SPECIAL PROCEEDINGS OF THE

READING GEOLOGICAL SOCIETY

Field Visit to Chablais, France

7th – 14th September 2014

INTRODUCTION

As an active and enthusiastic group of geologists, the Reading Geological Society organises many field trips during the year. Every second year a major week long trip, usually abroad, is arranged; in 2014 the Chablais Geopark in the Haute-Savoie region of France was the destination. This area was chosen as it promised to provide not only stunning scenery but more importantly an insight into the structure of the Alps and the complex history that created them. Large structural geology with folds, faults and nappes were to be the key features to be studied, but also some classic geomorphology associated with glaciation.

Prior to the trip itself the Society prepared with a lecture from Dr Mike Streule of Imperial College. This lecture provided an overview of how the Alps were formed, the key structures found, with many superb photographs and was an excellent introduction to the area.

Carole Gregory was the key driver and organiser of the trip; she was assisted by David Ward and Dave Riley. The role of organising a trip such as this is not an easy one and involves coordinating travel, hotels and arranging for field trip leaders amongst many other tasks. Carole is to be congratulated on the smooth running of the successful trip and also for collating and editing this report.

Our hotel was one used previously by Dave Riley and proved to be a great success; comfortable rooms and excellent food.

Dr Sophie Justice, an independent geological consultant was to be our trip leader. Sophie lives and works in Chablais and was involved in the setting up of the Chablais Geopark. She has an extensive knowledge of the geological structure of the area. We were joined most days by mountain guides from the Geopark and on our visit to Chamonix by glaciologist Dr Sylvain Coutterand.

Photographs are attributed in individual reports. Diagrams throughout the report are sourced from visit handouts and various web sources; attributed where possible.

The meanings of some of the specialist geological words are explained in the Glossary at the end of the report.

Ailsa Davies, Chairman, Reading Geological Society

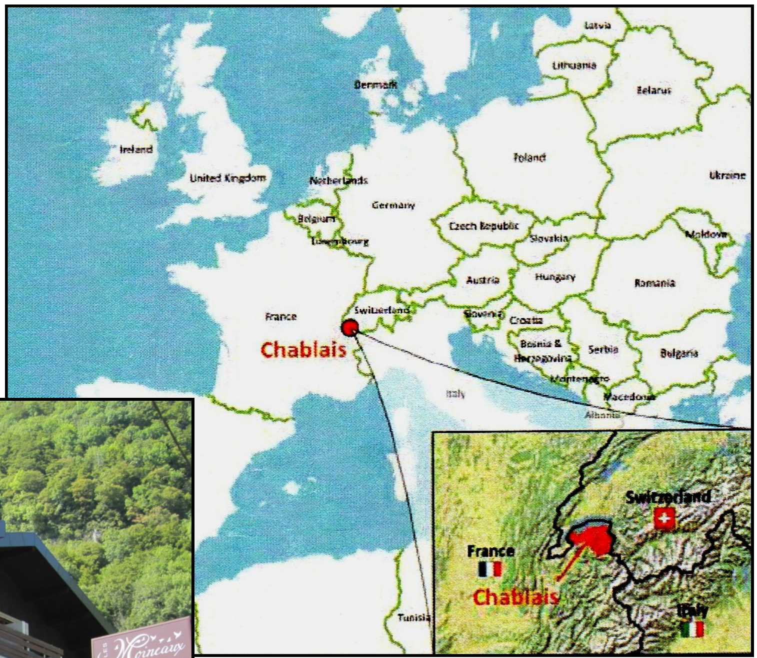
Members who attended:

Susan Barr	Ann Marriott
Barbara Barrett	Christine and Roger Moore
Ailsa Davies	David Price
Chris and Clare Fone	David Riley
Carole and Norman Gregory	Edmund Shirley
Christine Hodgson	David Ward
Hilary Jensen	Peter Worsley
Louise Knight	Roger York
Michael Ledger	

Sunday 7th September

Our trip started with an early morning flight from Heathrow to Geneva; trippers made their own way to the airport arriving between 7 and 7:30 am.

After an uneventful flight we were met at the airport by Alexandre who was to be our driver for the week. Arriving at the Les Moineaux Hotel (The Sparrows) in Bellevaux we were warmly welcomed and allocated our rooms. Bread and cheese for lunch was our first introduction to the superb food provided throughout the week. See Fig 1 for the location of Bellevaux.



With a free afternoon the group relaxed and various members took the opportunity to explore locally. One group took a walk through the village and on to the waterfall just outside. We absorbed the ambience and watched as many people, including young children, enjoyed themselves on the zip wires and climbing course in the trees.

At the waterfall there was little water and a walk back above the waterfall, through the trees, looked promising, until the ropes were spotted……

We took the path back to the village on the other side of the river, part way this group divided, with some of us crossing back over the river on an interesting covered bridge. This path took us past the village graveyard where the headstones were quite spectacular. They were very impressive and made from many types of granite and metamorphic rocks.

Back at the hotel there was swimming for those who had brought their costumes (I have been told not to mention that David Ward fell out of the shower at this point!) Kir aperitifs were provided by the hotel before a marvellous five course dinner. And so to bed in great anticipation of things to come…………

Report by Ailsa Davies, photo Dave Riley

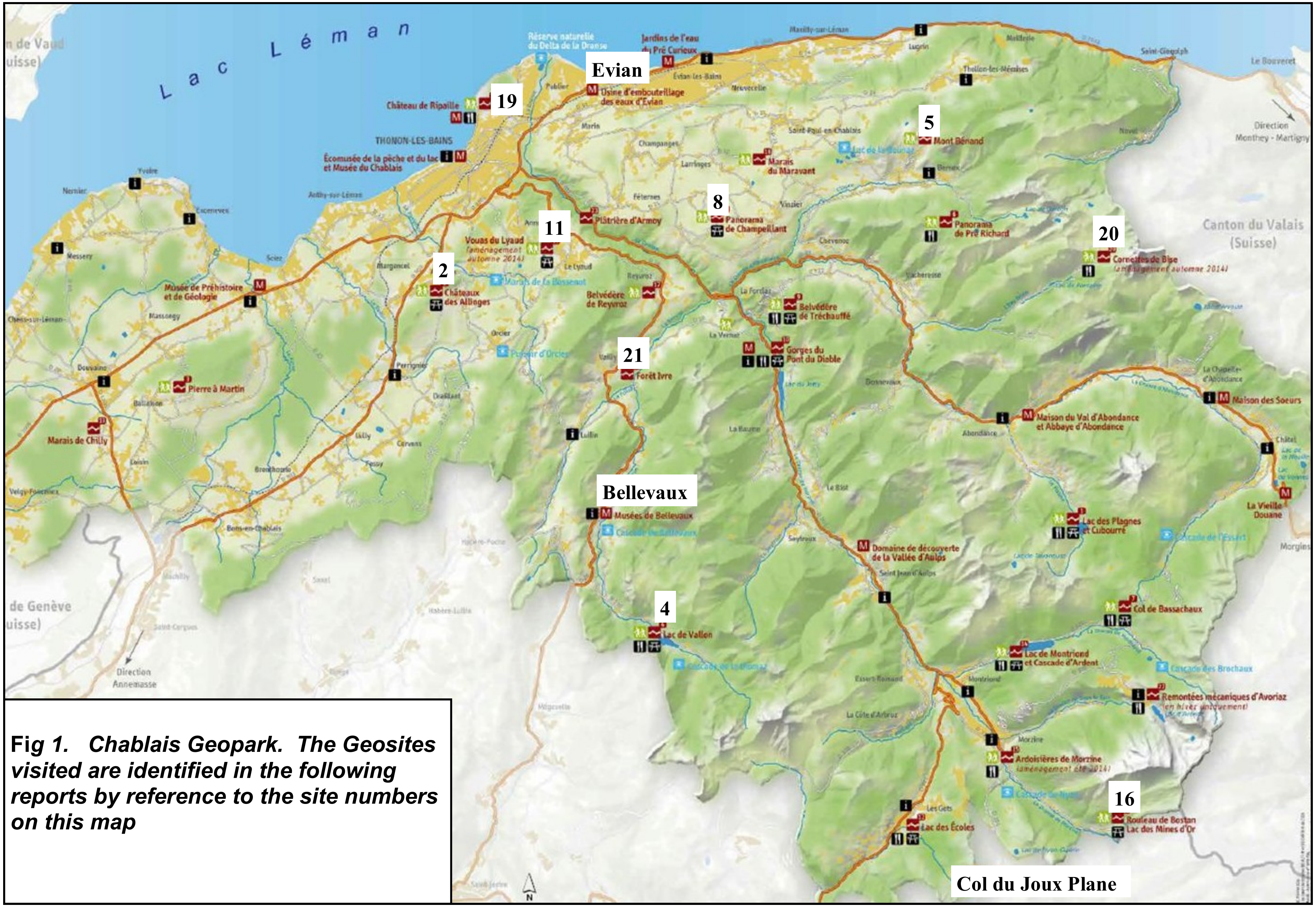


Fig 1. ***Chablais Geopark. The Geosites visited are identified in the following reports by reference to the site numbers on this map***

Fig 2 Chablais geology

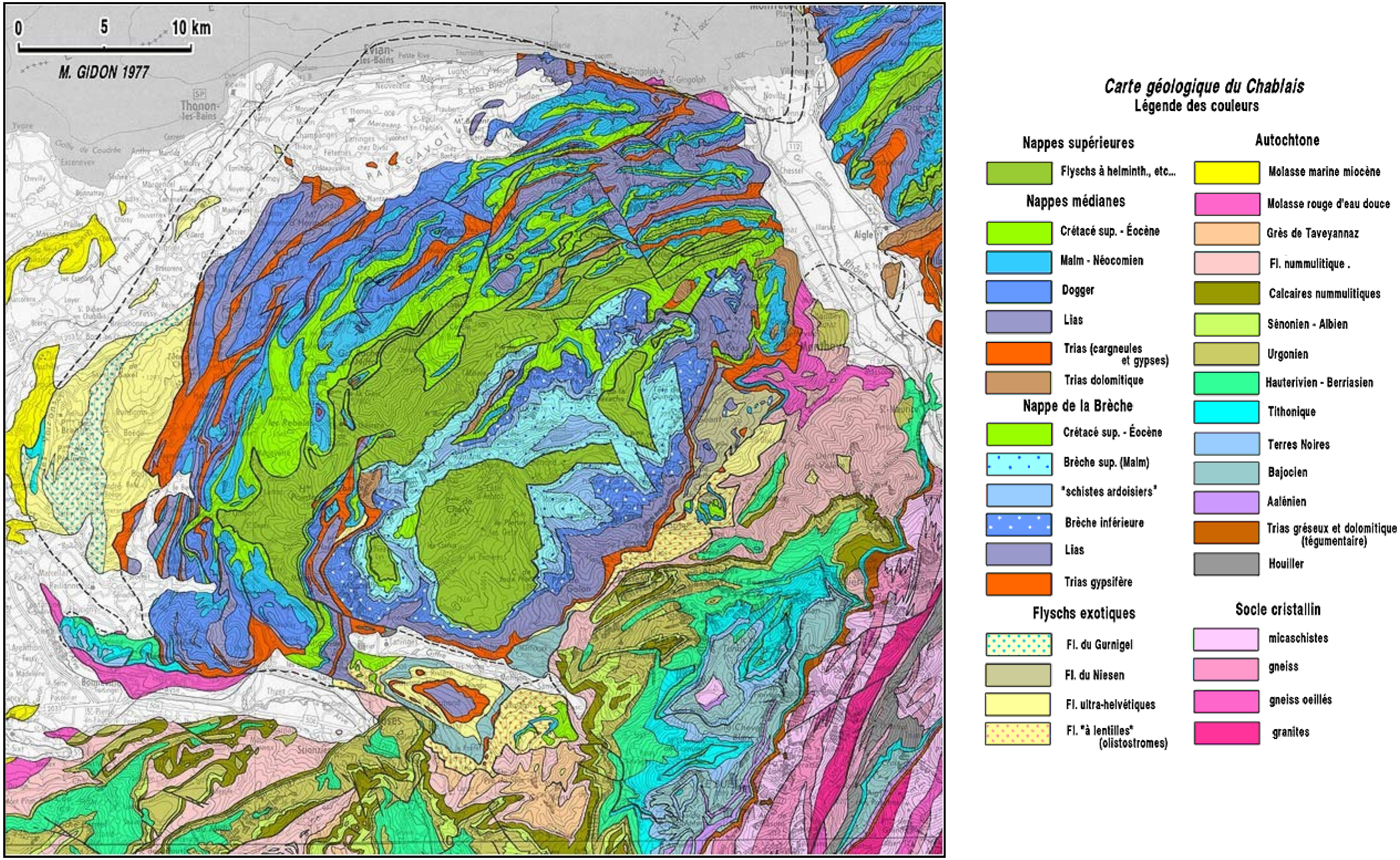
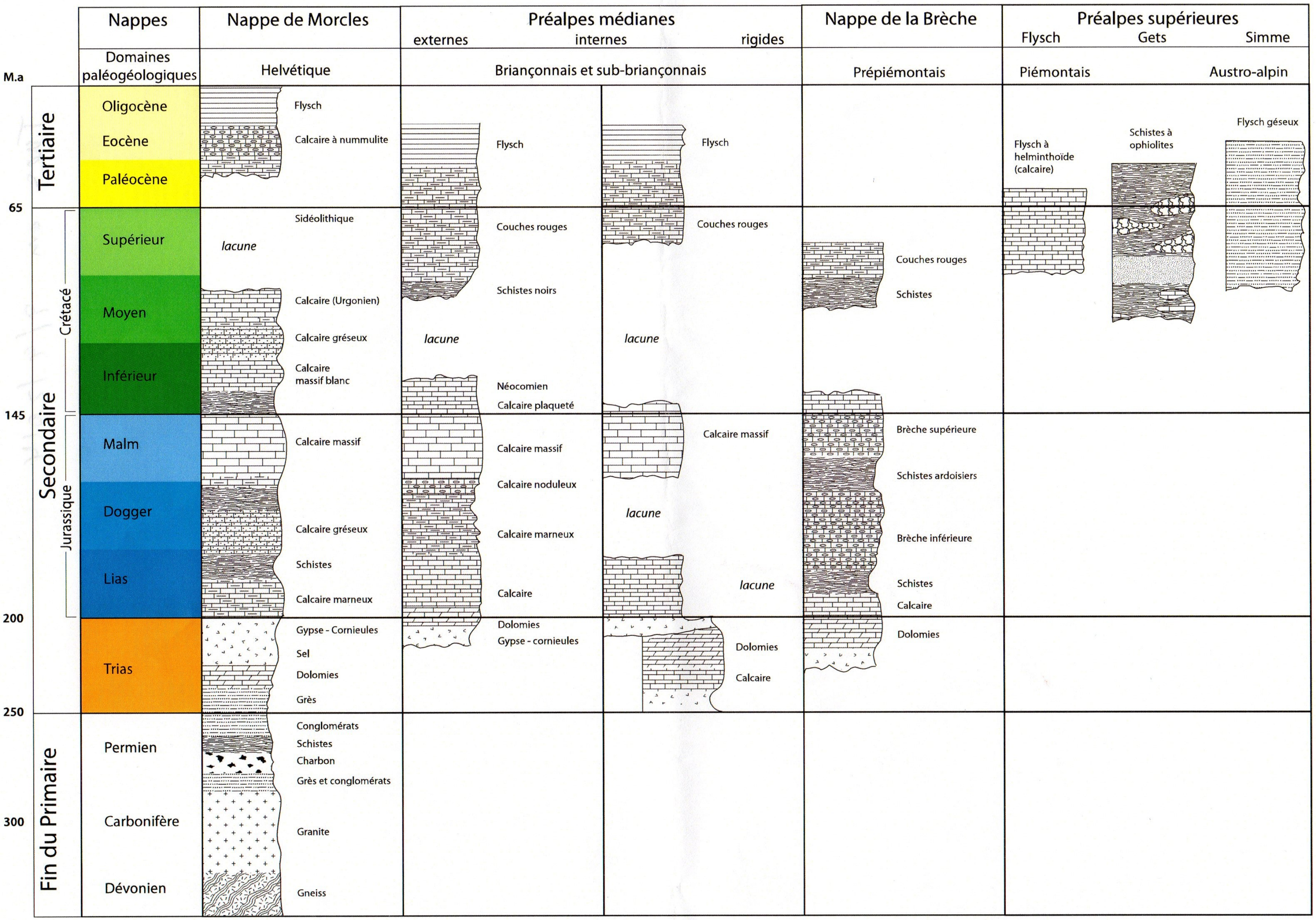


Fig 3 Colonnes stratigraphiques de l'histoire Téthysienne du Chablais



Monday Morning 8th September

Leader– Dr Sophie Justice

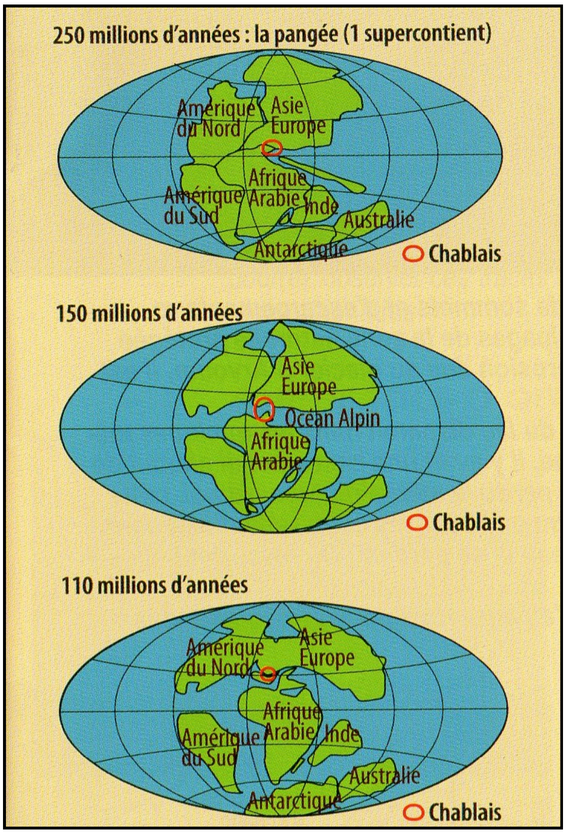
Our leader for the week was Dr Sophie Justice, who is a consultant structural geologist resident in the Chablais region. Sophie started the Monday excursion by giving an overview of the Chablais Geopark. The latter was instituted in 2012, with the aim of tying the geology of the region into all other aspects of the region which might be of interest to visitors. The Geopark organization has several permanent employees, but has no legal powers to protect the environment (compare this to our own National Parks); however it is active in 23 separate locations, where it provides visitors with information. Skiing and winter sports are the greatest employers, but there is a push to develop green (or "alternative") tourism throughout the year. Currently tourism provides 70% of the area's economy. Sophie pointed out that although the area is a mountainous one, it has a high population due to the settlements along the banks of Lac Léman. Other major employers are the hospitals and the mineral water bottlers.

Geosite 8 Champeillant, Plateau de Gavot

Our first stop was Champeillant on the Plateau de Gavot, high above Evian and with stunning views both of Lac Léman and of the surrounding mountains. Sophie began by outlining the main geological features which we would see during the field visits. The week would cover the period 230 Ma to a mere 50 ya. Within 50 km there is a complete record of the thrust pack of the Alps. The area was important in the development of geological theories within the nineteenth century, especially relating to thrust and tectonics, as well as quaternary processes relating to glaciation (including the succession of glaciations). We were warned of the difficulties of finding outcrops, because agriculture is being abandoned as inhabitants turn to other income sources, resulting in increasing forest cover.

The formation of the Alps started with the breakup of the super-continent Pangea. Crustal extensions in the Triassic period resulted in rifting and deposits of evaporites; however from their exceptional thickness, it is suggested that the deposits of gypsum and anhydrite may be older. In the Lower Jurassic, the Tethys (Alpin) Ocean was opening which is evidenced by the existence of pillow lavas, although the remains are largely limestones and shales. Recent studies give the width of Tethys as 500-1000 km measured north - south. This opening was linked to the formation of the central Atlantic, which pushed the proto-African continental plate to the east.

During the Upper Cretaceous the Valais Ocean formed as the Iberian micro-continent broke away from the European plate. There were the first signs of subduction, when the North Atlantic began to open. The subduction rate is estimated to be 1.5cm / year and was linked to the opening of Biscay.



Later subduction in the Eocene largely consumed the ocean, and the Briançonnais island accreted.

During the Lower Oligocene a full collision between Africa and Europe formed the Pre-Alps as a result of a succession of thrusts, and a slowdown of subduction to 0.2 cm/year. In the Upper Oligocene the Alps were still low, but the subducting slab broke off and fell away, resulting in rising land levels; Mont Blanc itself was not formed until about 5 Ma.

Group at information boards with southern view towards Mont Blanc from Plateau de Gavot

To the south is Mont Blanc (although not clearly visible during our visit) and to the north the Jura mountains. The Chablais is an allochthonous stack of sediments, the source of which was well south of Mont Blanc.

Starting in the north and moving progressively east and south, Sophie described the landscape and the rocks.

- The Jurassic limestone Jura mountains were structurally deformed 3 – 5 Ma and have been little eroded.
- Lac Léman is a piggy back basin underlain by an autochthonous molasse, the eroded and consolidated remains of the rising Alps, and 20-30 Ma.
- Fine-grained marine shales, known locally as Flysch, were the first to be deposited as the mountain chain emerged.
- The Helvetic Alps are largely autochthonous and haven't moved for 230 Ma; they are a marine deposit made up of mixed marls, limestones and shales from Mont Blanc.
- The Penninic Alps were formed 540-400 Ma, and the Mont Blanc granite has been dated as 303±5 Ma.

Sophie then turned to the immediate vicinity and the Gavot plateau. Beneath us were glacial deposits formed when the glaciers melted about 12 ka, overlying the nappe des Préalpes. The Rhône glacier filled the whole Rhône valley 40 ka, and at its maximum extent, 50 ka, almost reached Lyon. On its retreat it left an impermeable moraine layer. A later advance 30-27 ka, only reached Geneva. It was followed by 13 separate advances and retreats, which compacted the earlier moraine deposit. This left layers of lacustrine sands and silts and glacial moraine to a depth of about 200 m above this moraine. Water destined to be extracted at Evian circulated in these deposits, and is protected from the underlying nappes by the intermediate compacted moraine layer. This will be discussed further in the afternoon report.

Geosite 5 Mont Bénand, Bernex

Our next stop was Geosite Mont Bénand where we embarked on a circular walk around the hill top. Bénand is a mountain surrounded by, and covered by, a glacial moraine. To the east, there are two neighbouring mountains which project out of the moraine levels - Montagne des Mémises and Mont César. All three mountains are part of the same sub strata unit, although faulting between them (described later) has differentiated their geology. Both Mont Bénand and Mont César have been very heavily fractured but Mont Bénand has suffered much greater collapse than Mont César. Consequently it has been covered entirely by the glacial moraine, hence it's lower rounded shape. This range was the frontal lobe of a syncline with its axis about 0.5 km south of the visible ridge.

Here the group stopped to admire the view and enjoy lunch in the sunshine

Mont Bénand looking north to Lac Léman and Jura mountains.

Report by Edmund Shirley, photos Edmund Shirley and Norman Gregory

Monday Afternoon September 8th

Leader - Dr Sophie Justice

Geosite 5 Mont Bénand (continued)

After our picnic lunch in a field near the top of Mont Bénand in glorious sunshine. Peter Worsley noticed a circular dip in an adjacent field, of about 20 m diameter and proposed this was the remains of a ‘kettle lake’ from ice dissolution in the most recent glaciation.

Outwash fan (centre) and kettle hole (right)

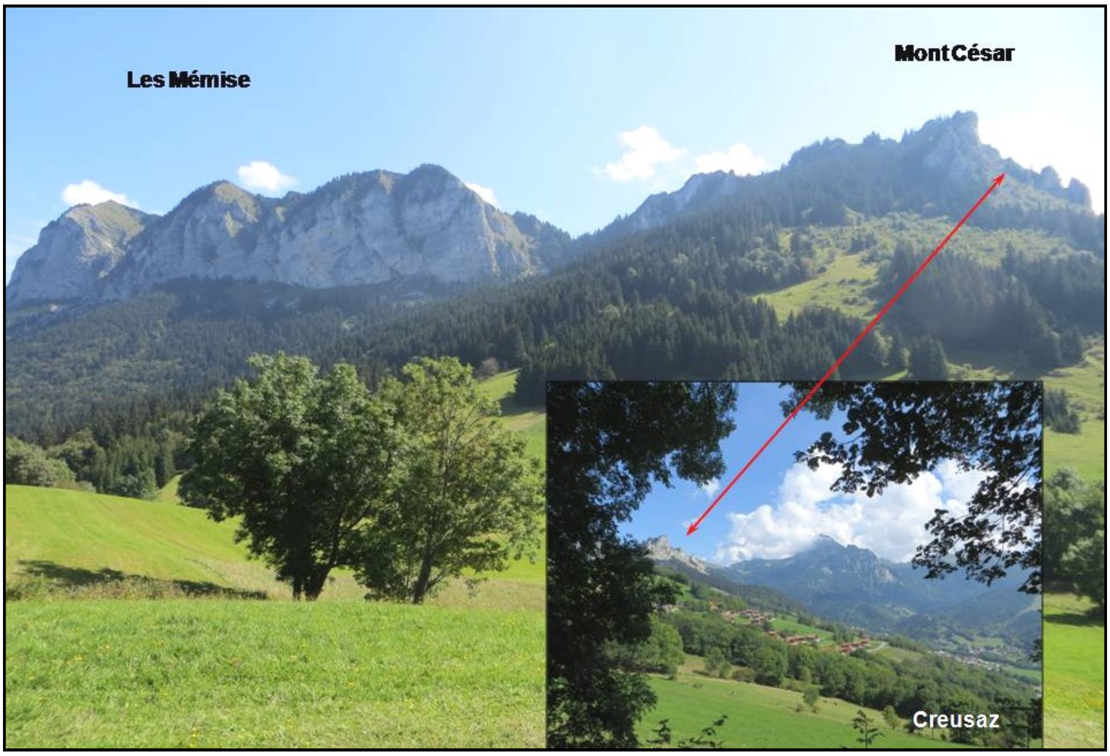
Rejoining the path around Mont Bénand we stopped to review the faulting in the adjacent Mémise mountains. The faulting had occurred contemporaneously with the folding, post Oligocene. This had faulted the syncline primarily with strike-slip faults at a right angle to its axis in northwest/ southeast and north/south directions.

Mémise range

These faults were quite visible in the northern flank of the Mémise syncline. Between the Mémise and Mont César a widespread and larger normal fault had occurred which was visible as a bealach between the two mountains. Another strike-slip fault separated Mont Bénand from Mont César but this was not visible as the area was covered with moraine deposits.

Mont César had unfortunately suffered an excessive level of faulting and as the Upper limestone rests on the more unstable Middle Jurassic marl limestone, it is prone to slippage. Massive blocks could be seen in the process of slipping down the hillside, making the area dangerous for climbers and creating concern for the village of Creusaz below.

Mémise & César



After a short distance we had a wider view of Lac Léman downslope to the north. Sophie explained that there had always been a basin between the Chablais and the Jura Mountains but glaciers, particularly in the last glaciations, had taken advantage of this and carved a deeper valley. During glacial periods the Rhône glacier flowed northwest from Martigny toward Montreux, at the current easterly point of Lac Léman, where it split into two directions (see Fig 4 and 5). One forked northeast toward Berne and the other west, following the southerly flanks of the Jura.

In the Riss glaciations (equivalent to the UK Wolstonian) the Rhône glacier reached as far as 70 km west of Geneva and the outwash emptied into a large lake south of Dijon which in turn emptied northwards into the Rhine.

It is believed that in the last glaciation (the Würm, equivalent to the UK Devensian), the Rhône glacier followed the same route but had not extended as far west of Geneva and its outwash was diverted south.

Today the Rhône river flows toward Lyon where it turns southwards and exits into the Mediterranean. The reason for the diversion is controversial. One view is that there was a tectonic rise in the north, another, that the glacial lake level in the Würm was lower and as a moraine from the earlier Riss could not be exceeded, the river took an easier route south.

Lac Léman is the valley carved by these successive glacial advance and retreats of the western Rhône glacier. At its deepest the lake is 310 m deep, being about 60 m above sea level (masl) at this lowest point.

Fig 4

Glaciation Würm

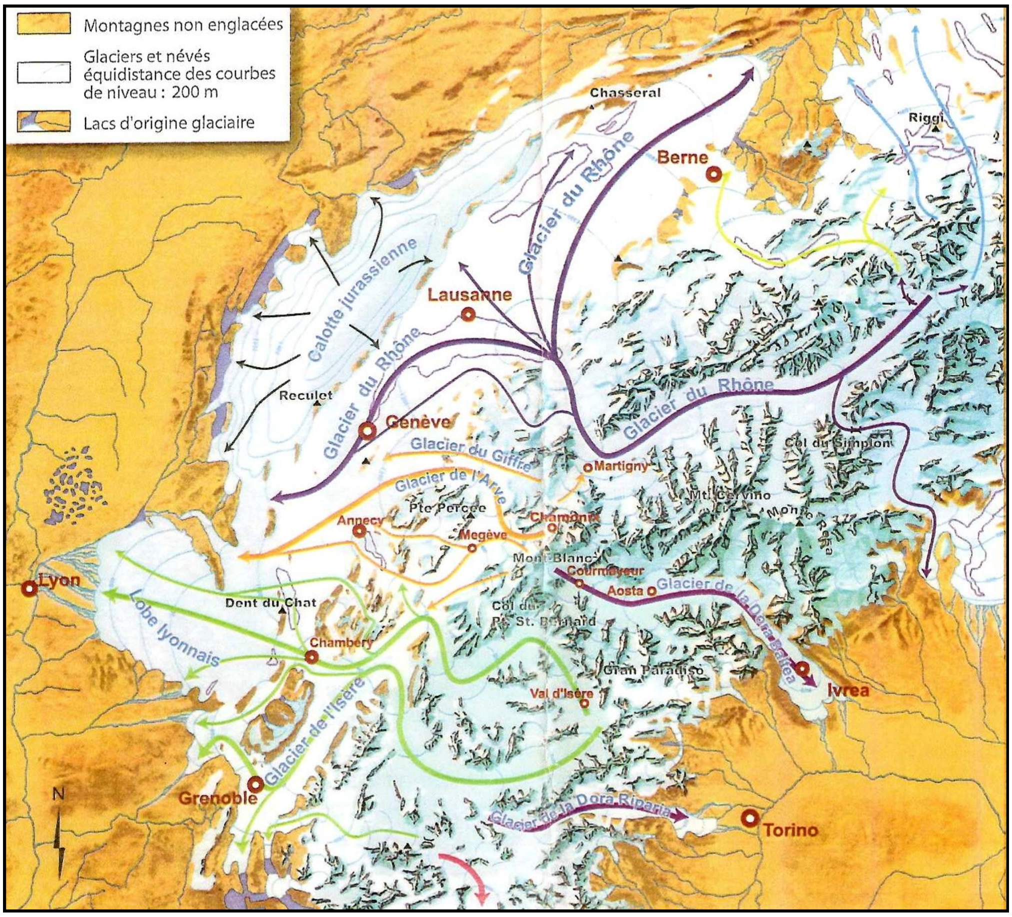


Fig 5

Extent of glacier 37 ka to 27 ka

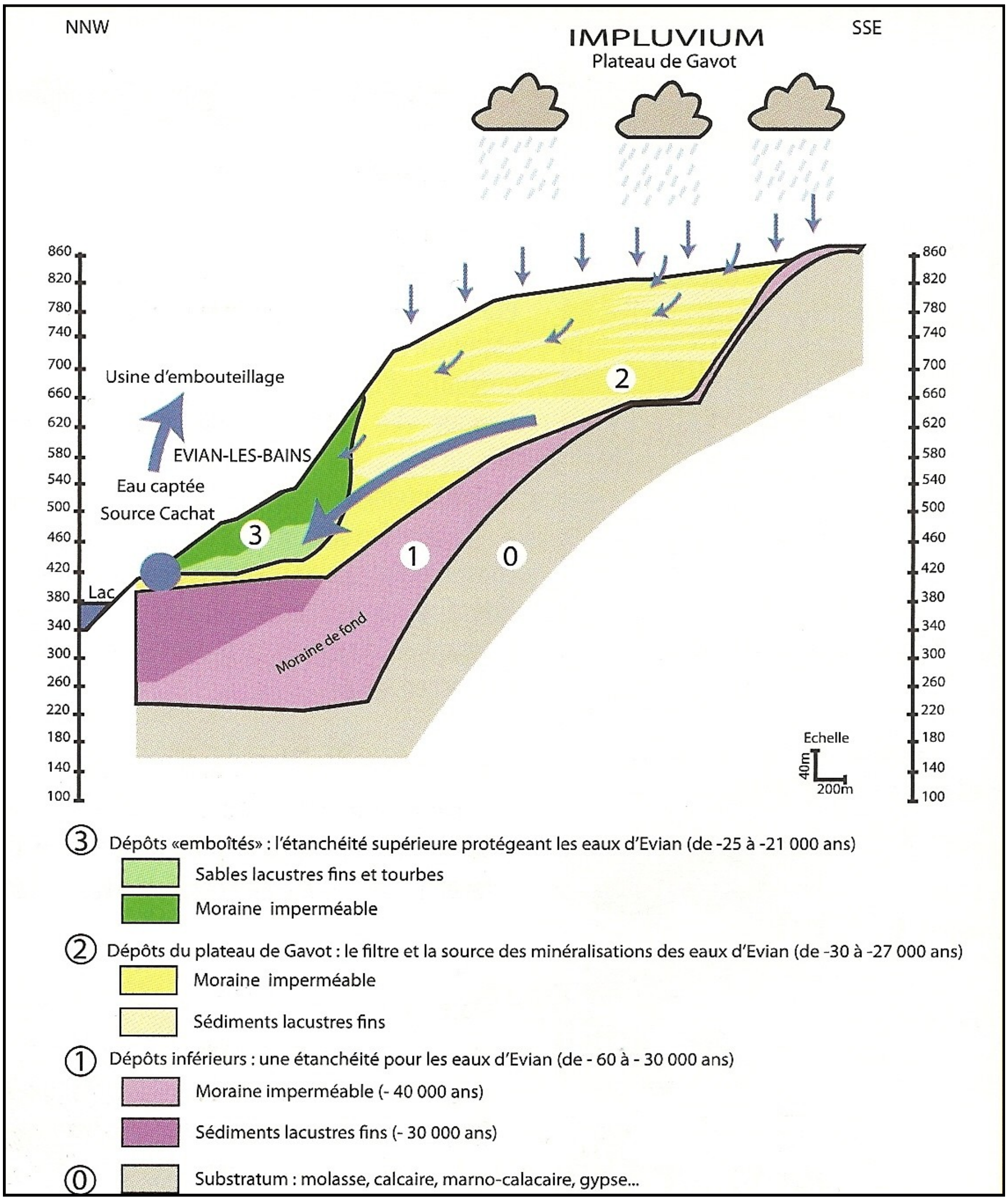
To our west the drainage into the lake from the Gavot Plateau was discussed. The plateau is about 850 masl and in its upper part consists typically of a 200 m thick layered sequences of lacustrine and glacial moraine deposits from various advances and retreats of the glacier front (30 ka to 27 ka) sealed from further gravimetric permeation by an earlier impermeable moraine layer (60 ka to 30 ka). Constrained by this moraine layer the water flows north until it is gathered in an aquifer close to Lac Léman. This aquifer is a later but similar sequence with the base sealed by a moraine deposit from about 25 ka.

The aquifer water appears at the surface near the lake at Evian in the form of springs and is the source of the famous natural spring water of Evian that the group were due to see during our visit to the bottling factory later in the afternoon.

Sophie explained that hydrological research in the area of Mont Bénand, however, had shown a different water drainage path. Rather than following the gravimetric route into the lake northwards, as occurred in the Gavot plateau to the west, rainwater on Mont Bénand was found to surface near the lake some distance to the east. This was thought to be caused by heavy west/east faulting in the local underlying structure, thus supporting the view that Evian water is sourced from an isolated plateau area.

Fig 6

Cross section of Evian aquifer

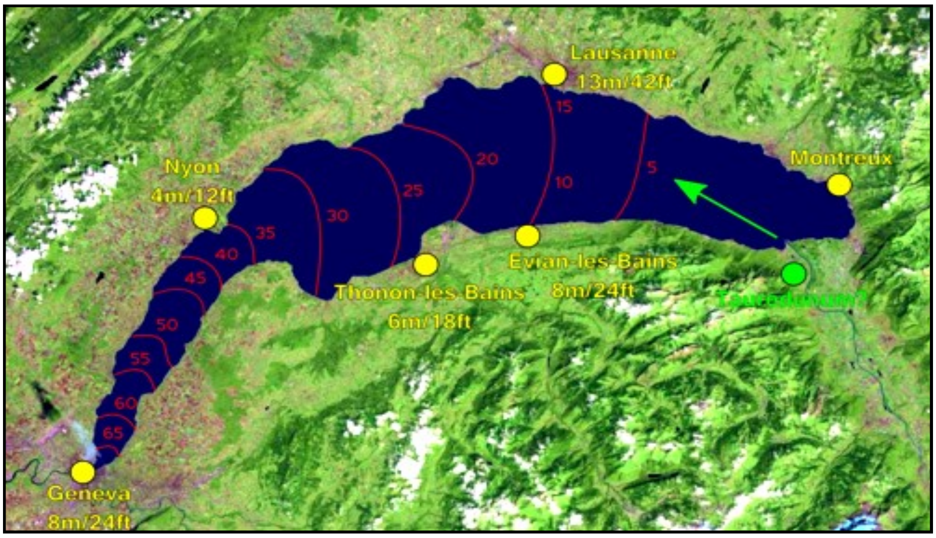


During the next stage of our circular walk the group were asked to look out for unusual boulders adjacent to the path as these were likely to be erratics carried by the Rhône glacier. At one point we witnessed a gneiss boulder, about 1 – 1.5 m dia, which had apparently travelled from an area in Switzerland, some distance to the southeast.

Further down the path we stopped at an information board recording the background of a tsunami in Lac Léman. In 563 BC a massive rock fall of about 20 M tons occurred at a location chronicled as Tauredunum, near the deltaic exit of the Rhône glacial water into Lac Léman. Tauredunum is now believed to be Mont Grammont. The vibration from the rock fall caused a large volume of sediments from the front of the delta (estimated to be 30 to 40 M tons) to slump into the lake, which in turn produced a tsunami. This wave travelled the length of the lake in a period of 70 min. The wave was estimated to be 8 m at Evian, dropping to 3 m in the deeper area of the lake and finally growing in the narrower, shallower western end to 8 m when it hit Geneva. It is believed that 100's of people perished in the city of Geneva

Fig 7

Lac Léman tsunami



We then continued on the walk, reaching a wooded area which gave us some relief from the burning sun. At the exit of the wood the group further discussed the hydrology of the region prior to the visit to the Evian Bottling factory. Sophie said that the average rainfall over the Gavot plateau was 1200 mm/y. It had been estimated that only 700 mm/y was required to recharge the current aquifer at Evian. The final stage of the walk was through the village of Creusaz to the coach which then took us to the Evian Bottling Factory in Evian-les-Bains.

Visit to Evian Bottling Factory

The group were met by the factory guide, Aude. She explained that Evian is part of the Danone organisation; the factory covers an area the size of 10 football pitches, employs about 1000 people and is in a major stage of process improvement. The current capacity of the plant is 6 million bottles daily which is exported world-wide. The discovery of Evian's mineral water dates from 1790, when a visiting nobleman, Jean-Charles de Laizer, having drunk from a spring in the grounds of his friend, Monsieur Cachat, recovered from an illness. This developed into a global business exporting the Natural Mineral Water sourced from the Cachat spring.

The water filters down from the Gavot plateau over a period of 15 to 40 years, absorbing Calcium, Magnesium and Bicarbonate minerals from the lacustrine and glacial sediments. The natural spring water is accessed by the bottling plant from adjacent wells drilled over 25 m deep and exits at a temperature of 11.6 ^{o}C. Aude presented us with complementary bottles of Evian water and escorted us through a display area which recorded the history of the Evian factory. We then were guided along viewing platforms to witness the processes of producing the PET bottles, their filling and final packaging.

Fig 8

Report by Chris and Clare Fone, Photos by Chris and Clare Fone and Hilary Jensen

Tuesday Morning 9th September

Leader - Dr. Sophie Justice with M. Patrick Guilhot

Geosite 16 Rouleau de Bossetan, Morzine

The second excursion took the group to the Rouleau de Bossetan geosite, near Morzine, in the far southeast of the Geopark on the Swiss border. We were accompanied by mountain guide Patrick Guilhot.

We disembarked the coach and walked a short distance to the plateau of Le Lac des Mines d'Or. A rubble pile of slatey material explained the lake's name. Morzine miners excavated roofing material from overhanging cliffs, bringing prosperity to the town. This local 'slate' was known as grey gold, and this recently built reservoir was named accordingly.

Standing on the plateau, the fine views in clear weather enabled Sophie to further explain the geography and geological history of the Chablais. Landmark features were identified and orientation established. An excellent handout described the later history of the Tethys Ocean explaining the sequence, provenance and facies of the nappes responsible for the geology and landscape of the Chablais.

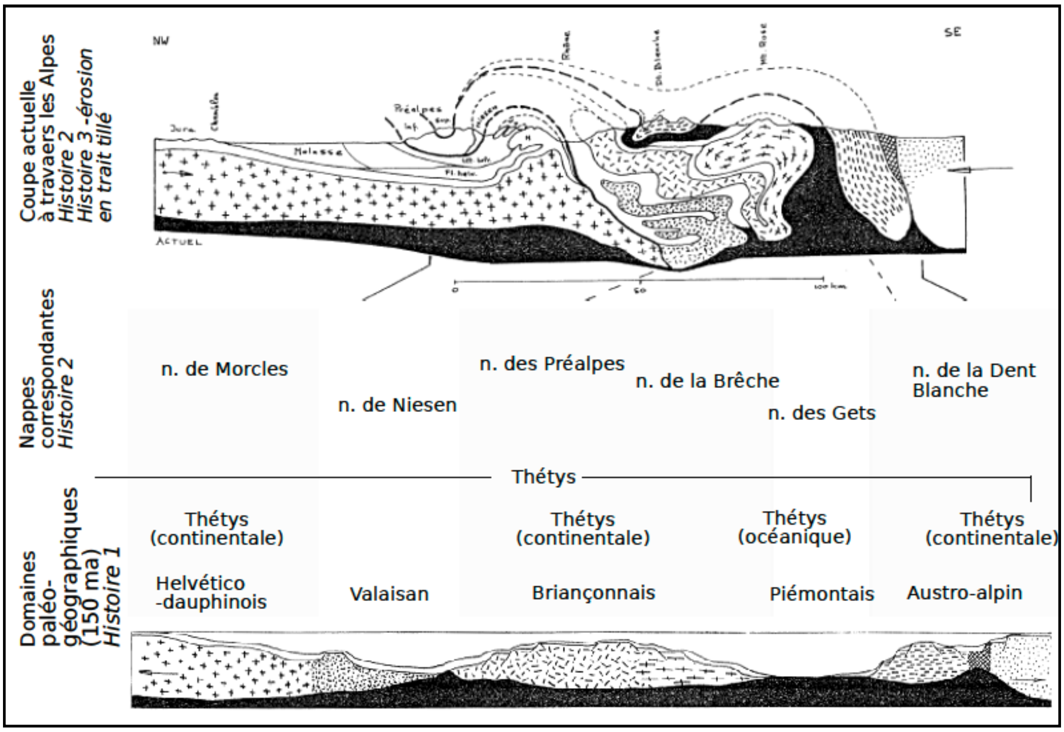


Fig 9 Formation of Western Alps

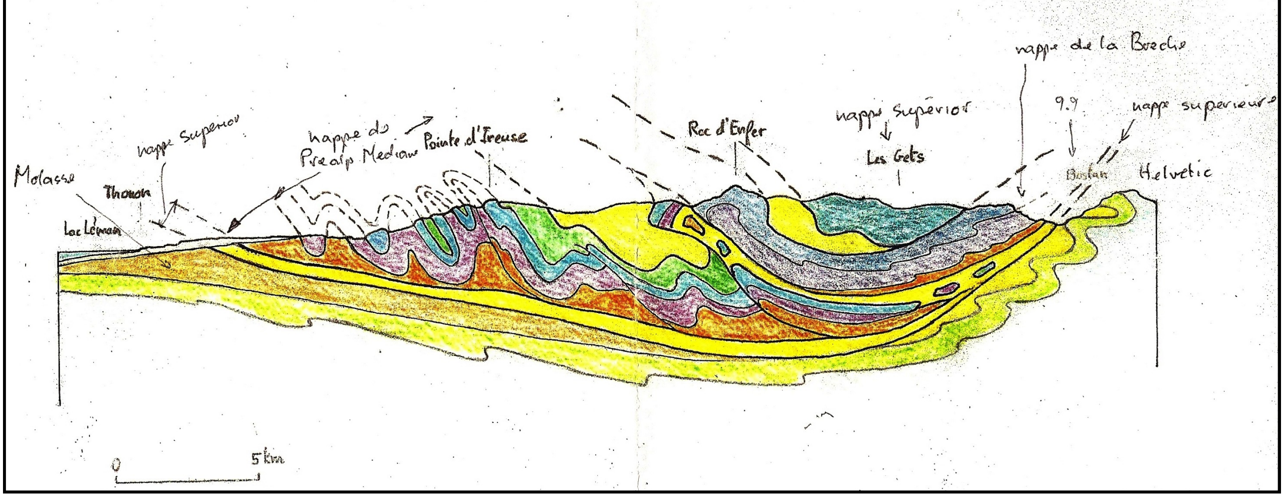
This area underwent subsequent erosion almost to sea level. However final continental collision around 5 Ma caused great uplift, and today after more erosion we see into these nappes (and the Mont Blanc Massif as it was 350 Ma).

In the Cretaceous tectonic forces initiated subduction of the European plate and an accretionary wedge formed, which with ocean floor material slumping and reworking, caused olistostromes. Movement of the later Cretaceous marine shales and mid-ocean lavas produced extensive conglomerates. Continuing tectonic movement lead to immense compression which, with gravity slide across the underlying Trias gypsum, thrust sequences of rock great distances to the northwest. (Mont Blanc, Mont de Gothard etc, were not then at their present height). The origins of individual nappes have been determined by matching back the facies.

Specifically for the nappes of the Préalpes area the following is envisaged:

In repeated thrusts, the Briançonnais and Sub-briançonnais gave rise to the Préalpes Médianes; the Prépiémontais was then transported to become the overlapping (and interleaving) Nappe de la Brèche. From the Piémontais came the overlaying Nappe Supérieure, the base of which is the Nappe du Gurnigel. This lies as a very shallow bowl, in which the Nappe Flysch à Helmintoïde, Nappe de les Gets and Nappe de la Simme (the latter the most travelled – Austro-alpin from Davos area) are incorporated together with interleaved Nappe de la Brèche – supérieure and inférieure. All the above mentioned are allochthonous nappes (exotics and can be described as 'rootless mountains'). The Helvetic Nappe results from local rock and is autochthonous. The stratigraphic column (Fig 3) supplied for the Nappe de Morcles, goes back to Devonian gneiss with no Trias break.

Fig 10 Cross section of Western Alps to south of Lac Léman

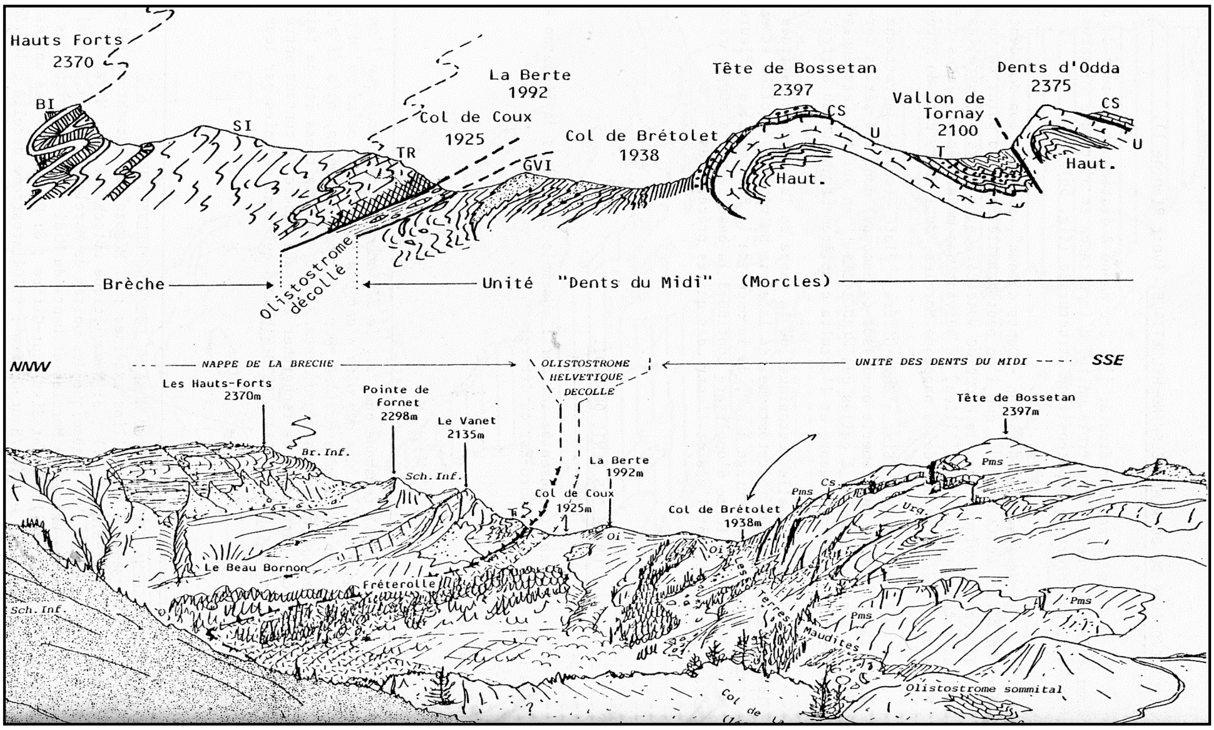


The group were standing on Nappe de la Brèche in a well vegetated area. This extends laterally in an immense thickness. Here was seen the rugged unstructured high ground consisting of this coarse sediment – the molasse conglomerate. Fortunately a road cutting en route had exposed the bedrock of this clast supported conglomerate and we were able to examine this in more detail (see photo right).

To the north, some of the Nappe des Préalpes Médianes was visible. This stretches from Bonneville in an arc past the eastern shore of Lac Léman. Beyond but not visible, Nappe du Gurnigel is exposed in a narrow band. In the south of the Geopark, the Préalpes Supérieures, Nappe de Les Gets and Nappe de la Simme are to the east of Morzine with Nappe de Flysch à Helminthoide to the northwest.

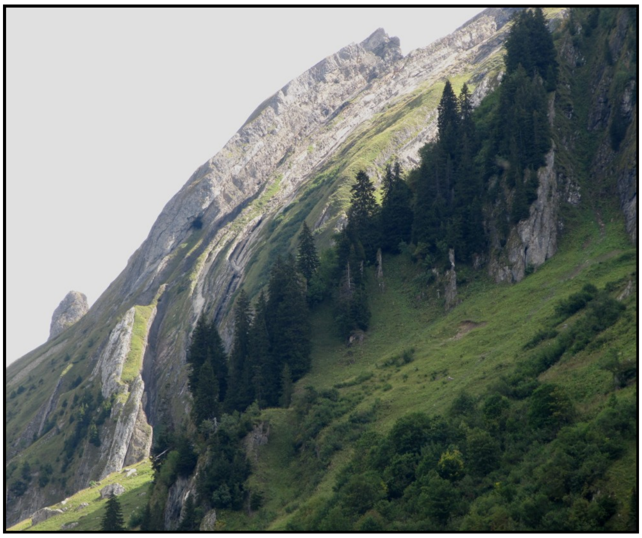
A handout showing the view and cross section of the front of the Helvetic Nappe (Fig 11) settled us into the landscape and looking at this overall picture, the group agreed that the name Rouleau de Bossetan was most appropriate. With the large scale onion skin weathering, it resembled an eroded Swiss Roll!

Fig 11 View and cross section of the front of the Helvetic Nappe



Helvetic Nappe and Rouleau de Bossetan (right)

The folding of the beds below is very apparent in the clean rockfaces of les Terres Maudites; Maudite translates as cursed or blasted.



This small area does not typify the geology of the whole Chablais Geopark. Although the rocks here derive from the Tethys they are largely limestones which formed in shallow waters on the margin of the later Alpine Ocean cover here (see Nappe de Morcles stratigraphy -Fig 3).

The first part of our trek up the mountain remained dry as we crossed ferruginous limestone beds with occasional ‘box iron’ inclusions. We walked over a fluviatile conglomerate and inspected a glauconitic sandy limestone, only faintly green (Upper/Lower Cretaceous). Further on a sample of dolomitic limestone was found, believed to be diagenetic alteration. The massive limestones in the area contain rudistids, corals and bivalves as reported in the literature. Here our guide has only found broken fossil specimens from a condensed Cretaceous band (ammonites and gastropods).

We climbed higher up onto the hay meadows very carefully, as the previous wet weather had left the muddy limestone path very slippery. Here the summer grazing was almost ending, with now deserted, summer farm dwellings around. The only noise distant thunder. This part of the country was once a smugglers’ route, now only the birds still migrate across.

There were good exposures of limestone pavement. Loose blocks of fine nummulitic limestone were examined, close-packed with nummulite specimens 4-6mm across, in good preservation with the granules showing the radiating pillars of calcite. These Cenozoic foraminiferida were surface dwelling and show that the average surface temperature of the water was between 22 and 30 degrees – as found in Tropical and into Southern Subtropical waters.

Sophie and the group looking for Nummulites

The trek had taken us up on an Eocene/Oligocene route. The roadway down gave wonderful views of the Lower Cretaceous massive limestones of the Terre de Maudites and the Upper Cretaceous onion-skin weathered Rouleau de Bossetan. For the last part we were able to use a tiny part of the long distance GR5 (Holland to Nice) path and avoid being caught in a mountain storm.

Report by Christine Hodgson, Photos by Christine Hodgson and Chris Fone

Tuesday Afternoon 9th September

Leader - Dr. Sophie Justice

Col du Joux Plane

We arrived at Col du Joux Plane near to the mountain summit and beside a clear lake to continue our study of the principal Nappes of Chablais. Here we will be looking at the Nappe Supérieure (Nappe des Gets) and the Nappe de la Brèche. The plan was to further study their structure and stratigraphy. In particular, we were going to examine the ophiolitic olistostrome exposed here.

On reaching the top of the Col, the increasing rain and mist caused us to stay on the low ground by the lake. We looked first at the hill behind us, where the contact between the volcanic rocks, resting on the Nappe des Gets, and the sediments of the Nappe de la Brèche, runs horizontally across the hillside. Although it was not possible to climb up the hill we were able to examine the rock on the ground, where many metre sized blocks had fallen. The big question of the day, was what is the ophiolitic olistostrome, why is it here and how did it get here?

As the oceanic European plate was being subducted under the continental North African plate, the lighter seafloor deposits were being scraped up along with oceanic crust and upper mantle rocks – the ophiolite. This seafloor ophiolite is a mix of sediments and volcanic rocks. It is an isolated outcrop and is the remains of the Neo-Tethyan ocean floor that was once 300 kilometres wide and separated the European plate margin from the North African plate margin. It is all that is left of the Mid Ocean Ridge (MOR) rocks, originally brown shales and mudstones mixed with igneous rocks, including pillow lavas, dykes and sills. An accretionary prism was formed, into which boulders and other eroded sediments fell. This rock, including debris from the upheaval and subsequent deposition, is the olistostrome.

The ophiolite deposit has been altered by Barovian low grade metamorphism of rising temperature and pressure, possibly resulting in mineral alteration to Greenschist Facies, which has overprinted much of the Westem Alps. The ophiolite suite contains mafic and ultramafic rocks such as basalt, dolerite dykes and sills and peridotite, containing minerals such as pyroxene, biotite and augite. It also contains associated pelagic sediments which have metamorphosed to the mineral Stilpnomelane, which is a sheet silicate mineral and belongs to the family of phyllosilicate minerals. The predominant chlorite mineral in the volcanics (replacing the augite) gives the rock a greenish hue. They show distortion and fracturing due to the upheaval processes and are known locally as 'Roches Vert'

In the Paleocene, as the African plate converged with the European plate, it forced a major thrust - the Helvétic Thrust - between the Nappe de la Brèche (the subducting plate) and the Nappe des Gets (the overriding plate). Consequently both nappes have been tightly folded and have suffered compression and deformation, as we see in the Alpine mountain chain today.

Magma resulting from the melting of the subducting slab was subsequently erupted and overlays the olistostrome, but was not seen.

The group spent some time examining the fallen blocks and identifying the small pillow lavas within some of them. These pillow lavas showed distortion and a high degree of fracturing, with possible alteration around their edges due to the uplifting forces. Greenshist facies and xenoliths of country rock were also seen in the scattered boulders.

An examination of the rocks

revealed the ophiolite (below left)

and xenoliths of country rock in the volcanics (below right).

To the north is the Northern Alpine Front Thrust, which is on the southern edge of the lost Piemont Ocean; Chablais is the "island" between this and the Helvétic Thrust. Le Col de Joux Plane lies at the southern end of this Chablais “island".

If the weather had been better and we had been able to climb to the top of the hill, the view across the Ophiolitic deposit at the top of the mountain, displaying the tremendous forces that were needed to form these structures, would have been nice to observe.

Report by Barbara Barrett, photos by Norman Gregory and Chris Fone

Wednesday Morning 10th September

Leader - Dr Sophie Justice with Mme Marie-Laure Page

Geosite 20 Cornettes de Bise, Vacheresse

We were joined for today by mountain guide Marie-Laure Page. The trip up the very narrow winding mountain road proved a challenge for Alexandre, our driver, who only abandoned the attempt when the coach proved too big for the final few bends.

The Cornettes de Bise is part of the Préalpes Medians, the Vallee de Bise is a syncline with the northeast/southwest axis running along the valley floor and is asymmetric. The lower part of the valley is wooded but the upper slopes are alpine pastures.

The high ranges are Malm limestone formed in the marine environment of the alpine Tethys deep ocean off the underwater Briançonnais island 135 - 155 million years ago.

The valley was glaciated by local glaciers up to 18 thousand years ago. When they melted the release of pressure particularly affected the northern side where the beds dip from east to west, which can be seen behind the coach. This northern side is more susceptible to erosion and many rock falls have resulted in a chaotic landscape of rocks on the valley floor, where a rich flora has developed.

The southern side of the valley has been subjected to more faulting and the bedding planes are vertical.

The morning walk started through the chaotic limestone rock falls on the valley floor. As we descended the going became steep and sticky as we came onto the youngest rocks which had formed on the continental margins and had a much higher percentage of silts and clays giving a red limestone. As it erodes, the clays form impermeable pockets.

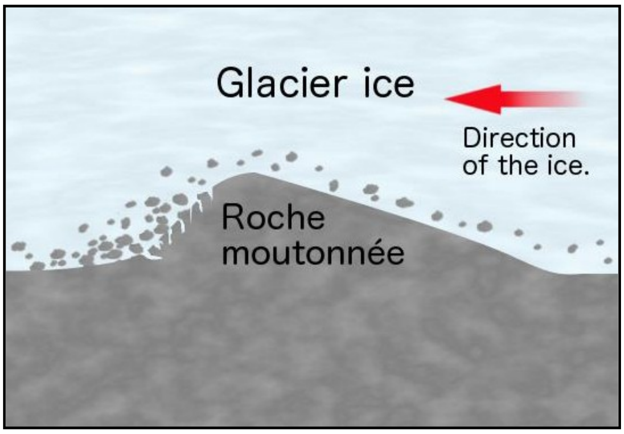
These youngest beds are the Couche Rouge, 65 million years old, formed at the end of the Cretaceous in shallow offshore waters. Due to folding, the Couche Rouge is now seen both high in the valley walls and on the valley floor, where erosion by glaciers has exposed it. Larger trees grow well here and there are some rare plant species.

Southern side of valley

Couche rouge in the valley

There was discussion on whether the rocks in the valley were Roches Moutonnée caused by the passage of the ice along the valley

Fig 12



Sophie and Marie-Laure in discussion

As we walked towards the eastern head of the head of the valley we came to the glacial lake. This was formed from melt water after the last ice age, around 12,000 years ago. The clay rich Couche Rouge forms the impermeable layer to hold the water.

The glaciers did not have a regular flow and some areas in the valley are over-carved with rock bars causing the formation of basins and kettle holes.

In the last thirty years the reed margins have become extensive and it is estimated within 20 years the open water will close. Nitrate pollution from the cows, goats and pigs pastured here every summer has affected the lake. In the 19th century there would be over 500 cows and goats here in the summer but now herds are restricted to around 50 animals.

Inflow is from mountain streams and the lake is not well-oxygenated. Local history relates that if it rains hard in Vallee de Bise, everyone is ill in Richeburg in the neighbouring Abondance Valley the next day. There is no natural outflow from the lake but dye tests have borne out this story. 75% of the water appears in Richeburg 20 hours later and only 25% finds its way into the River Drance which geographically is directly downstream of the lake. The water must percolate through a series of underground faults.

We then made our way to the mountain restaurant for lunch before our climb to the Pas de Bosse.

Report by Christine Moore, photos by Christine Moore, Chris Fone and David Riley

Wednesday Afternoon 10th September

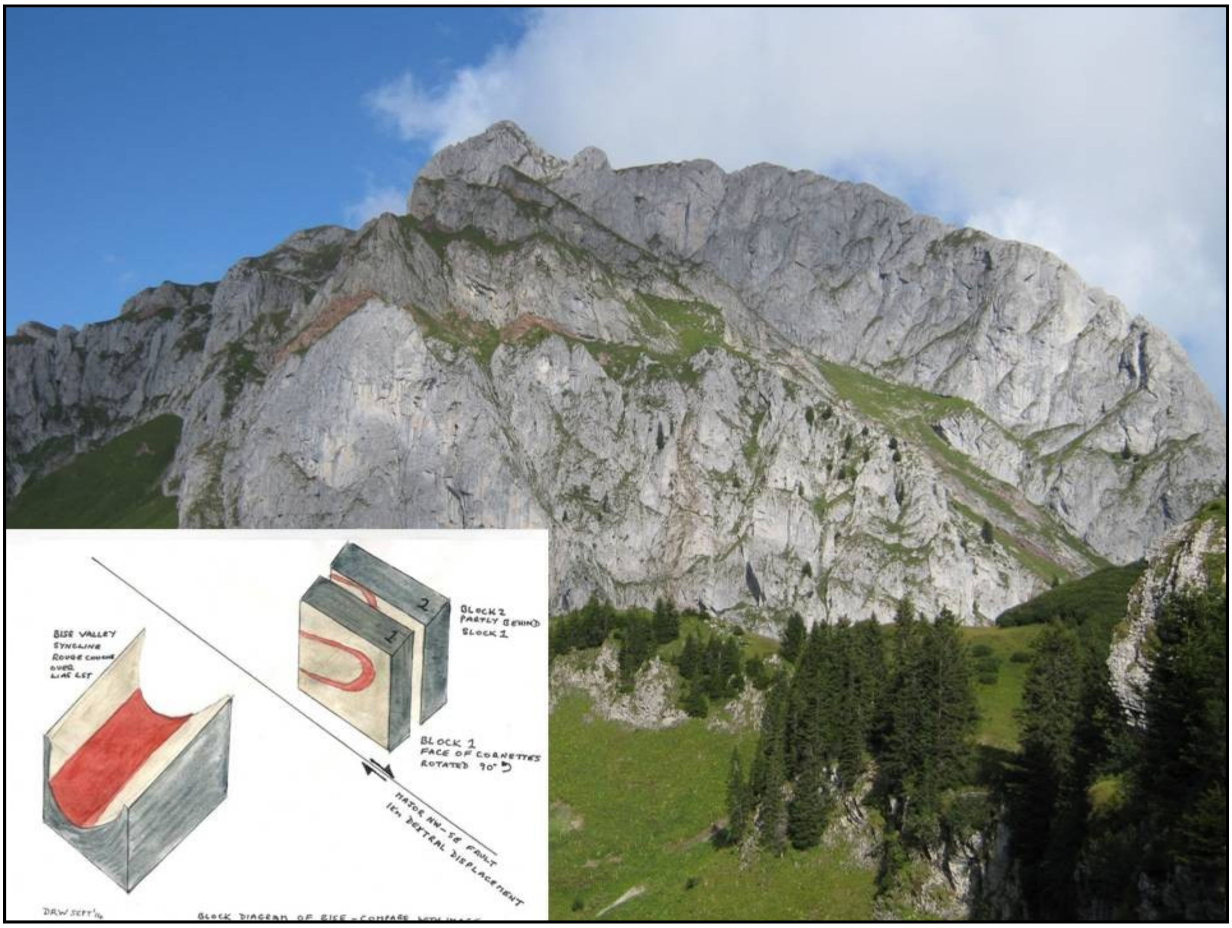
Leader - Dr Sophie Justice with Mme Marie-Laure Page

Geosite 20 Cornettes de Bise, Vacheresse (cont)

After a very nice lunch in Les Cabrettes, including cold meat, beignettes (a local potato rosti), salad, bread, the inevitable cheese, bilberry tart and of course wine, the group faced the afternoon's geology. Sophie had explained that we would have a closer view of the sequence of rocks we had seen this morning, would be able to collect fossils – something slightly exceptional on this visit – be able to place the Couches Rouge in its structural position and have excellent views of the area. The only slight problem was a climb of 300m on top of a good lunch!

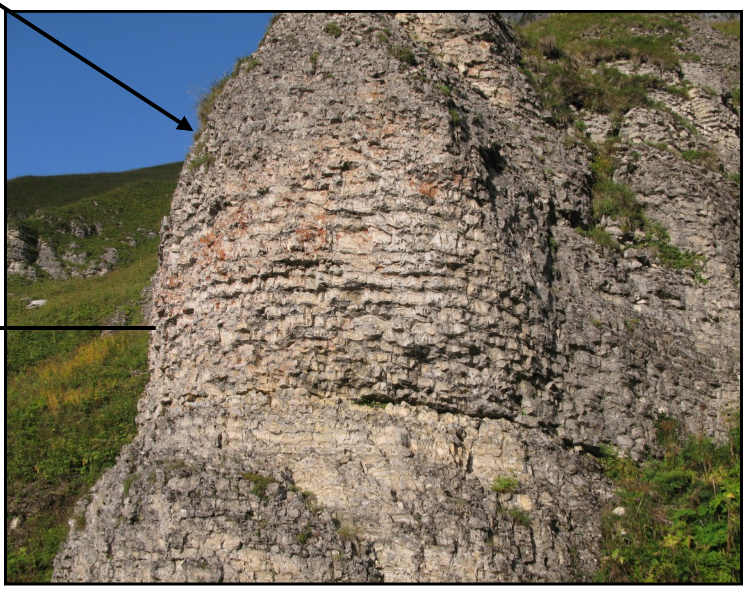
A track ran from the Auberge past the museum and the hostel before climbing steadily uphill on the south east side of the valley. The group stopped to admire the view and to examine roche moutonnées beside the track – these were in the Couche Rouge. The track then passed onto the Malm, here, a Jurassic white limestone. A cry from an animal drew our attention to a small brown bump on a rock – identified as a marmoset by the sharp eyed amongst us. Climbing steadily, if beginning to breathe deeply, we continued uphill. Another pause and Sophie pointed out more evidence of glacial action on the surrounding slopes – moraines, U shaped valleys and lakes formed by terminal moraines, including Lake Bise below us. Several major faults cross this area, cutting the "Briançonnais Island" and are now exposed at the surface. A major one in a NNW-SSE direction formed west face of the Cornettes, displacing this block about a Km to the southeast and allowing also an anticlockwise rotation of the block. The result of this is that while the Couche Rouge formed the floor of the Bise valley and it and the underlying limestones were approximately conformable with the valley sides, it was now seen high up in the Cornette, turned on its side.

Couche Rouge high in Cornettes de Bise



More uphill brought us to a limestone pillar on the east side of the track, this one showing bands of chert – brown coloured in the white limestone

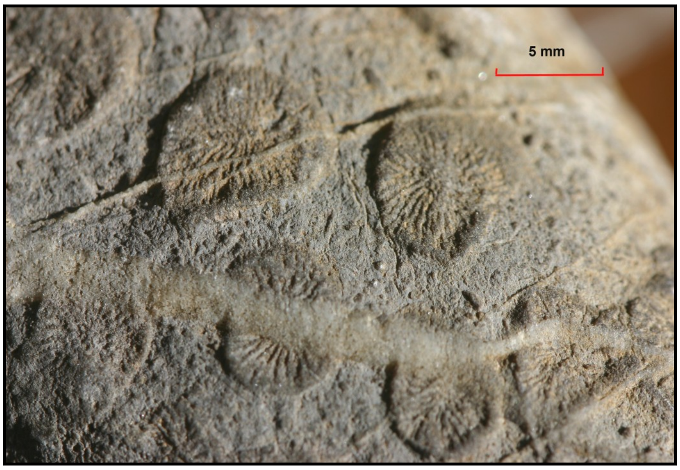
Limestone pillar with bands of Chert



As we progressed up the limestone sequence, Sophie explained that we were moving away from deepwater limestones into a shallower sea, and eventually into a lagoonal setting where thin limestones and marls were the typical rock types. Oolites, bioclastic limestones and silt bands could all be identified, indicating variable, near-shoreline conditions. Before we arrived at this sequence, we had to mount Pas de la Bosse, about 300m above the valley floor. The views made the climb worthwhile – while Mt Blanc was lost in cloud, the nearer peaks and valleys were geologically great and scenically stunning. What was now an almost casual walk to the west took us along the top of the valley wall, so we could look down on Bise and over the landscape.

Peering over the edge and down the valley side, we were able to observe that the limestones were now thin, 5- 20 cm thick, beds of the lagoonal sequence. This is named the Couches à Mytilus Formation after the common fossil found here. To calibrate UK geologists, this sequence is equivalent to the Bathonian -Callovien sequence in England. Slightly unnervingly, Sophie pointed out a route marker indicating that we were on a 'Nice to The Netherlands' very long distance footpath. While we liked the concept, few had the muscle to consider this!

About 0.8 Km from the Pas de la Bosse, the group turned south off the valley wall and descended into the next valley.



Several small exposures of thin bedded limestones with brownish bands in between were the Mytilus Formation and were descended on by the fossil collectors of the RGS. Some searching was required to find anything of animal origin – but eventually Edmund – not our most avid collector – produced a limestone fragment with beautiful corals. These were solitary corals, about 5-10mm diameter and apparent on the weathered surfaces, where they stood slightly proud of the rock. Further searching produced more coral specimens and fragments of the Mytilus bivalve.

The group now faced the return march to the coach, but this was aided by less cloud and more sunshine, allowing us to enjoy the fantastic scenery. A cautious descent of the paths we had walked earlier – with suggestions from Sophie and Marie-Laure to watch our feet as well as the view – brought us back to Les Cabrettes, where we found those who had rushed ahead, or had stayed behind, had slaked their thirsts. A walk down the valley, past the hairpin bends where the coach had stuck earlier, brought us to Alex, our driver waiting patiently in a lay-by.

All was not over, however – a confrontation with a mobile home on a narrow road resulted in the mobile home driving off the road so we could pass, on the understanding that, if needed, we would push the van back on. We did!

After a great day, we arrived back at the hotel at 8.30, ready as always for a beer and an excellent dinner. We were not disappointed.

Report and Bise block sketch by David Ward, photographs by David Ward, Norman Gregory, David Riley and Christine Moore

Thursday Morning 11th September

Leader - Dr Sophie Justice with M. Richard Brand

Geosite 11 Vouas du Lyaud, Lyaud

The geosite visited this morning was the Vouas du Lyaud and our mountain guide for the day was Richard Brand. After transferring from the coach to two minibuses in Armoy, we drove to the entrance to the geosite from whence we walked along tracks, viewing the scenery and hearing about the landscape and the fluvial, glacial and lacustrine processes that formed it.

The Ice Age started about 2.6 Ma. The Alps were still being built, but the present geological structure had been established. The mountains of the PréAlpes Médianes were to the south-east and the land to the north-west was a basin, with the Jura Mountains beyond. The last glacial period (the Wurm glaciation, c. 70,000-10,000 ybp) was in its final stages and was at its last maximum about 20,000 ybp, with ice over most of the area of the Alps and Jura, with rocky mountain tops projecting through it (Fig 5)

Of the many glaciers, one of the largest was the Rhône Glacier. The Rhône Glacier flowed north-west towards the current eastern end of Lac Léman where it split, with part turning to the north-east and part moving to the south-west (towards Geneva and beyond), gouging out the Léman basin as it went.

The River Dranse flowed north-west from the Alps, but when it came to the glacier, was diverted to flow south-westwards alongside the glacier. As the ice retreated the glacier shrank in height and length as well as width, leaving a bottom moraine and a side moraine with a lacustrine clay at the bottom of the lake that formed in the valley, between the mountains and the glacier. The river, emptying into the lake and exiting towards Geneva, brought sediment of all sizes with it which were deposited in a delta extending out into the lake. The delta was also subject to shocks causing turbidity currents which flowed down the faces of the delta and onto the moraine at the bottom of the lake.

Successive retreats meant that the southern edge of the glacier and the lake beside it, moved north-westwards, becoming lower. The river then cut down forming successive deltas, each being further north-west out into the lake and leaving terraces behind. There are 14 such terraces formed to the south-west of the River Dranse: the first eight (Upper Terraces) dropping from about 730m to about 580m, formed in the Geneva Stadial Retreat; and the next five (Lower Terraces) dropping from about 530m to about 400m during the Yvoire Stadial Retreat. As the river, today flows out into Lac Léman, the fourteenth delta is forming at about 372 m (Fig 13-see next page).

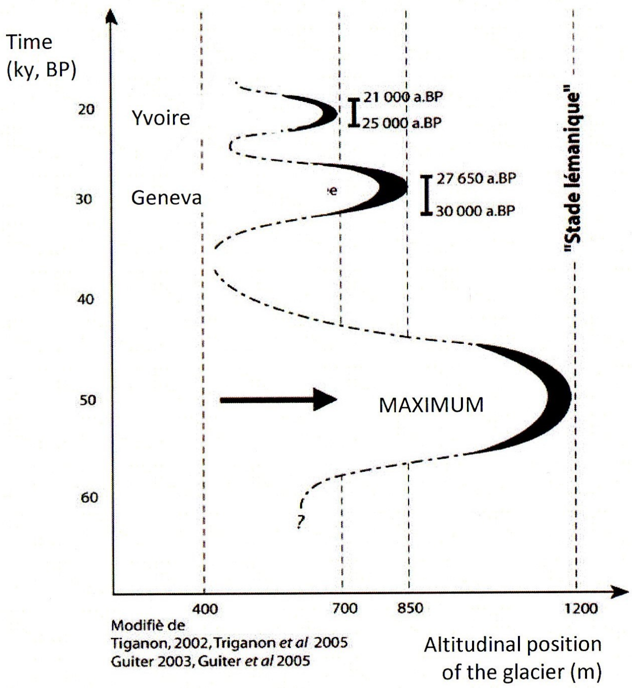
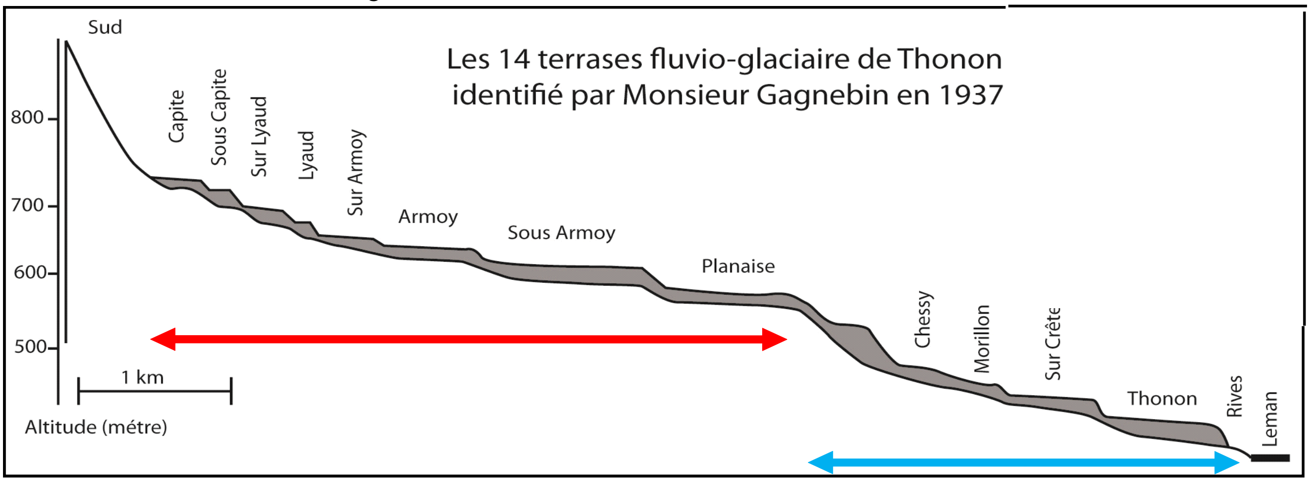


Fig 13 The Thonon terraces



Upper terraces Geneva stadial retreat *Lower terraces Yvoire stadial retreat*

We started our walk in the south-east on the side moraine left behind by the Rhône Glacier as it flowed towards Geneva. As the ice retreated it occasionally left blocks of ice in the moraine. When the climate became warm enough or the ice was exposed, the ice melted and left depressions in the surface known as kettle holes. These are often lined by fine clay sediment and filled with water to form small lakes. We saw two such kettle holes; the first at the entrance to the area, which was maintained by rain-water run-off and the second further along the walk which we were told was maintained by groundwater We had seen a third [dry] kettle hole on the side of Mont Bénand on Monday afternoon.

There are still a few quarries working the delta and moraine deposits, one of which we had already passed a couple of times, (a working quarry at the junction of D26 with D1005) that had an old face, about 20m high, visible from the road, that showed a section through one of the later deltas. On this walk we visited another quarry, although this was now only used on a small scale. Here we could see the different grades of sediment, dipping towards us, strike about 330^{o}, forming thin beds and the fining-upwards grading of turbidites.

We also saw erratic blocks including some of Mont Blanc granite and one, in the deposits in the quarry face, that was completely degraded and broke up as it was being prodded.

During the walk, Richard explained how the groundwater flows in the area and how it sustaines the villages. The catchment area is between the river Dranse to the east and the river Pamphiot to the west. There is a deep aquifer of limestone but the main water supply to the villages is the water flowing down the terraces. This water has to be carefully managed to maintain quality and volume. In the past excessive removal of water from the upper terraces had caused shortages lower down and pollution by animals had also affected lower water supplies. Now a system of buried reservoirs, each of which allows outflow of excess water, ensures that sufficient volume is supplied to each village, even in times of drought. Measures to control pollution and manage problems, including complete removal of some waste tips, are in place in each local authority.

After leaving the woods of the water management area, we walked through the village of Les Moulins d'Amphion where we found sweet chestnut trees and chestnuts. Richard explained that the local mill had a surface leet, fed by groundwater and had at one time ground the nuts for flour.

We crossed the leet and continued along the road towards our next geosite, passing one of the largest erratics we had seen during the week – Pierre à Passet (also known as Pierre du Diable) - a piece of gneiss about 7m high and 9m long. It is said to be an erratic but how could it have been glacially transported when it is resting on a river terrace? It is possible that it is from a moraine.

On the way to our next site, we passed through the village of Macheron and visited the back garden of our guide's cousin. Here was a beautifully preserved section through the deltaic deposits, approximately perpendicular to the strike of the beds, with a dip of about 30^{o}. Although some of it was partially obscured by a lean to, the bedding was clearly visible and showed the varied grades of sediment.

Continuing on, we could see the steep ridge of Allinges with the village below and the two châteaux on the top. The ridge is of “flysch” which is a deep marine turbidite sequence, deposited in the Valais Trough and the Ocean (north and south of the Briançon Rise) from the period 90 Ma when the African plate was beginning to move northwards towards Europe and the Piemont Ocean to close.

A steep footpath led us up the hill to the top and, once assembled at the top, Richard showed us some clasts, found in the flysch, that contained fossil burrows. However, by now, our main objective was to find the minibuses and retrieve our packed lunches so we moved on to the newer château to have our picnic.

Report by Roger York, photos by Roger York and Michael Ledger

Thursday Afternoon 11th September

Leader - Dr Sophie Justice with M. Richard Brand

Geosite 2 Châteaux des Allinges

After yet another superb picnic lunch in the grounds of Le Château-Neuf d'Allinges, supplied from our hotel, supplemented by Sophie's home-cured ham and locally produced cheeses and sausage from Richard Brand, our local guide, Sophie called the group together to talk about the geology of the region. The ridge formation on which the Château stands was a flysch deposit and is composed of sandstone and pebbles mixed with some limestone blocks, consolidated in a siliceous cement. This had been part of a very early component of the Alpine Orogeny and was a section of the Nappe de Gurnigel.* This thrust front extends over a distance of 200km. from here at the Lac Léman to Lake Lucerne, in Switzerland. The ridge stands today at 713m. high, but would have been considerably higher had it not been re-sculptured by later glaciation. To the north it gives views over Lac Léman and into Switzerland on the far bank. To the south there is a low plain towards the Préalpes Médianes in the distance.

Above; Le Château-Neuf d'Allinges

Below; looking north from Château gardens over the village of Allinges in the foreground, the west of Thonon-Les-Bains is to the top right and the town of Margencel to the centre top.

The consensus view is that the Nappe de Gurnigel was created as one of four sedimentation fans within the South Penninic Ligurian Ocean in a trench bordered by the northern edge of the Austroalpine Island. These deep ocean fans were separated from each other by crevasses in the slope wall and are of slightly different compositions. The Gurnigel Nappe is significant in that it contains both volcanic debris and nodules of amber. The volcanics could have been derived from the Austroalpine Island itself, but the amber would have come from the northern shore of the approaching African landmass, indicating its proximity to that continent. The island was moving steadily northwards and on contact with the southern edge of the European plate these sediments were squeezed upward, over the lower arm of the Nappe Supérieure. The sediments were so waterlogged that they flowed right over the Nappe Supérieure to form the most northern deposits in the Chablais region.

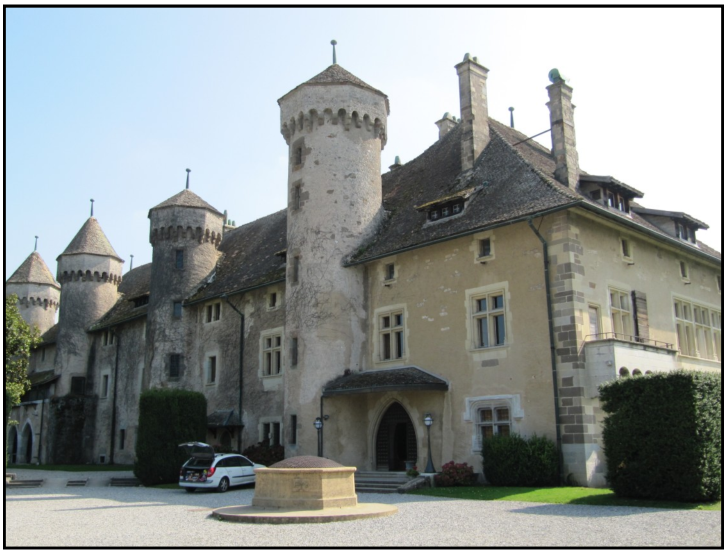
Time was getting on so the group was told that the next stop would be the wine tasting at the Château de Ripaille; this got us all back on the buses. It was slightly confusing when they began heading in the opposite direction. The buses eventually stopped at a small hamlet called Jouvernaisinaz where the group was informed that we would be driving down over some of the glacio-lacustrine deposits that the group had been told about in the morning session. The journey began with a switch-back ride over a number of the terraces with a sharp change in elevation at the end of each one. The distance between each drop would tend to suggest that the route took us along the eastern edge of the lake deposits as each successive lake turned towards the current route of the Dranse River. The buses eventually reached the D1005 AutoRoute and we were taken around the periphery of the town of Thonon-les-Bains to our final destination.

On the way Sophie told the RGS members in our bus about the Iron Age burial site which had been found during the building of the D1005 during the 1970s. Eventually nearly 4000 ancient remains were found close to the route of the Dranse River, all lying with their heads towards the east. The number of burials made this the largest known necropolis site in Western Europe.

*Later studies have suggested that the Allinges outcrop is a section of the Voirons Nappe, which may be a distinct nappe in its own right or a sub unit of the Gurnigel Nappe.

Geosite 19 Château de Ripaille, Thonon

Our next stop was at the Château de Ripaille, a mid-15th century edifice in the classic French style with crenelated towers and a big courtyard in front of it. The foyer had a reddish -brown marble floor which Sophie told us was called the Marble of Laverne and was not actually marble at all, but a very hard limestone cemented in a ferruginous matrix. Very hard-wearing and considerably cheaper that the real thing.



Richard then took the group down to the basement to get the bottles and glasses needed to sample the product. The 'Cave' contained nine very large wooden casks used to ferment the grapes. They were unfortunately empty but had all been used at some time.

We were then escorted to the grassy area at the north of the property to sample the white wine. The vineyard has some 22 hectares (around 54⅓ acres) predominantly planted with the Chasselas white grape, although there are some smaller terroirs of the Gamay red variety. The Chasselas grape was developed in Switzerland where they are grown on southern facing slopes. At the vineyard in Ripaille the ground is almost level as it is situated on the last of the glacial lake terraces before the actual delta. The soil here is very sandy with some gravel and this makes it free-draining so the vines have to work hard to survive. The AOC Château de Ripaille wine that the group tasted was slightly unusual as it is a single variety vintage; most French wines are blended from two or more terroirs.

Richard then gave the group a bit of the history of the château. The area had belonged to the Duc de Savoie since the 11th century and had been used for hunting. The Duc did not stay in any one place for too long and the first building was a relatively modest hunting lodge. The current château was built around 1453, but had fallen into disrepair after Savoy was amalgamated into France in 1860. In 1892 it was bought by Frédéric Engel-Gros, an industrialist and art lover, who renovated it to its current standard. Wine production began in 1996 under the present owner, Madame Paule Necker.

After the wine, Richard Brant said goodbye and the group walked the short distance down the delta area of the Dranse River where we waited for the bus to arrive to take us back to our hotel. The lake provided a useful diversion after a hard day's geology. We did not actually get to see the point where the Dranse River enters Lac Léman as this was about 1km further on, but we found a wide variety of unusual pebbles that had been brought down by the river and deposited on this, the western horn of the delta.

The delta actually covers an area of 8 square kilometres, but only 3 kilometres are above the level of the lake. Although the Rhône river flows through the lake, there are no significant currents in it due to its size. However there is long-shore drift along the beaches as the strong alpine winds whip up the waves during stormy conditions and these are capable of moving the stones.

Sophie told the group about the lowering of the lake every four years. The lock gates at Geneva are raised at this time and the water level is allowed to drop several metres to permit local residents to clean their jetties and anchorages. This event, known locally as '*Tirer la chasse d'eau'*, translates into English as to flush the toilet. An example of Gallic humour, perhaps?

Report by Michael Ledger, photos by Michael Ledger, Norman Gregory and Hilary Jensen

Friday 12th September

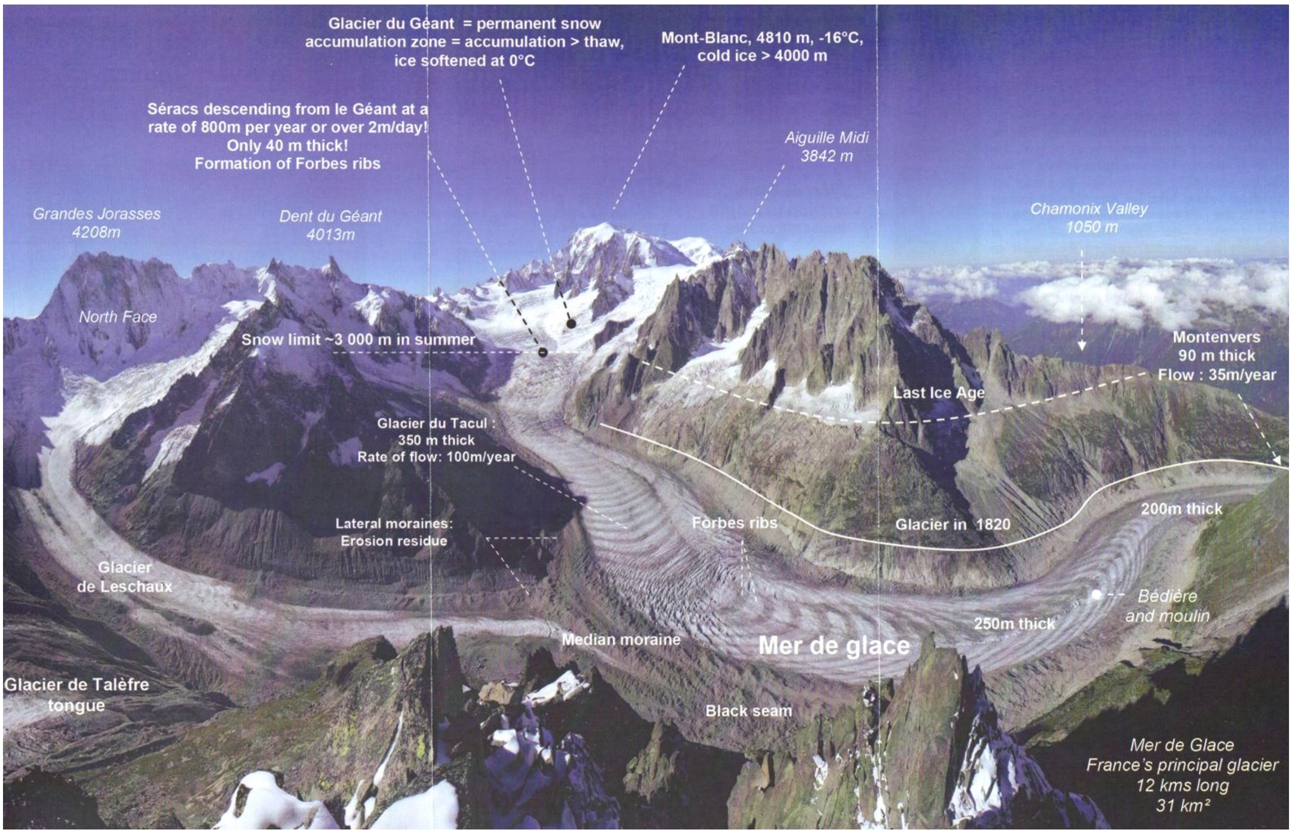
Leader - Dr Sophie Justice with Dr Sylvain Coutterand

Chamonix and La Mer de Glace

The visit to Chamonix and the Mont Blanc region revealed a window on the older Variscan basement rocks. Gneisses were intruded by late Variscan granitic plutons; the granites being about 300 Ma old. These rocks were part of the Pangea supercontinent and those now outcropping in the Mont Blanc region have been exhumed from a 15 to 20 km depth. The uplift began about 22 Ma and continued at least to 4 Ma but may still be active today, with the rate of uplift being matched by the rate of erosion. Younger rocks have been eroded away to reveal the gneisses and granite.

Dr. Sylvain Coutterand, a leading glaciologist, joined the group at the Chamonix station of the famous little red funicular railway, which took us on an enthralling 1000m climb to Montenvers at an altitude of 1913 m. Here, the group had a panoramic view of La Mer de Glace (sea of ice), France's longest glacier, and the surrounding mountains.

Fig14 Diagram of La Mer de Glace

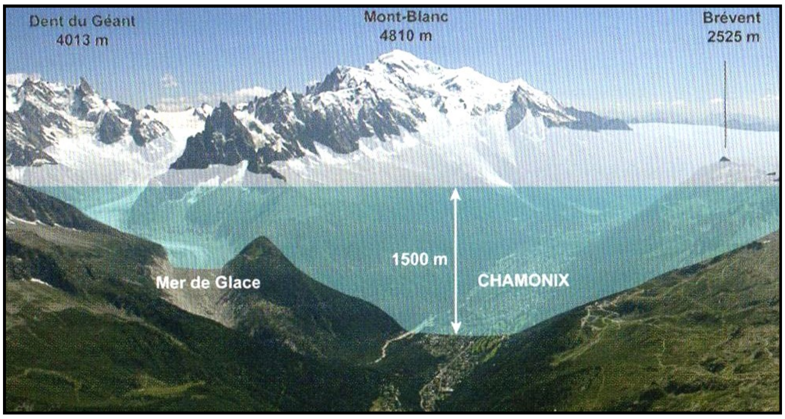


Using this diagram Sylvain described the principal parts of the glacier. Above 4000 m the ice is cold, -16° C at the top on Mont Blanc (4810 m). There is no melting at the surface and insufficient pressure to melt the ice at the base. Consequently movement is mainly by internal deformation of the ice, which means there is very little erosion of the rocks. Below 4100 m on south facing slopes and 3600 m on north facing slopes, the ice temperature is close to zero at the base and the pressure sufficient to cause melting. This melt water facilitates movement of the glacier over the rocks causing much erosion. At the surface the snow is below 0° C in the winter but there is melting in the summer; some of the water moving through the snow and refreezing to form ice.

The zone where snowfall exceeds thawing is referred to as the Accumulation Zone. The Ablation Zone is the part where the mass of the glacier is decreasing due to melting, sublimation and net movement. The junction between the two zones is called the Equilibrium Line. Typically the Accumulation Zone is twice the area of the Ablation Zone.

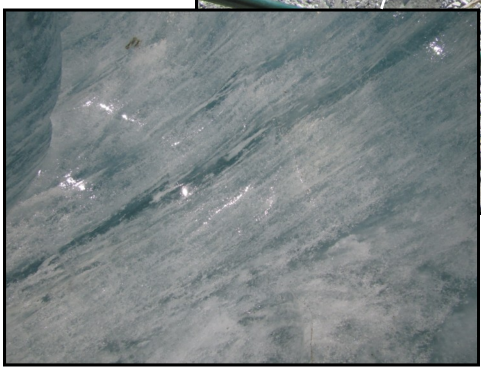
The many advances and retreats of the ice during the past 2.5M years is a fascinating story. Earlier in the week we heard about the last major advance, the Würm glaciation, and the giant glaciers in the Rhône valley, which nearly reached Lyon. There was a large ice sheet in the Mont Blanc region with only the mountain peaks poking through, with ice more than 1km thick in the valleys. The landscape would have looked like Greenland today.

Fig 15 Ice thickness during Würm glaciation



Following the last ice age the glaciers continued to retreat to beyond their current position. For example during the warmest period 7- 6,000 years ago La Mer de Glace retreated to 3 km above its present position. Forests extended up the valleys, which were also occupied by humans during the Neolithic, Bronze and Roman periods. The size of the glaciers continued to fluctuate and in 1200 AD were approximately the same length as today. They again advanced during the little ice ages and in about 1350, 1600 and 1850 AD typically extended 2 km beyond their present positions. The advancing ice destroyed several villages as well as the forest. Two thousand year old pine logs have been found in the moraines. Since 1850 the glaciers have again been in retreat, about 2 km, with only a few minor advances.

The party then descended to the glacier. Rather puzzlingly, the gondola lift only took us halfway down and we then had to descend 420 steps down to the glacier. Sylvain explained that 20 years ago the gondola did go down to the level of the glacier but since then it has lost 75 m of thickness. Its rate of flow has decreased from 90 m/year in 1980 to 30 m/year in 2012. The glacier below Montenvers is still 90 m thick but becoming darker as the lateral moraine debris falls onto its surface; however the 2-300 year old ice within the glacier, which we observed in an artificial tunnel (the Ice Cave), is relatively clean.



Sylvain and Sophie climb the 420 steps

Walking back up 420 steps (75 m) from the glacier to the level of the ice 20 years ago forcefully emphasized how quickly the glacier is shrinking. Modelling simulations of the effects of global warming suggests that by the end of this century the area covered by ice in the Alps could be reduced 80%.

The rock on the valley side was a gneiss with many surface striations produced by the glacier. Sylvain pointed out that in the gneiss rock the striations only survive about 10K years, unless they are buried.

On returning to Montenvers the group enjoyed a well earned picnic. The views of the glacier and mountains, from the 2,000 m high moraine ridge, were magnificent.

After lunch the group visited the excellent new Glaciorium, which explains glaciations in detail. La Mer de Glace was explored and named by two Englishmen, Windham and Pocock, in 1741 and has become a major tourist attraction. The Grand Hotel at Montenvers was built in 1880 and a steam railway from Chamonix to Montenvers, opened in 1909, making the glacier easily accessible.

Following a return journey on the little red train, now electrified, Sylvain showed the group a moraine in the middle of Chamonix. This is rather unusual because most moraines in the valleys have been either eroded away or buried by lacustrine deposits in glacial lakes. Erratic boulders sitting on the now grass covered moraine were examined by the group.

Chamonix is a pretty Alpine tourist town with beautiful gardens. The fantastic dahlia displays distracted two members of the group. We hear a lot about the many negative effects of global warming and the melting of ice, but surely Chamonix is a better place than when it was under more than a km of ice. Perhaps one day there will be attractive tourist towns in Greenland with stunning dahlia displays!

More detailed information on the glaciers can be found in a book published by our leader, Sylvain Coutterand in 2013: “Les Glaciers du Mont-Blanc. Les Comprendre, Les Explorer”.

Report by David Riley, photos by David Riley and Norman Gregory.

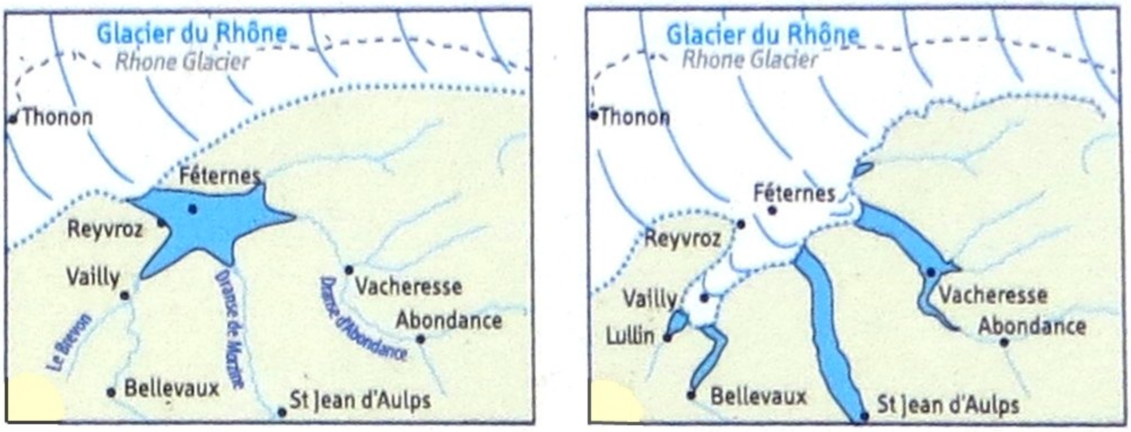
Saturday Morning 13th September

Leader - Dr Sophie Justice with M. Jean-Louis Meynet

Geosite 21 Forêt Ivre, Vailly in the Brevon Valley

An advancement of the Rhone glacier (25 to 30 ka) in the Lake Léman area had blocked the exit of the three main Chablais valleys (Abondance, Dranse, Brevon) and a large lake developed. During phases of advance and retreat over this period, the ice height grew up to 850 m and was able to push uphill into the Brevon valley.

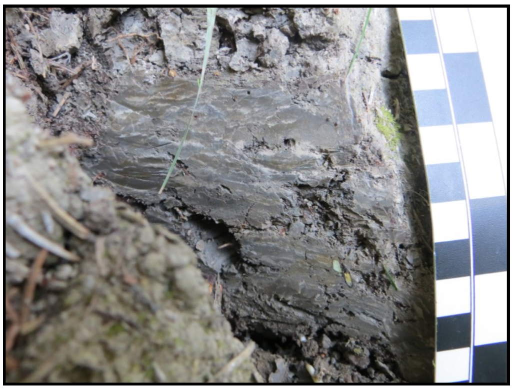
Fig 16 Lakes formed behind ice dam



The consequence of these glacial phases was that the Brevon valley became filled with alternating layers of clay, sands and silts. During the subsequent interglacial period the River Brevon has cut steeply down through these deposits. The result is a valley side that today is extremely unstable with the sandy layers being easily able to slide down slope on the slippery clay layers; roads and buildings are continually at risk of subsidence. In 1733 the village of Vacheresse in the Abondance Valley was completely swept away and as recent as 2004, 24 houses in this village were also swept away. The river has still not reached its equilibrium profile and there is still more than 100m of down cutting that it can do before it reaches the lake.

Much of the area has been covered with trees by the French National Forestry Commission in an effort to use roots to stabilise the land and to reduce run off. Below the village of Vailly, on the valley side, is what is described as the 'drunken forest'. Trees are moved with the regular periods of subsidence and result in having trunks with adjusted growth angles or at various angles to the vertical, hence the nickname.

At one location there was clear evidence of the clay causing the problems, exposed in the bank.



The civil engineers had concluded that the most profitable way of minimising the future valley subsidence was to slow down the speed that the River Brevon cuts down into the sediments. To achieve this a series of three dams had been built along the river. We visited one of the dams, 12 m high, called The Pierra Bessa, built in 1937. The bank on the eastern side of the river is of hard limestone and forms a solid barrier to the river. The sediments that collect upriver of the dam press against the western (glacial) side increasing the stability of that bank. As the water falls over the dam it scours the river bed; to counteract this and to ensure the stability of the dam a small sill has been introduced a little downstream.

Other attempts to reduce the problems of slippage include a system to improve drainage in the hillsides behind the village, to protect the buildings and road. A series of pipes between the sandy layers and clay take the water, in steps, directly to the river.

Further evidence of this work was seen alongside the main road where ditches were being dug, filled with gravel and pipes introduced to collect the water draining from the hillside. This was then taken beneath the road and to the river.

Report by Chris Fone, photos by Chris Fone and Norman Gregory.

Saturday Afternoon 13th September

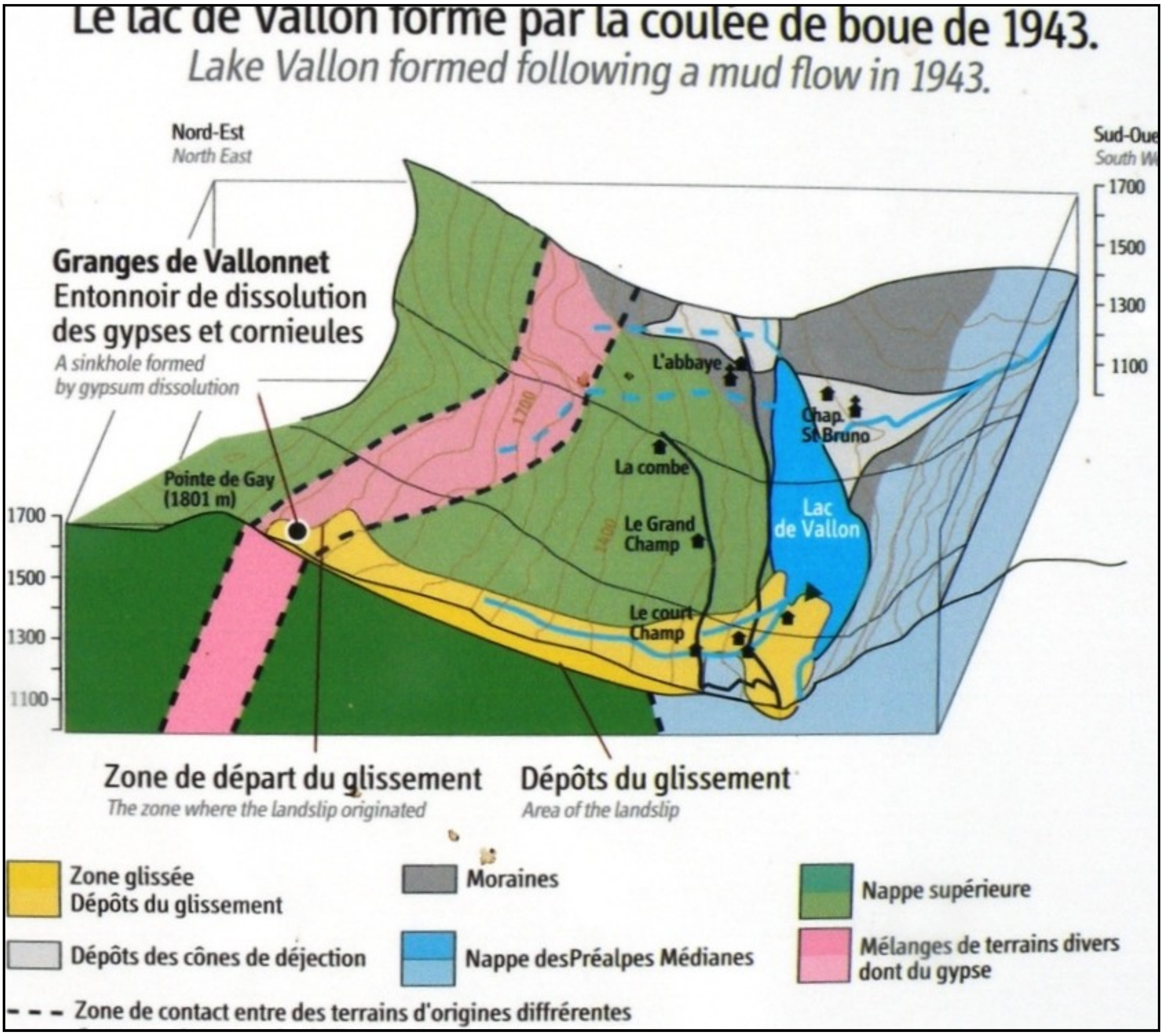
Dr Sophie Justice and M. Jean-Louis Meynet

Geosite 4 Lac de Vallon, Bellevaux

The Geosite Lac de Vallon is in the valley of the River Brévon which rises below Roc d'Enfer and flows north east and then north across the Geopark as a tributary of the Dranse. The geological setting can be seen from the diagram (Fig 17) and map (Fig 1).

The Brévon valley marks the junction between the Nappe des Préalpes Médianes and the window of the Flysch Helminthoid nappe, a subdivision of the Nappe Supérieur. Continental collision in the early part of the orogeny and subsequent crustal shortening gave rise to the Nappe Supérieur; subsequent tectonic activity resulted in the Nappe des Préalpes Médianes sliding over the whole package resulting the Nappe Supérieur being "sandwiched" between the Nappe des Préalpes Médianes above and the Nappe de la Brèche below, both of which have décollement horizons in gypsum.

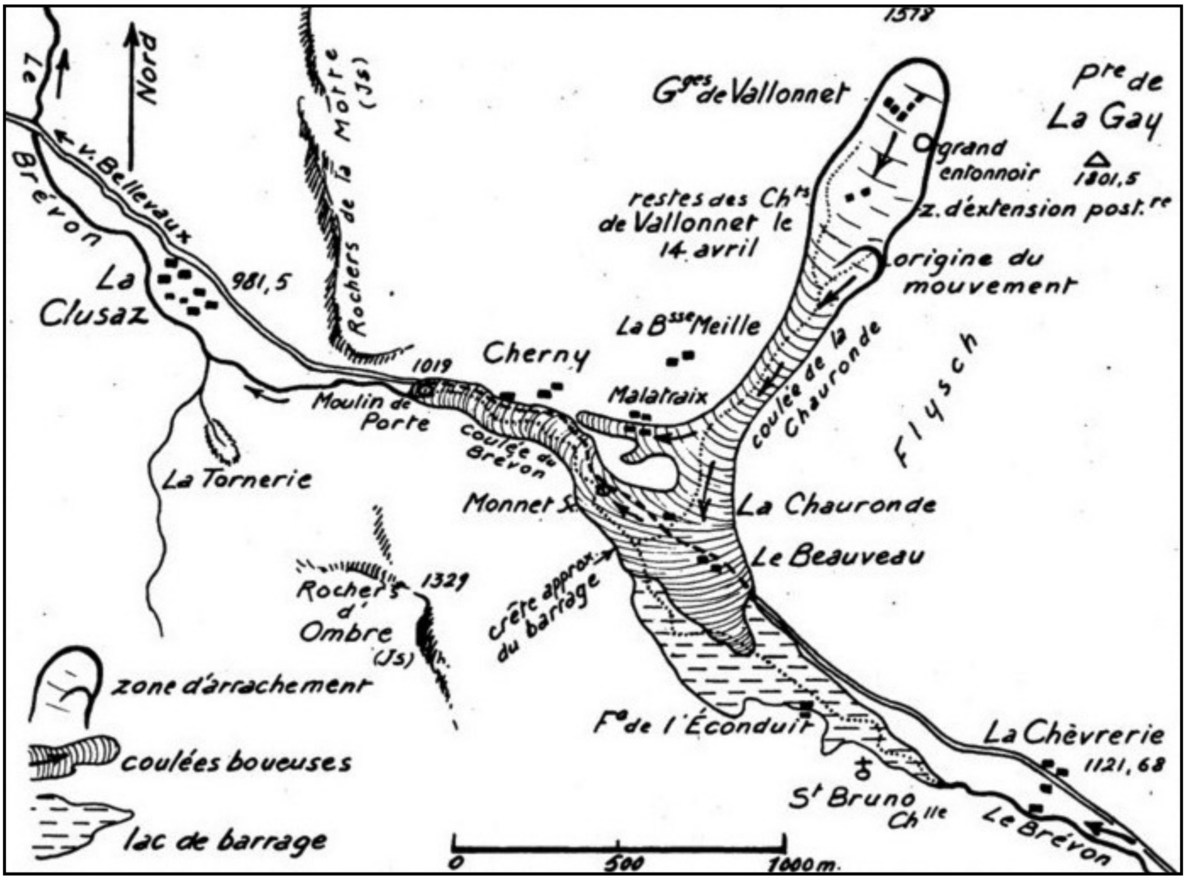
Fig 17



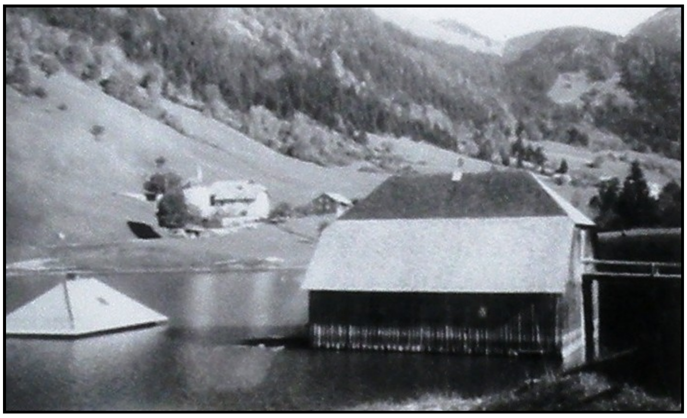
View from above Lac de Vallon looking to the south showing Roc d'Enfer, 2400m, at the frontal thrust of the Nappe de la Brèche.

During the autumn of 1940, there was substantial rainfall and this initiated instability at the top of a tributary ravine of the Brévon and over the next two and a half years, water soaked into the rock below. Dissolution of gypsum was instrumental in the collapse. Large crevasses appeared in the upper slopes above the Chauronde valley and also a large solution hole was observed. The landslide that was triggered on 11th and 12th March 1943 was composed of sediments from the Upper Cretaceous/Palaeocene calcareous rocks of the Flysch Helminthoid nappe, mixed with fluvial and glacial material.

Fig 18. Brévon valley showing the extent of the slide mass. It flowed down from the Pointe de la Gay as a debris slide in a south-westerly direction down the Chauronde ravine into the main river valley forming a dam 1100m across, which blocked the river and formed a lake. The lake water rose during the spring of 1943 and eventually overflowed the dam and escaped down-stream.



The damage was extensive. These are pictures taken at the time, (Office de Tourisme, Bellevaux). More than two million cubic metres of material moved slowly down-slope at the rate of 20 to 30 metres a day. Movement eventually ceased after a month. Many chalets from the hamlets of Chaurond, Malatraix and Beauvau were destroyed and the road was blocked. However, there was no loss of life and it was possible to move some farm buildings and to relocate two sawmills. Jean-Louis explained that there was a lot of documental evidence about this event, which was surprising considering it was during the 2nd world war. There were numerous articles in newspapers, photographs and geological reports. This was of course in Occupied France at the time, but there are stories of German aid being offered and possibly was channelled into the area.



The group, guided by Sophie and Jean-Louis, discussed the geology and the events of 1943 in the car park of the Geosite, which had many excellent explanation boards. The group then walked round the northern end of the lake and examined the material of the dam. It could be seen to be landslip debris and contained key rocks demonstrating its provenance. A large lump of limestone contained trace fossils, helminthoids, which characterise the calcareous turbidites deposits in the Alpine Tethys and are common in this locality.

Helminthoids

Block of gypsum probably from the base of Nappe des Préalpes Médianes.

Walking downstream a short way, the river was seen to be eroding the debris dam and cutting down, thereby progressively lowering the lake level. From a viewpoint above the lake the landslip scar could be seen. The vegetation pattern on the hillside showed the contrast between the coniferous forest above the landslip and the deciduous forest which had grown on the landslip itself over the last 70 years and the remains of a submerged barn and stumps of trees could be seen in the water.

Various signboards told how the lake was silting up with the influx of material coming down the valley, where a substantial delta is forming. This, and the erosion of the dam, reducing the depth of the lake. This presents the local councils with the conundrum of whether to let nature take its course with the lake eventually disappearing or dredging it to maintain it as a local recreational feature. In 1943, shortly after its formation, it was 25m deep, it is now only 10m deep.

In conclusion

We then sat on a grassy bank overlooking the lake for a final session with our leader, Dr Sophie Justice. Two weeks previously, we had the introduction to the Alps with the lecture in Reading by Dr Mike Streule on the Tectonic Evolution of the Alps, where we heard that nappes are "tectonic sheets of rocks and rock assemblages, many remote from their sources … allocthonous nappes, originating in a place other than where it is found or autocthonous, formed in the present position". Over the week, through visits to the various geosites in Chablais, and under Sophie's tutelage, our understanding progressed a long way as we studied both the rocks and the structure of each of the nappes in this area of the Western Alps and the relationship between them. Our "bible" had been the hand-drawn Coupe Geologique (Fig 10) and each day we had been able to locate ourselves on this diagram, piecing together the complicated story of the formation of the Alps with the help of Sophie's expert knowledge. She introduced us to the current work that was taking place in this field. Alongside this over-arching story, each geosite had other features to study as well as its location related to a particular nappe structure. We were able to piece together the glacial history of the Chablais area and Lac Leman, the post glacial drainage pattern and the hydrology related to the water supply industry. A day spent at le Mer de Glace gave us the opportunity of studying active glacial processes. The mass wastage of the glacier over the past 20 years is a stark reminder about the effects of global warming.

Report and photos by Hilary Jensen

We are very grateful to Sophie for leading the interesting, informative and diverse field meeting in the Chablais Geopark and we were pleased to meet some of the Geopark guides at the various sites.

Also many thanks to the hotel staff who made us very welcome, provided memorable meals and transport throughout the trip. During the smooth journey home we could ponder over our next venture. These are wonderful opportunities to learn some geology, in wonderful surroundings and with great company.

GLOSSARY

Allochthonous: Displaced from its parent geological unit and forming part of an unrelated geological unit.

Autochthonous: Produced or formed in the location where it is found. The term refers to whole formation rather than the constituents.

Décollement: A detachment structure of strata associated with over-thrusting. It results in disharmonic folding, i.e. independent patterns of deformation in the rocks above and below the decollement.

Flysch: A sedimentary deposit typically consisting of a thick sequence of interbedded marine shales and greywacke sandstones that were deposited by turbidites and display graded bedding.

Molasse: An association of shallow marine and non-marine conglomerates and sand stones, the non-marine sediments being deposited as alluvial fans and lacustrine deposits. Rocks of the facies are associated with erosion and deposition during the post-tectonic phase of mountain building.

Nappe: A large sheet-like body of solid rock that has moved a long distance at low angles over the underlying rocks either by over-thrusting or recumbent folding (in which the fold axes are approximately horizontal).

Olistostrome: A sedimentary deposit containing a chaotic mixture of blocks, some very large, in a muddy matrix that is believed to form by submarine gravity sliding or debris flow in a continental slope and rise environment. The clasts are known as olistholiths.

Ophiolite: A suite of igneous rocks which represent segments of oceanic lithosphere emplaced on the continent during plate collision.

Xenolith: An inclusion in an igneous rock that has been introduced rather than crystallising from the same batch of lava.

From Left to right: David Ward Ailsa Davies Mike Ledger David Riley Clare Fone David Price Chris Fone Peter Worsley Edmund Shirley Sophie Justice Susan Barr Christine Hodgson Christine Moore Hilary Jenson Roger Moore Barbara Barrett Norman Gregory Roger York Ann Marriott Carole Gregory Louise Knight