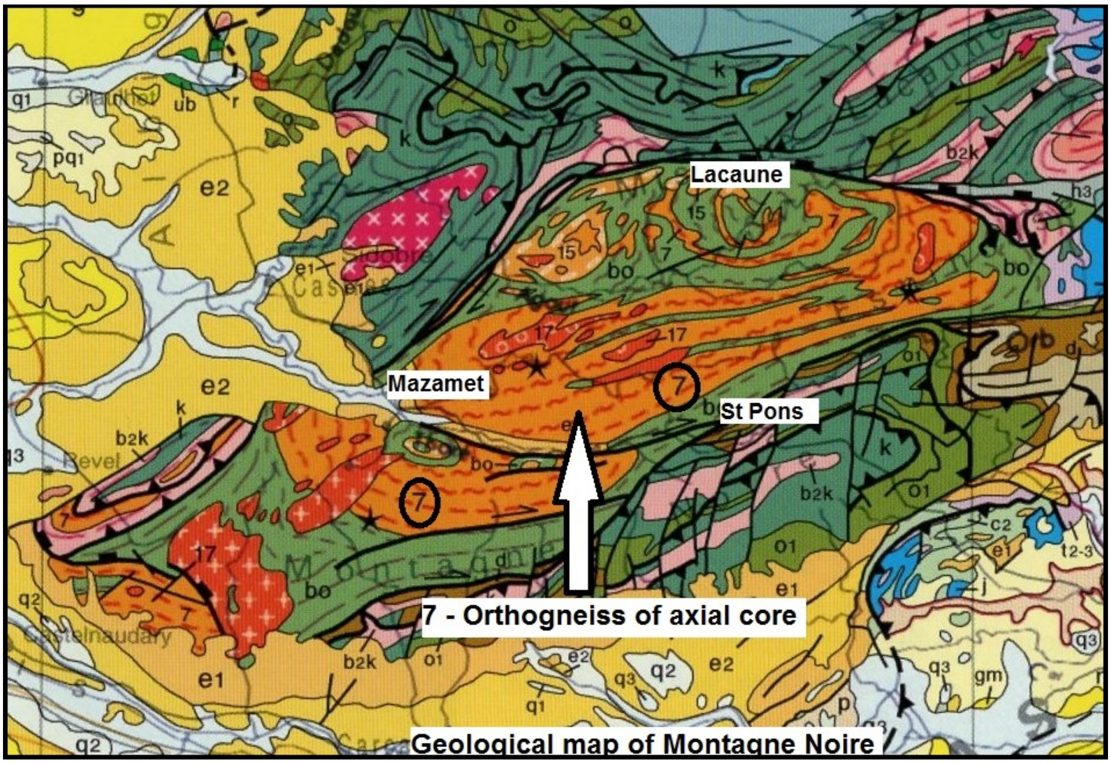



Fig. 1: The geological setting of Montagne Noire.

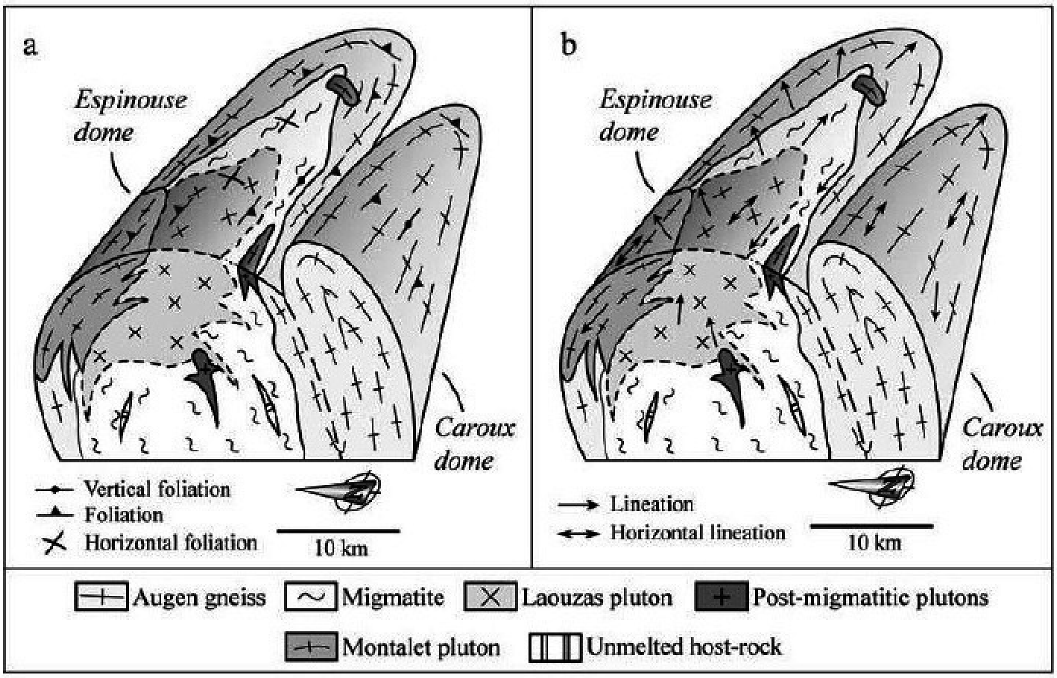
This is also known as the axial zone. There is still controversy about the metamorphic dome emplaced in the Variscan Belt, but there is agreement on the relative chronology of the tectonic events of the Hercynian orogeny:-

- Recumbent folding and thrusting
- Crustal melting and doming
- Post-migmatitic granitoid emplacement
- Later infill of the coal basin to the north of the Graissessac Fault indicative of orogenic collapse

The patterns of foliation and lineation were discussed on many occasions during the week. Foliation and bedding are recorded in the field with dip and strike, lineation with dip and the down direction of dip. Definitions of these are as follows:

- Foliation - the word comes from the Latin *folium*, meaning "leaf", and refers to the sheet-like planar structure. It is caused by shearing forces (pressures pushing different sections of the rock in different directions), or differential pressure (higher pressure from one direction than in others). The layers form parallel to the direction of the shear, or perpendicular to the direction of higher pressure.
- Lineation - refers to linear structural features within rocks.

The core complex shows an E-W orientated dome-parallel-axis foliation, dipping to the north in the northern part, flat in the central part and inclined to the south or vertical in the south. This change in orientation was seen during the course of the week when different localities were visited. The lineation is more varied, but approximates to NE-SW varying to N70ºE, following the orientation of the axial zone.




Structural elements: foliation complies with preferred orientation of biotite, enclaves and migmatitic foliation; lineation exihibits a contrasting pattern with a dominant NE/SW trend.

Fig. 2: Block diagram of the core complex showing foliation and lineation. (Guide Fig. 5)

**Stop 1.1 (Guide 1.1): D907 Roadside (43.523390, 2.741963)**

The coach took us east from Mazamet to St Pons, then north out of St Pons on the D907 towards Lacaune. The first stop was at a road cutting on the D907 just before Col de Cabaretout.

The mineralogy of the gneiss was examined - muscovite, biotite, quartz and traces of epidote but the most conspicuous feature was the augen of white, alkali (potassium) feldspar. The word “augen” comes from the German “eyes”, and they were up to 2 or 3 cm in size. Distinct foliation was noted where the feldspars lined up across the exposure, as did the platy minerals, muscovite and biotite. Measurements were taken and the strike was 060º and the dip as 80º towards the north, almost vertical. (Fig. 4 shows the almost vertical alignment of the feldspars).

The origin of the gneiss was discussed - it was suggested that this was originally an Ordovician granite (450 MA) which had been metamorphosed during the Hercynian (Variscan) orogeny – an orthogneiss. Further measurements of strike and dip of the foliation were made across the outcrop and similar values were found.

There was also a secondary lineation on the foliation dipping to the west possibly due to younger deformation and the outcrop exhibited fracturing along the lineation. A quartz vein was examined and found to consist of boudins of quartz following the foliation direction. About 200m down the road, it as noted that the feldspar in the augen had been replaced by quartz.

Fig. 3: The road cutting exposure that was examined

Fig. 4: The almost vertical alignment of the feldspars

**Stop 1.2 (Guide 1.3): Lac de Vésoles (43.551667, 2.792500)**

We next drove north along D907, right onto D169, then right again to the viewpoint near Lac de Vésoles where the weathering of the orthogneiss resulted in the creation of incipient landforms.

Fig. 5: A general view of the rock outcrops

Again, augen orthogneiss was present but deformation had created small-scale folding. (Fig. 6 shows this). It was suggested that this was due to second-generation deformation. Visualising the folding in three-dimensions helped to understand the direction of the foliation and the dip. Also it was said that the quartz and feldspar augen were more competent and responded less to stress that biotite and muscovite. It was also possible to see a marked degree of stretching in the augen, some of which developed "tails".

Fig. 6: Augen orthogneiss was present but deformation had created small-scale folding

Reported by Hilary Jensen

**Day 1, Monday 17th September – afternoon**

After our picnic lunch at Lac de Vésoles we met Hilary's friend Doris who brought a well used copy of the geological map of the Pons area. A brief study before moving on to the Barrage de Lac de Laouzas (Fig. 1) a location recommended by Doris although not previously visited by Hilary.

Fig. 1: The dam at Lac de Laouzas

**Stop1.3 (not in Guide): Barrage de Lac du Laouzas (43.635278, 2.754444)**

Granites were the feature here. The blocks at the side of the road at the parking/ information area were studied and found to have been slightly altered and weathered though large feldspars were found. Quartz, kaolinised feldspars, biotite and tourmaline were also observed.

However this is not what we expected to see; according to the map and book we should be looking at anatectic granite. This is granite which is derived from partially molten country rock and not solidified rising magma.

Bob scrambled down the steep slope towards the dam returning with a sample. This had greenish grey patches which were identified as cordierite (Fig. 2). The brown 'splodges' were the result of the rapid degradation of the cordierite and are known as 'chataigne' or chestnuts. Cordierite is rare in most granites but does occur in anatectic granites in association with tourmaline. Cordierite also occurs in metamorphic spotted slates.

Fig. 2: Cordierite

Black layers (schlieren) were also observed in this sample and determined to be relics of the biotite in the original country rock. Further metamorphism would lead to orthogneiss; (paragneiss being derived from sedimentary rocks).

**Stop 1.4 (not in Guide): Track just off D907 (43.597993, 2.702719)**

Moving on to the second stop of the afternoon, a path south just south of La Salvetat, we were looking for migmatites. Here we found Salvetat migmatites (Fig. 3). These are the result of the partial melting of the metamorphic country rock which recrystallises with a granitic texture though remnants of the metamorphic fabric may remain.


Fig. 3: Salvetat migmatite (RY)

Within the migmatite there was banding of light and dark material. The dark bands are melanosome and consist of a mafic mineral which is melting into a eutaxitic texture. The melanosomes form bands between the lighter bands called leucosomes.

**Stop 1.5 (Guide 1.4): D907, roadside (43.595833, 2.702500)**

Our third stop of the afternoon was just beyond the second of the next two hairpin bends in the D907 where hydrothermally altered granite was to be found. Here we saw 'grus', the granular detritus resulting from the intense physical and chemical weathering of granites. Quartz and feldspar remnants were found and some remaining granite boulders. Some granite veins were noted.

We discussed how the alteration could have occurred and at what point in the development of the rock. As the granite moved up at the end of its formation hot waters would be present causing chemical weathering. Reaching the surface physical weathering would take place; with the feldspars altering to clays which would be removed from the grus leaving a 'sandy' deposit. The surface weathering would have taken place in an arid or semi-arid environment. (Fig. 4)

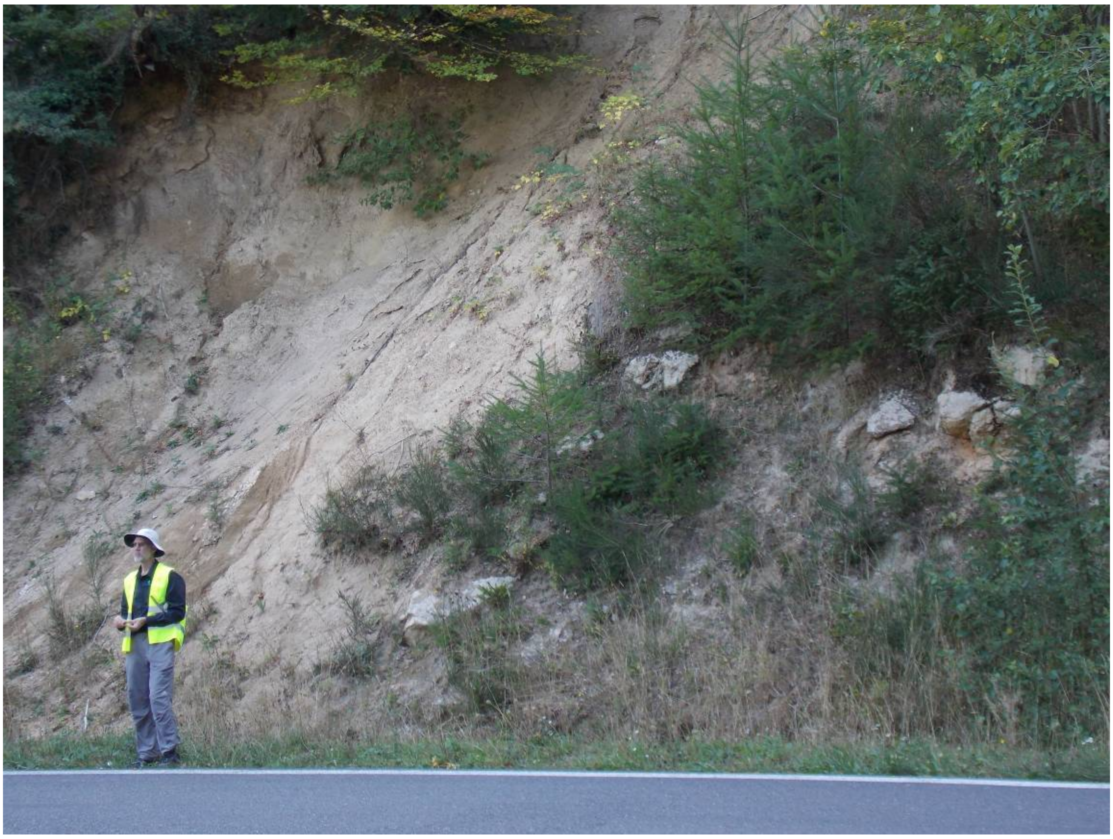


Fig. 4: Bob and 'grus'

**Stop 1.6 (Guide 1.2): Field off D907 (43.546111, 2.745556)**

Our final stop of the day required the more hardy of the group not only to walk along the road and down a track but also to climb over a barbed wire fence.

In the field we found some large rocks and studied some large augen. Some of the augen had been stretched into lens shapes, but not all in the same section of rock. The explanation for this phenomenon is that the augen which are aligned with the foliation of the rock will be subject to deformation along with the country rock but those aligned against the foliation will not (Fig. 5).


Fig.5: Stretched augen and unaffected augen (RY)

Reported by Ailsa Davies

**Day 2, Tuesday 18th September – morning**
***A traverse across the Montagne Noire metamorphic core complex (part 2 – the Palaeozoic sedimentary cover)***

**Stop 2.1 (Guide 2.1): D607 Roadside granite exposure, south of Lacaune (43.688048, 2.659528)**

After a classical French breakfast, we travelled east from Mazamet towards St Pons, then north on the D907 towards Lacaune with the intention of visiting the northern part of the Montagne Noire complex.

At Labastide-Rouairoux we took to minor roads and travelled through woods and over hills with excellent autumn foliage. On the D55 we passed a roadside dolman,. Our first stop was a small roadside outcrop of white granite about 3 km south of Lacaune on the D62. After crossing a trench and barbed wire tripwires, the face was examined.

Fig. 2: Foliation in granite, south of Lacaune (RY)

Feldspars, quartz and some stretched biotite micas were identified, confirming the rock as a granite, but further examination revealed both lineation and foliation, indicating that the granite had been stressed and distorted after emplacement. Very small pink spots could have been garnets. Measurement of the foliation gave a dip of 40º and strike of 270º. This rock was an anatectic granite, generated in situ and was positioned on top of the main body of the gneiss.

Fig.1: General view of outcrop of granite on D607 south of Lacaune (RY)

**Stop 2.2 (Guide 2.2): Palaeozoic sediments in quarry by D81, west of Lacaune (43.711627, 2.667717)**

A short drive through Lacaune and out to the west on the D81 brought us to a large, disused quarry on the north side of the road, surrounded by a considerable barbed wire fence. Time and considerable effort was spent mounting this obstacle, magically achieved without personal damage.

The main face of the quarry was about 200m long and 25m high, with sheer, vertical grey faces. The east face was examined first, where we saw a grey rock, with apparent bedding dipping to the SW.

Hand specimens fizzed with acid, indicating a limestone. Tracing the beds in the face showed us that major folding had occurred – at least one 30cm thick bed showed recumbent folds and even hand specimens had bedding which turned through 270 deg within the specimen. No success was seen with attempts to identify "way up" structures, so no conclusion could be reached on whether the rocks were inverted – but it seemed extremely likely that some must have been.

The west face repeated the grey limestone sequence seen earlier, but here there were thin, whitish, very crumbly, layers between the limestones. Hilary interpreted these as phyllites – low level metamorphic rocks, resulting from alteration of clays deposited alternately with the limestones. A number to white calcite patches were examined, in the hope that they would be fossils and therefore give us an age, but none were convincing.

The geological map records these as "Palaeozoic" so clearly others have also had trouble giving them a positive identity.

An orderly retreat across the wire allowed us to return to the bus and head back towards Lacaune, where a Pizzeria, a pub and a restaurant provided well earned lunch.

Fig. 3: Phyllite and limestone in quarry on D81 at Lacaune

Fig. 4: General view of quarry face – Palaeozoic limestones at Lacaune

Reported by David Ward

**Day 2, Tuesday 18th September - afternoon**

**Stop 2.3 (Guide 2.3): Track above disused slate quarry (43.723778, 2.688833)**

After lunch and to the south of Lacaune we are still on the northern flank of the Montaigne Noir. We drove north along the D607 then turned off west to the first stop, a roadside exposure above a very large, disused slate quarry (now Granier Industrie) near to the Col de Sie (Fig. 1). The formation is of Lower Palaeozoic black schists (slates). The original bedding cannot be readily identified, but there are two planes of cleavage resulting from different phases of stress. The slate cleaves into elongated pieces, so called pencil slates "arboisier". Along the cleavage planes there is also some evidence of slight movement with the recrystallisation of pyrite, and slickensides (Fig. 2) showing where packs of slates have deformed and slipped over each other. There are minor surface features which may be the deformed remnants of grazing trails, burrows, and enigmatic plumose structures. There are also tiny faults. It is likely that the pyrite and recrystallisation along the cleavage planes are the result of water getting into the rock.

Fig. 1: Exposure of slate above the Granier Industrie quarry (RY)

Fig. 2: Slickensides are just visible on the slate (RY)

**Stop 2.4 (Guide 2.4): Old Station, St. Pons (43.486306, 2.774472)**

Leaving the northern flank we now moved south to St Pons, crossing the central core of the axial zone. At St Pons our destination is a disused marble quarry on the edge of the town. The rocks here dip southward away from the axial core. The exposure is some 10 - 15 metres high, and approximately 100 metres in length. There a number of marble quarries around St Pons in strata, originally limestone dating from Ordovician to Devonian ages. This exposure is most probably Ordovician. The rock is not fully crystalline, and has tension gashes at several horizons, implying stretching during formation of the marble (Fig. 3). Movement during formation is also indicated by slickensides at several horizons.

These two exposures, on the Northern and Southern flanks of the axial zone are both in rocks which are still recognisably sedimentary. There has been much erosion as well as deformation during the process of doming which has resulted in the uncovering of the core of the Montagne Noire, a crystalline complex of gneisses and schists of presumed Proterozoic or early Palaeozoic ages, later intruded by late Variscan granites.


Fig. 3: Tension gashes in the limestone at St Pons (RY)

Reported by John Banks

**Day 3, Wednesday 19th September – morning**
***Gorges d'Heric – cross-section through the gneisses and granites of the Caroux dome***

**Stop 3.1 (Guide 3.1): South end of Gorges d'Heric (43.573370, 2.967227)**

Arriving at the Gorge d'Heric and walking from south to north through the antiform, the sequence is visible in exposures on the path.

Fig. 1: The path up the Gorge d'Heric (RY)

Mica-schist with sub-vertical fabric dips steeply to the south (strike and dip recorded at 085/85). The mica-schist is relatively early in the metamorphic sequence, which is understood to progress from mudstone sedimentary host rock, to phyllite (not seen at this location), to garnet-mica-schist, eventually to an s-type granite melt.

Orthogneiss with large augen fabric outcrops next, at a sharp and likely unconformable boundary, with a similar strike and dip to the schists. Fine grained intrusions of s-type granite of sedimentary genesis intersect the gneiss, with visible feldspar, quartz and biotite as well as acicular crystals of tourmaline - indicative of a sedimentary origin and formed by partial melting in the magma.

The tourmaline is a striking feature of the granite intrusions which presents as a black opaque mineral with acicular and lenticular crystals up to around 0.5cm long.

Tourmaline crystallises in the late stage of partial melting. It ends up in the final watery fluids as the mineral and fluids are incompatible with the rest of the minerals crystallising out of the magma. The tourmaline crystals are less dense and float to accumulate against solid surfaces, or are crowded out by the other crystals, and were observed at the tops of small sills or at edges of intrusions.

**Stop 3.2 (Guide 3.8-9): 1st bridge over river (43.575567, 2.966328)**

Distribution of tourmaline varied in each intrusion. The following examples show the range: Tourmaline crystals in the centre of a feldspar and quartz vein (Fig. 2), tourmaline clustered on the edge of an intrusion, tourmaline distributed throughout an intrusion.


Fig. 2: Granite vein with tourmaline running with the foliation in the orthogneiss (RY)

The granite intrusions themselves are late-stage in the metamorphism of the region - they cross-cut the orthogneiss and do not show any foliation within themselves. Lineation is visible on some surfaces, and slickensides show dextral movement in at least one outcrop. The granite intrusions cross cut each other, at least three phases of intrusion were observed in the gorge.

Reported by Alex Booer

**Day 3, Wednesday 19th September - afternoon**

**Stop 3.2 (Guide 3.10): Gorges d’Heric shear zone (43.586083, 2.958139)**

The Gorges d’Heric is a river cut cleft in the most easterly region of the Montagne Noir structure. It trends NNW to SSE (Fig. 1). The river had cut down through 1000 feet or more leaving a spectacular gorge. Hilary explained that the walk through the Gorge d’Heric would provide an opportunity to view a cross section of the gneisses and granites of the Caroux Dome. The notes provided a very good diagram of the Antiforme du Caroux indicating the general dip of the structure at the expected stopping places as we walked our way up and down the gorge. A general view of the Gorges d’Heric is shown in Fig. 3. After our lunch (second lunch) the pathway provided an easy opportunity to scramble down to the river itself and examine some of the most deformed and metamorphosed rocks.

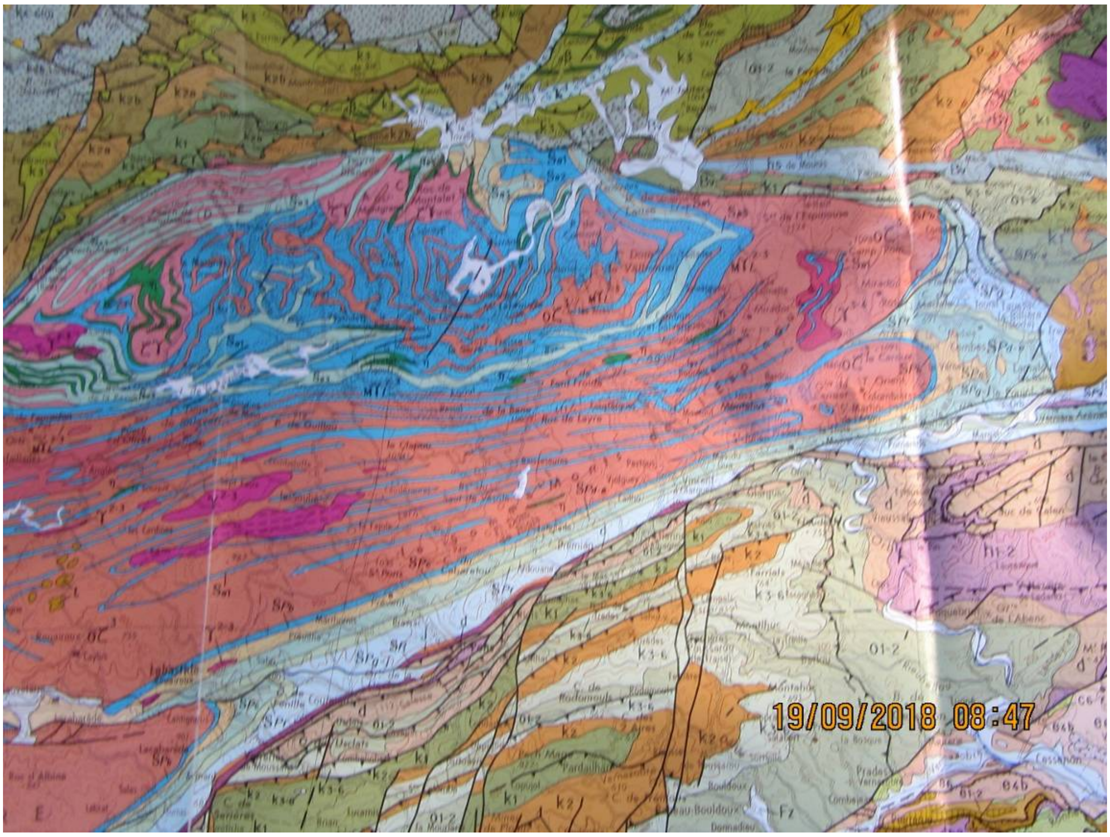



FIG. 1: Geological map of La Montagne Noire

We looked at the top of an outcrop which showed deformed orthogneiss with several isoclinal folds which had been folded again. Hilary explained that the deformation had resulted from a shear zone at depth with the rocks failing in a ductile manner rather than a faulted fashion. With greater pressure and temperature the metamorphism would continue until bands of felsic and mafic minerals appeared. Fig. 5 shows a striking example of this. The thickness of the bands varied with some of them being around 2 inches thick. Other samples showed boudinage. The main points made, we walked back down the gorge stopping only for photographic opportunities.


Fig. 2: Augen Gneiss


Fig. 3: View of the Gorges d'Heric looking north northwest

Fig. 4: Intrusive band (HelenJ)

Fig. 5: A migmatite showing mafic and felsic bands and additional folding (HelenJ)

Fig. 6: A small Z shaped fold (HelenJ)

Reported by Roger Lloyd

**Day 4, Thursday 20th September - morning**
***Lower Palaeozoic rocks and Eocene unconformity of Minerve.***

**Stop 4.1 (Guide 4.1): Old quarry beside D920 (43.438333, 2.649556)**

We again drove east from Mazamet but turned south onto D920 at Courniou, through Verreries-de Moussans, to stop at the quarry just before the Col de Serières.

The quarry is very overgrown and the shear face of the quarry is difficult to approach. There was discussion about what is planar bedding and what is cleavage. A rock corner on the weathered surface was the only place where you could see a 3-dimensional view of the bedding to obtain the dip and strike. The bedding is at 020/28. The cleavage is at 75°. The Lower Palaeozoic bed is a limestone as it fizzes with HCl. The limestone has been partly recrystallized to a marble. Above the limestone is a sandstone deposit. HD wrote that the sandstones had slipped over the limestone.

Fig. 1: Disused limestone quarry near the Col de Serières

We continued south from this quarry through Ferrals–les-Montagnes on the D12 to another disused quarry just south of the village.

**Stop 4.2 (Guide 4.2): Old quarry beside fire station off D12 (43.399750, 2.630139)**

The Cambrian Quartzites in the quarry are a local stone that has been quarried for millstones, road stone and building stone. The bedding dips at 40º to 60° NW. Fallen rock fragments show veining. The quartzites show sedimentary structures such as scours and flute marks formed by rapid deposition. The scour and flutes need clasts larger in size than the deposit itself to scour the surface of the flat deposit and leave a mark. Scouring can be caused by turbidite suspension load material and can be seen in a lake, but more common in deep marine environments. The scours are protruding upwards so the deposit has been overturned.

Fig. 2: Flute marks in upturned quartzites (RY)

**Stop 4.3 (not in Guide):** Road junction D12E3 and D12 (43.387667, 2.628500)

We were going to eat lunch in the quarry but it was so uncomfortable and hot that we decided to continue driving to find a more sheltered spot. This was found at a road junction with shade and a good rock exposure which also happened to be very interesting. Some flute marks, ripples and some cross-bedding were seen indicating that the rock was the right way up.

Fig. 3: Lunchtime roadside exposure (RY)

Reported by Barbara Barrett

**Day 4, Thursday 20th September - afternoon**

**Stop 4.4 (Guide 4.3): Viewpoint just off N side D182 (43.358639, 2.638222)**

After lunch we drove south from Ferrals–les-Montagnes to St Julien-des-Meulières before turning east onto the D182 towards Minerve.

On Thursday afternoon, we left the Montagne Noire and drove down onto the Languedoc plain - a sedimentary Eocene basin. We parked and walked in the lowland heat to an old millstone quarry now used for aggregate to examine some of the ancient marine sediments. Before examining the rocks, we admired an outcrop in the distance with an impressive unconformity: axial zone Palaeozoic rocks - dipping from our view point about 40 degrees to the south - underlying an almost level Eocene strata (dipping 5° to the S); a difference of hundreds of millions of years.

Fig. 1: View of unconformity from Sentier des Meulières

This stunning unconformity was due to an Eocene transgression, the result of the rotation of the Iberian Plate and the opening of the Bay of Biscay during the late Cretaceous and early Palaeogene. A large tectonic event during the late Thanetian in the Palaeocene, led to the westward flooding of the low lying areas of France into the surrounding areas of the Montagne Noir. The following regression from marine to lacustrine deposits to eventual disappearance was due to the opposing force of the uplift of the Alpine Orogeny.

Returning to the quarry, we examined the unusual rock of limestone and quartz - rich in carbonate and subsidiary quartz (possibly of detrital origin). Close examination of the discarded limestone from the quarry revealed fossils. The most abundant were the foraminifera- *Alveolinidae*, but we also saw *Orbitolites* and *Miliolidae* as well as a few bivalves which were too eroded to identify. These fossils are indicative of a shallow marine environment.

Fig 2: Specimen from Millstone quarry with forams and detrital quartz

The French refer to these rocks as marno-sableuses and they form a series of intercalations between the larger massive foram-rich Minervois limestone. The fact that the deposits were a mixture of calcium carbonate and silica caused much debate as to its origins (both sediments generally indicating different depositional environments). To account for the mixing of both sediments, the catastrophists among us argued for a storm deposit, whilst the gradualists for a multiple energy environment or a diachronous deposit. However they formed, the large hard quartz bodies in the limestone provided the Languedoc area with millstones for many centuries until they were made obsolete by the superior millstone flints of La Ferté-sous-Jouarre from the Parisian region in the 19th century.

**Stop 4.5 (Guide 4.4): Minerve (43.354102, 2.745135)**

We then travelled towards Minerve, driving along by the very dry looking river-bed of Le Briant. The river, over very long periods of time, has carved out a karst landscape of very narrow canyons and gorges. The karst exposed the massive nature of the Minervois limestone which is recorded to reach heights of 50 to 80 metres.

On top of the limestones were the marine marls, an Eocene lagoonal facies, which reach a few metres thick and are used extensively for the vineyards producing Minervois wine -the other strata presumably producing an inferior soil. Thinner black carbon rich beds could be seen whilst driving, indicating the very top of the formation, a third layer of lacustrine calcareous marls with intercalations of lignite - a lake facies with freshwater snails (*Planorbe*).

From this point on we spent time exploring the medieval village of Minerve and the underlying gorge. Formerly a stronghold of the Cathars, it was destroyed by the crusader, Simon de Montfort, father of Simon de Montfort of English history, in the early 13th century. The Cathars, Christian dualists or Manichaeans, were persecuted for another hundred years before finally being eliminated by the Catholic Church in the 14th century. Little did the Cathars know that the foundation of their fortress in Minerve was built on a foram rich limestone that coincidentally records another extinction event – the Palaeocene Eocene Thermal Maximum – a mass extinction of benthic foraminifera 55 million years prior to their own.

We undoubtedly crossed the extinction event as we descended into the gorge to explore the rocks below Minerve. At the bottom, we found the river had formed a limestone cavern. Examining the rock in situ, one could see masses of foraminifera and some occasional shelly (bivalve or gastropod) material within the minimal matrix. It was a hot day and a steep climb back to the village so we didn't stay too long. We ended the day having a cooling beer in one of the local cafes.

Fig 3: Minerve with Eocene foundation from the bridge

Fig. 4: Minerve from the car park (RDR)

Resources:

Rasser, M.W., Scheibner , C., Mutti, M., (2005) A palaeoenvironmental standard section for Early Llerdian tropical carbonate factories (Corbières, France; Pyrenees, Spain). Facies (2005): 217-232

Reported by Ben Dixon and Christina Fisher

## Day 5, Friday 21st September - morning
***The Nore Massif - two traverses of this massif, through Palaeozoic sediments and Precambrian gneisses***

Hilary explained that we were going to the Nore Massif today. This is part of the Montagne Noire south of Mazamet, so we are effectively crossing the massive twice, first to the south east and south then returning in the afternoon on the west side. She also told us that this part of the trip had not been checked so some sites may not be seen and others could be new.

**Stop 5.1 (not in Guide): Old quarry near Citou (43.440722, 2.608639)**

It involved drives on scenic mountain roads up and down and along gorges. From Mazamet we drove to Lacabarède and then turned south, over gneisses and mica-schists of probable Precambrian age. We stop at an interesting looking roadside outcrop of augen gneiss dipping 54/060. This is the rock we saw on day one at location 1.1. It has the same strike but a lower dip. It is on the south side of the Mazamet fault and has intruded into the 'X schist' ( X as the age is unknown). The X schists were seen at Gorges d'Heric on day 3.

**Stop 5.2 (Guide 5.1): Old quarry on E of D620, 500m S from Citou (43.370139, 2.539056)**

We continue driving along a dry gorge and through Citou to arrive at another quarry. At the roadside were some calcareous Devonian schists showing complex deformation with open upright folds.

Fig. 1: Devonian schists showing complex deformation with open upright folds.

It was assumed that the quarry was used for extracting a massive limestone which overlay the schists. Above the north face of the limestone we could see thinner beds of a grey, fine grained sandstone, dipping away from us at about 20º. This is a Cambrian limestone that had been thrust over the Devonian limestone. It was thought that the schistosity at the base of the limestones was caused by a lower fault.

Fig 2: Thin beds of Cambrian limestone that had been thrust over the massive Devonian limestone.

**Stop 5.3 (Guide 5.2): First disused Caunes quarry (43.330972, 2.530833)**

Continuing along the road down a steep limestone gorge we go through Caunes and turn up a hill to arrive at a grey marble quarry with planes dipping 55/280. The disused Caunes quarries are in middle and upper Devonian marble, which was used for the Grand Trianon in Versailles. The presence of stylolites, which looked like wavy lines at the edge of the bedding, was pointed out to us and it was explained that these were the result of solution under pressure. There were corresponding lineations on the underside of the bedding planes. The rock appeared brecciated as a result of numerous stylolites.

Fig 3: Stylolites.

Fig 4: Lineations corresponding to the stylolites.

**Stop 5.4 (Guide 5.2): Second disused Caunes quarry (43.330972, 2.530833)**

We then walked up the hill, past a succession of sculptures in red and white marble to the quarry of red marble with irregular white patches.

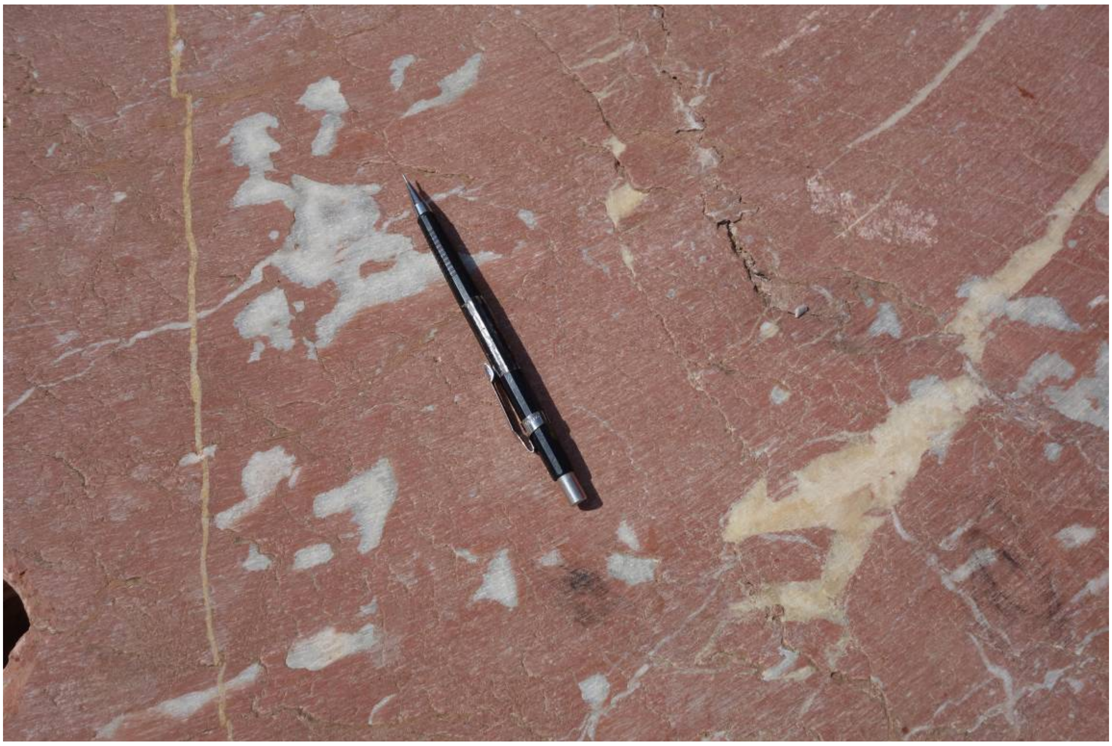


Fig 5: Red and white marble.

It was assumed that the red colouring was on account of haematite. It was noted that the crystals in the white patches were coarser and had grown inward from the red edge, so the white patches were holes which had been infilled with calcite. The holes may have been burrows or the limestone may have been a cave deposit, haematite washed in and then the holes filled with calcite.

Fig 6: Holes infilled with calcite.

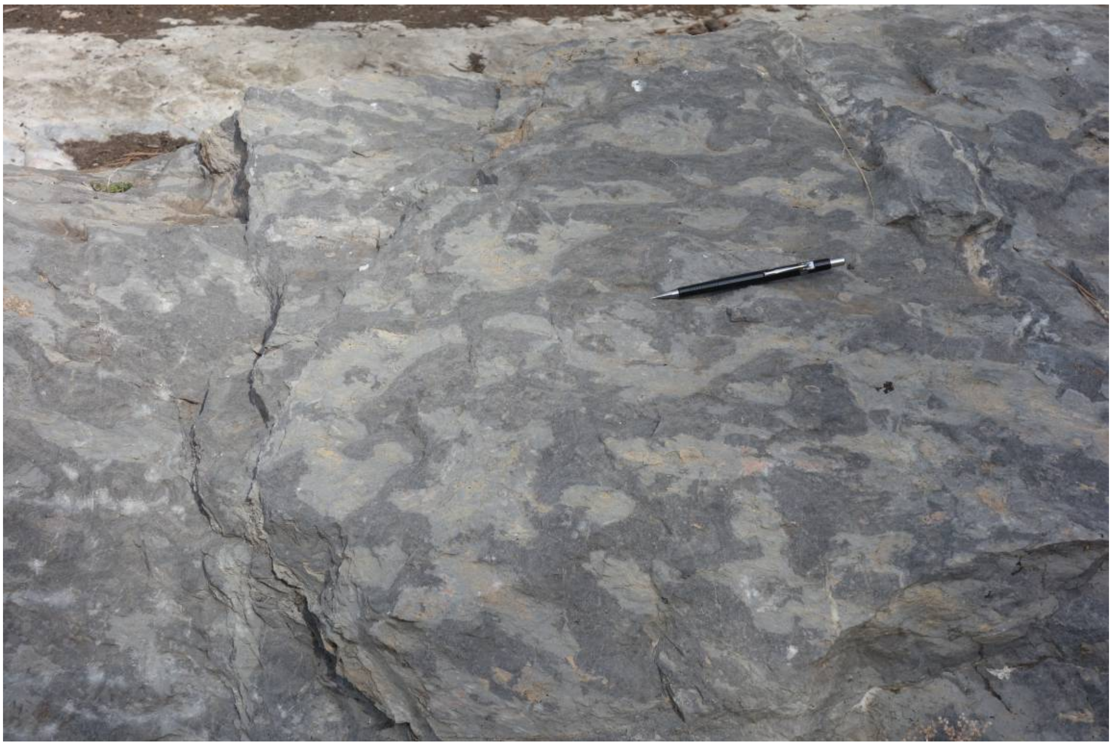


Fig 7: Shape of the 'holes' shown in the grey marble. Some crinoids were seen. The metamorphism was the result of regional metamorphism.

Reported by Helen James

**Day 5, Friday 21st September - afternoon**

The objective was to check out new locations, and fill in the gaps in the Montagne Noire story.

Coffee was taken in Caunes and the drive to stop 5.3 took us south off the Montagne Noire Massif into the Pyrenean tertiary basin (Eocene carbonates) to Villalier and then north to Conques, and then back into the Montagne Noire - Le Caroux dome axial zone - between Miraval and Les Martys

**Stop 5.5 (Guide 5.3): Quarry on the D101 between Miraval and Lacoste (43.410399, 2.324195)**

Both incompetent mica schist and a more competent gneiss were found in the quarry. The white to grey gneiss had fine grained crystals of quartz, feldspar, muscovite and biotite with small feldspar augen. The yellowish schist had a similar composition but a much larger percentage of the micas and quickly weathered both mechanically and chemically.

Fig. 1: Two-mica gneiss (RY)

Fig. 2: Schist (RY)

Three fracture planes were observed.

The rocks were mapped as part of the axial zone and the two micas in the gneiss indicated that the parent rocks were sedimentary rocks, probably shales, siltstones and dirty sandstones. While the age of the rocks could not be determined they were pre orogeny, so either early Palaeozoic or late Pre-Cambrian. These rocks have been referred to as the X-schist as the date of the precursor sedimentary rocks has not been determined.

**Stop 5.6 (not in Guide): Lac de Laprade Basse (43.424389, 2.280083)**

Guide Stop 5.4 was not located but an alternative site on the D101 near the causeway over the northern end of Lac de Laprade Basse at Laprade Basse (near Les Martys) was found.

Outcrop at the lake shoreline was a white, biotite (no muscovite), medium to coarse euhedral crystalline, non-foliated granodiorite. There were rare rounded xenoliths. Onion skinned weathering was also observed.

The granodiorite is approximately 300±34 Ma old and the lack of foliation demonstrated that it was a post tectonic intrusion and the lack of muscovite indicated that it was formed from a non-sedimentary source.

Fig. 3: Lakeside granodiorite (RY)

**Stop 5.7 (Guide 5.5): Roadside outcrop along the D56 (continuation of D101) (43.487222, 2.264028)**

Augen gneiss (probably the X-schist) similar to the gneiss seen at Guide Stop 5.3. Foliation was 65/200 (right hand rule).

Reported by Bob Rall

**Day 6, Saturday 22nd September - morning**
***Sidobre granite complex***

In the morning we visited the Sidobre Granite which is a separate intrusion on the north side of the Axial Zone. This was emplaced in the Hercynian (Variscan) about 278±13 Ma into a lozenge shaped cavity in the Cambrian shales during a period of extension. It rose but did not reach the surface until erosion of the shales eventually exposed its surface. It is possible that this took place very soon after emplacement (≈300 Ma).

The granite rocks that form this intrusion are of two types. The central part is a granodiorite, which is a granitic rock with s reduced silica content. It is essentially a rock consisting of quartz and plagioclase which are more abundant than alkali feldspar. Below the granodiorite and on its flanks, the rock is a monzonite – being sodic plagioclase and potassium feldspar with minor pyroxene and amphibole. The extent of the pluton is 15.3 km long, 6.6 km in width and probably 10 km thick. The depth of the pluton was probably 7.5 km to 20 km below the then surface of the country rock cover. The Sidobre massif, the Montagne Noire and the Massif Centrale were once part of the Hercynian mountains but now are the sole survivors.

**Stop 6.1 (not in Guide): Chaos de la Balme (43.609508, 2.391859)**

The first site visited was the “Chaos de la Balme” which is an area of woodland and granite blocks – some independent and many piled together. Water erosion along fractures in the granite caused by the Pyrenean orogeny allowed extensive weathering – especially in the hot and humid Tertiary. Water broke down minerals along the fractures and washed away the residues, leaving separated blocks of granite. Some of these remain precariously perched on other blocks (Fig. 1) while other, smaller blocks rolled down into valleys forming rivers of granite boulders (Fig. 2). Short paths led to named groups of boulders such as “Chapeau Napoleon” and “Hamburger” and to a re-created stonemason’s workshop.

Fig. 1: Chaos de la Balme - granite boulder, Napoleon's Hat

Fig. 2: River of granite boulders

The entrance to the area is through a stonemason's yard and, on our way out, the party spent a short time there looking at the various cut rocks and wondering at how the mason knew where everything was.

**Stop 6.2 (not in Guide): Plo quarry (43.606373, 2.383138)**

We then travelled to a nearby, disused quarry where we could see the depth of the weathering, from rounded boulders at the top to more irregular blocks and to weathered fissures in solid granite (Fig. 3).

Fig. 3: Plo granite quarry showing weathering and extraction

Of the quarries of the Sidobre, the Plo was the largest. This is the very large one we visited. It was once producing 150,000 tonnes of granite a year. The Champs-Elysees in Paris was paved with the stone from this quarry.

We could also see the marks left by quarrymen as they cut the blocks of solid granite. They used long iron rods, turning them and hammering on the end to make a long thin hole. This was repeated along a row and again on two other sides to define a rectangular block. Plug and feathers were then used in the holes to crack the rock along the rows. Some blocks and rods were left in the quarry. This granite was one of the most quarried in France (1/2 the total) as it was uniform in all directions – no foliation, no inclusions, same colour throughout.

Fig. 4: Drilled holes to extract a block of granite

Reported by Roger York and Ted Smith

**Stop 6.3 (not in Guide): La Maison de Sidobre (43.634329, 2.407144)**

At midday we arrived at the Espacemuseologique museum which the custodian kept open for us. Here we could see that the old techniques were still in use but using modern technologies which allowed many holes to be drilled at once, and blocks to be sawn and polished by machine. Outside a park had been created with examples of rock landscape and granite art. There were also paths leading to carved monoliths, which may or may not have been representative of original ancient stones.

After an hour we travelled to Lacrouzette where we had an excellent long lunch.

**Stop 6.4 (not in Guide): "Peyro Clabado" (43.660055, 02.364058)**

After lunch we still had time for a further visit so we then drove to visit "Peyro Clabado" (clenched nail), a perched rock but spectacular for its size and the smallness of its perch. This was also a popular place for locals and other tourists who tried to throw stones onto the top of the rock for luck.

Fig. 4: The perched rock - "Peyro Clabado"

Here our visit to France came to an end and we left Sidobre and Montagne Noire to start for Toulouse and the flight home.

Reported by Roger York

Group dinner in the hotel (RDR)

Group in the Chaos de la Balme (CF)