Farnham Geological Society

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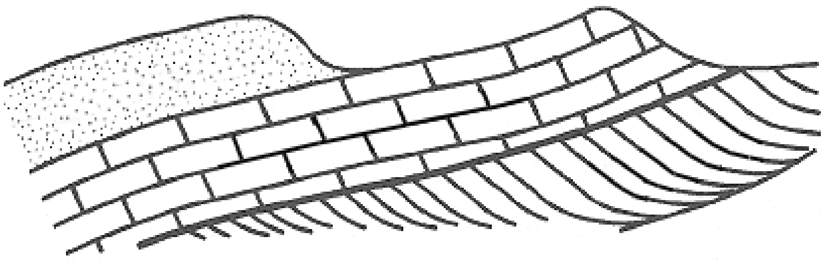

A local group within the GA

Vol. 17 No.1

Newsletter

Issue No: 86

February 2014

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Editorial

Sadly during 2013 Julian Bentinck died; he was a founder member of the Society and contributed significantly to its development, particularly throughout its early years. Also Roy Mitchell of Camberley died, he had only been a member since 2012 but like Julian, will be sadly missed.

Janet Phillips has decided to resign from the Committee, she will be very much missed but her resignation comes after a long period on the committee as publicity secretary. We would like to thank her for all her efforts and to now wish her the enjoyable 'leisure time' this will give her.

2013 was a busy year for the newsletter - with summaries from most speakers and with good reports of most of the fieldtrips. Whilst it is impossible to get all speakers to provide summaries of their talks, I should like to get reports from ALL the fieldtrips – not only is it a good record of the society's activities but it is interesting for members who were not able to go and if any member wants to visit (or revisit) the location they have at least a starting guide to the area. So if Graham has not volunteered you to write up something on the trip, could you please volunteer yourselves and send me your contributions for the newsletter.

We have been asked to advertise the GA Southeast Regional Conference on Saturday 29 November 2014 at Amberley (Chalkpits) Museum and Heritage Centre, with the broad theme of Geology and History in Southeast England **(**the entire Wealden Anticline), a broad spectrum of interests and presentations. Details and Registration Form, will be available in due course from the GA. If any FGS members are interested in presenting their research or ideas, they should contact GA (Michael Oates)**.**

Lastly, a note from Lyn Linse: "*A huge thank you to all who have sent cards, visited or helped me during my recent surgery and recuperation for an unexpected heart problem. You lifted my spirits. I am recovering well and shall soon be back in action. Cheers to all*".

FGS field trip to the Paris Basin – October 2013

Led by Rory Mortimore, Prof. Emeritus, University of Brighton & reported by Helen Davies, Member FGS

An introductory talk on the Paris Basin field trip by Rory Mortimore

Rory presented the Society with an outline of the geology of the Paris Basin as a forerunner to the following field trip to the Paris Basin which has been written up in detail by Helen Davies below. He explained how his work had concentrated over the years on the engineering geology aspects of the Chalk - the significance of fracturing, pore water saturation and rainfall on rock stability and flooding potential; and on the stratigraphy and facies changes, both widespread and local, that are present in the Chalk. The engineering work had required drilling and flooding Chalk sections to analyse the locality's potential for cliff instability and flooding.

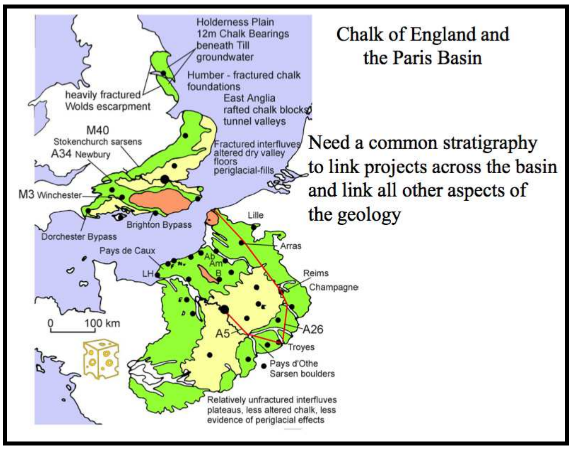


Fig. 1: Geological Sketch Map of Cretaceous & Tertiary Beds of England and Paris Basin

Rory described one area of flooding, in the Somme: Flood forecasting based on effective rainfall, evapotranspiration and piezometric levels had not provided reliable predictions. It was known that the aquifer (groundwater) contributed to the extent and duration of flooding (picked out by a rise in piezometric levels) but a crucial unknown remained - when or where would floods occur and for how long. The conclusion was that research should focus on well-instrumented catchments in areas where the geology had been mapped and the material tested**;** further a common stratigraphy was needed for the Chalk of the English and Paris Basins to link projects and all aspects of the geology across the basins.

A simplified map (Figure 1) and stratigraphic section (Figure 2) has been developed and was shown for use in the subsequent field trip. This had been developed using basin or interbasinal marker beds:

- Marl seams - many volcanogenic;
- Types of flint e.g. Tubular Flints (Lewes/Shoreham); Zoophycos flints; Paramoudra flints;
- Trace fossils e.g. Cuilfail/Beachy Head Zoophycos Beds; and
- Macro-, micro-, and nannofossils.

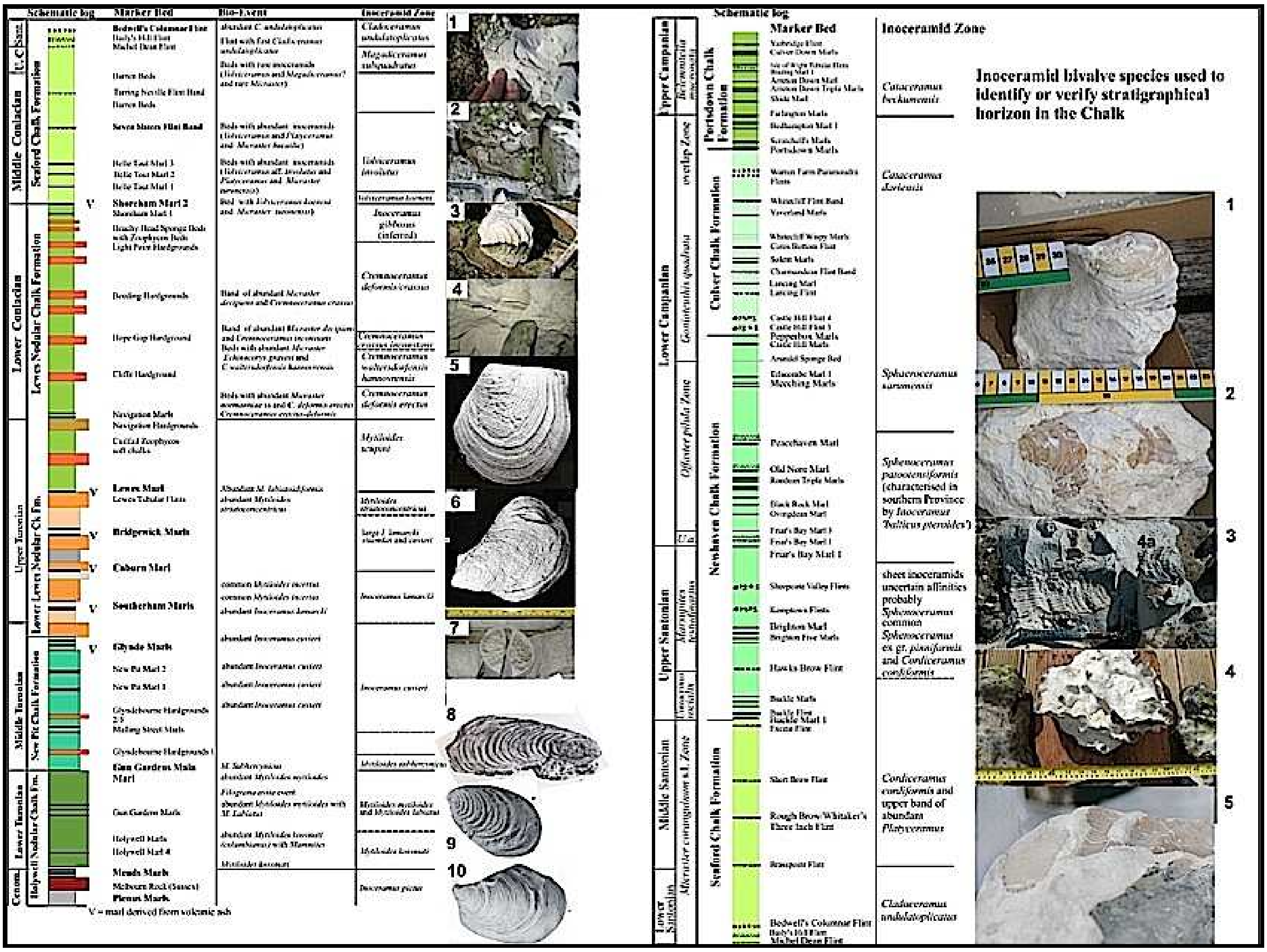


Fig. 2: Detailed Stratigraphy of the Chalk showing Marker Beds and Associated Fossils

Work for the detailed stratigraphy (Figure 2) from the numerous field sections described by his teams, identified not only important regional marker beds but also localised, interesting variations in the facies of the Chalk. These varied from hardgrounds and heavily bioturbated sections, to various types of flints in various stages of formation and to distinct sedimentary structures, many of which could be related to localised highs, actively moving during deposition. These are all presented in detail by Helen in her field trip report but a sketch showing their development forms Figure 3 here.

This talk prepared the party for the trip to the Paris Basin and the coast of Normandy, with its interesting facies, flint development and cliff instability, which commenced the following day and is reported below.

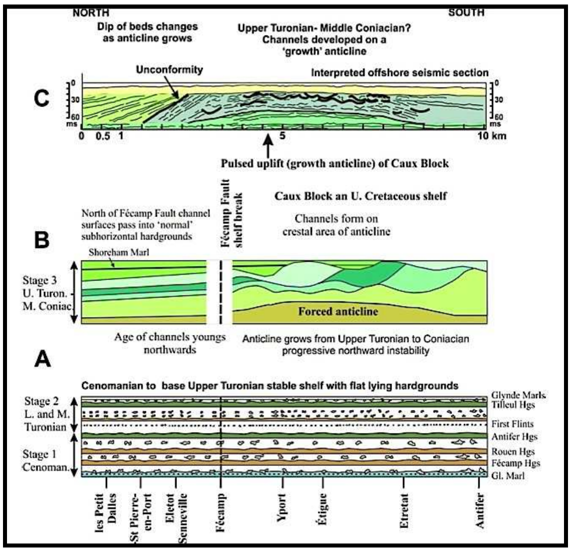


Fig. 3: Sketch to demonstrate growth of localised anticlines and resultant channels, slumps and hardgrounds.

The Field Trip Report:

This excellent field trip was organised by Graham Williams, led by Rory Mortimore. We were joined by Bernard Hoyez from the University of Le Havre, who, like Rory, has worked on these exposures for many years. The field trip set out to observe and investigate the origins of Chalk deposits, its structures and lithologies and geographically traceable stratigraphic units throughout the Paris Basin and across the Channel into S England. The Paris Basin exhibits classic inversion tectonics which pre-date the Alpine Orogeny. The structures and major faults trend NW-SE. The cliff sections along the Upper Normandy coast in France offer the chance to see an excellent succession through Chalk, which contains complex depositional geometries such as erosional features, channelling, hardground formation and dolomitisation. Perhaps the most distinctive feature in the Chalk is the formation of flint, particularly in traceable bands that can often be correlated across thousands of kilometres. Particular marker beds are observable such as marl seams, nodular horizons and flint bands, e.g. the Seven Sisters Flint Band (SSFB). In the absence of these features, macrofossil markers, most notably inoceramids, *Micraster* and *Echinocorys* and trace fossil markers, such as *Zoophycos*, *Chondrites*, *Bathicnus* and *Thalassinoides* are used to define the stratigraphy. The map in Figure 1 sets the scene showing the localities to be visited.

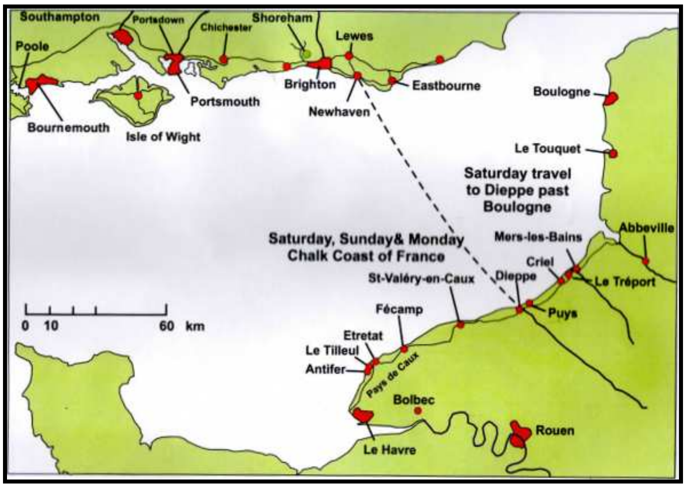


Fig. 1: Location Map (Rory Mortimore)

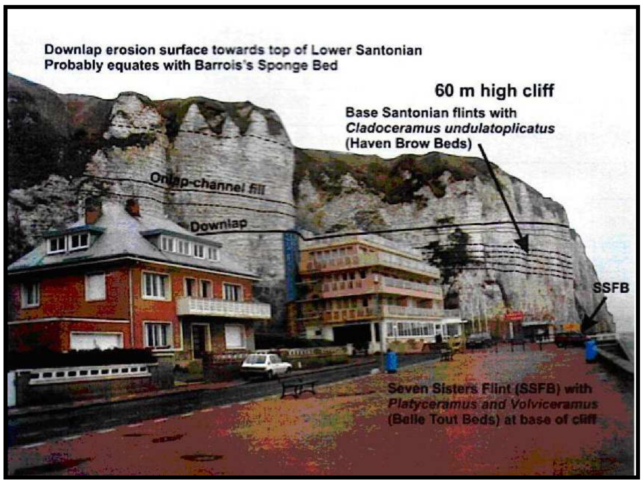


Fig. 2: Dieppe W Seafront (Rory Mortimore)

Flint Formation in the Chalk

Flint is a cryptocrystalline form of quartz (SiO_2) and forms when the chemistry of pore water in seafloor sediments changes during diagenesis. As sediments build up on the seafloor, they eventually become compressed and silica-rich organisms (such as sea sponges and siliceous micro-organisms - radiolarians) are buried and begin to decay anaerobically (oxygen absent), producing hydrogen sulphide (H_2S). Cavities, such as burrows, provide a preferential pathway for the upward migration of H_2S. The sulphur component reacts with oxygen in the pore water, resulting in silica precipitation (SiO_2) both in these cavities and in beds parallel to the seabed. This 'mixing zone' occurs in the top 0.3m of the seabed and runs parallel to the seabed. So three necessary elements are required for flint formation to develop; a source of oxygen (in the pore water), a source of sulphur (bacterial decay) and a mixing zone (H_2S gas rising through the sediments and oxygen moving down through the sediments in the pore water).

Day 1 – Dieppe West Seafront

This section of coast is a vast cliff expanse of columnar jointed Chalk containing fractures typically inclined at 15-18°, parallel and cross-bedded flint bands, karst features, filled cave systems, hardgrounds and an underground river. A distinct downlap surface cuts down through the underlying Chalk (top of Lower Santonian). This is a hardground, a former sea floor surface, which has been mineralised and hardened. This particular hardground represents the inclined surface of a marine channel. Deposits above this layer on-lap onto this surface and represent a long period of erosion and deposition. In the parallel flint bands at the base of the Lower Santonian, the inoceramid bivalve *Cladoceramus undulatoplicatus* occurs (refer to the stratigraphy column, Fig. 2, of Rory's talk above for details).

Figure 2 shows the cliff face at Dieppe West and some of these features. This locality is at the western end of the NW-SE trending Pays du Bray Fault axis (also seen in E Isle of Wight). Movement along this tectonic axis has impacted on the deposition of Chalk sediments. Reactivation of existing faults results in basin inversion and can create an environment in which erosion of the hardgrounds can occur.

Near the base of the cliff a prominent flint band, the SSFB, can be seen and is traceable laterally along the cliff. This represents a change in permeability of the strata (an aquiclude), preventing further downward water migration, causing it to concentrate at this point, instigating karst development, which eventually caused the development of an underground river system (Figure 3).

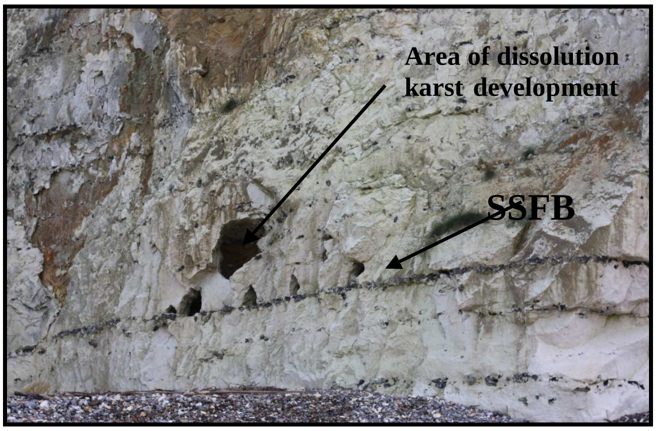


Fig. 3: Karst development above SSFB (lower arrow)


Fig. 4: 'Holey' Chalk above SSFB (arrowed).

The initial karst or tubular development appears as a 'holey' chalk situated above the SSFB. The 'held-up' water gradually dissolves the chalk, due to it's chemistry or changes in chemistry, initially creating an interconnecting network of small tubes, which grow upwards from the permeability contrast surface (also from faults etc.), see Figure 4. The creation of voids can lead to a significant (30%) reduction in Chalk volume. As dissolution continues, the underground river deposits sediments within the voids, which can become larger, forming caves, and exhibit cross-bedding.


Fig. 5a: Dissolution features such as fluted surfaces and cavity formation.


Fig. 5b: An unfilled cavity with finely laminated red 'washed down' sediment.


Fig. 6: Red sediment has been washed down, filling collapsed chimney pipes in the Chalk.

‘Fluted’ surfaces (Figures 5a and b) are evidence of subterranean palaeostreams, often within an open cave system. Some sediment infills show fine banding and cross bedding, indicating the direction of water flow. On a larger scale within the cliff, chimney formation (cave collapse) provides pathways for downward water movement, resulting in further Chalk decay and infilling with orange-red Quaternary sediment (Figure 6). A large cave collapse adjacent to a fault formed a vertical column, or chimney, through which water had flowed down, carrying sediments deep into the karst system of the underlying Chalk. Nearby a cave had collapsed and filled with laminated sediment washed down via joint planes, dissolution pipes and fractures.

The age of the SSFB can be ‘bracketed’ by it’s associated fossil assemblage. Typically 1.6m below the SSFB, the inoceramid bivalve *Volvivceramus* is present, characterized by it’s curved shell. Above the SSFB, the inoceramid *Platyceramus* occurs with its large, flat, thin shell (refer to the strat. column in Rory’s talk).

Another feature present in the Chalk is white patches that appear to pinch out (Figure 7). They cut through primary features and so must be post sedimentary.

Fig. 7: White veins and ‘pinching’ features, characteristic of secondary features in the Chalk.

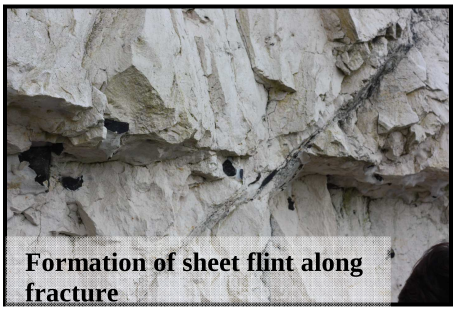


Fig. 8: An example of sheet flints in fractures within the Chalk.

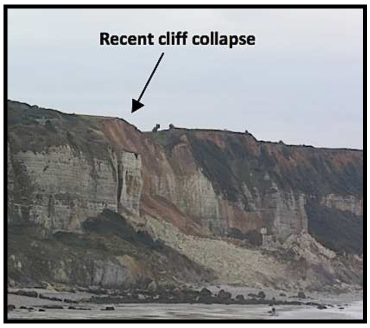


Fig. 9: View from Cap d’Antifer towards le Havre

Some flints have formed inside fractures, initially forming on the walls, indicating an early fracture, with a chalky layer in the middle (Figure 8). The creation of voids accelerates erosion of the chalk by creating zones of stress relief, resulting in “stress flaking” of the chalk - often circular fractures on the ceiling of a cave; as the chalk breaks up in this way, large ‘chambres’ are created. This sort of erosion in the Chalk can have significant considerations for engineers when tunnelling.

Day 2 – Antifer, Tilleul, Coast of Pays de Caux

Travelling West from Dieppe to Antifer (cliffs in Figure 9) the geology ‘youngs’ (Figure 10). The topography consists of deep, faulted valleys (trending NW-SE, in line with the regional tectonic trend) and high, gently dipping plateaus, covered with red loess. This section of the coast, the Pays de Caux, exposes the margins of the Paris Basin.

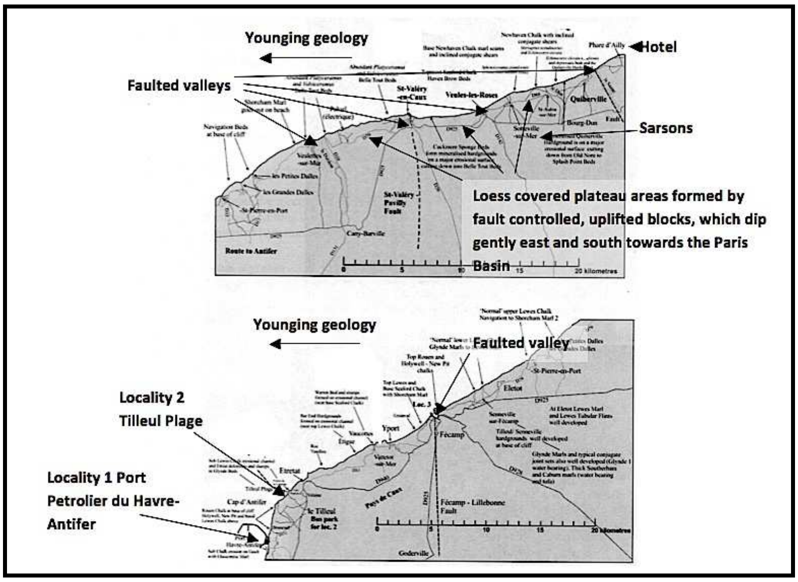


Fig. 10: Dieppe to Port du Havre-Antifer

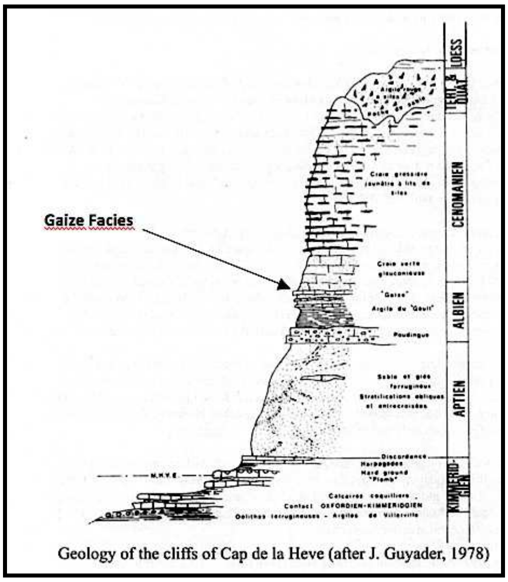


Fig. 11: Section exposed from d’Antifer to Havre

Locality 1 – Port Petrolier du Havre – Antifer

Here (Figure 9), at the most southerly end of the section, the base of the Cenomanian can be observed. It comprises dark green 'flecked' glauconitic silt/marl with many bored, rounded clasts of glauconite, quartz pebbles, shells and wood. This rests on a softer grey silty base with tubes and burrows of glauconitic sand from above. This is the Gault at the top of the Albian in the Gaize facies (see Figure 11). Above the glauconitic beds, moving up into the Lower Cenomanian, is a grey chalk containing banded black-centred, flints and sporadic grey-centred, cherts and shallow water bivalves. The re-worked glauconitic succession at the top of the Lower Cretaceous can be seen across the base of the Anglo-Paris Basin and signifies a marine transgression from shallow sea, deepening to a shelf environment.

The cliff face shows deep dissolution pipes, faults and flints with different characteristics. Some flints are irregular in shape, reflecting burrows and formation in the mixing zone just below the seabed. Some are iron stained inside with pyrite and gypsum, which is used as another marker bed. Other flints appear bigger than the original burrow they have replaced, where the flint starts to form on the walls of the burrows and then over-grows the burrow cavity into the adjacent sediment.

Hardgrounds are present; the hardening is a long process, with many layers of mineralization and sedimentation in burrows. The ages of the burrows vary vastly from seabed hardgrounds so the locations of both micro and macro fossils are important in determining the age of hardgrounds. Higher up in these vast cliffs, the Plenus Marls sits below the Melbourn Rock succession of Late Cenomamian. Here they contain flint/chert bands and hardgrounds.

Locality 2 – Tilleul Plage

At Tilleul, the transition from top Cenomanian into Turonian can be observed as a change in chalk colour from grey to white, again indicating a deepening water setting. The base of the cliff contains knobbly cherts up to 0.6m, caused by animal burrowing. The early stages of flint development, pseudoflint, is present showing a weaving texture and a squashed, mottled clay layer with a black flint core. There are burrowed glauconitic horizons (Figures 12 a and b) and trace fossils such as *Thalassinoides* are present.

Fig. 12a: Green glauconitic material highlights the bioturbation.

Fig. 12b: A branching burrow, *Thalassinoides*, associated with glauconitic material.

Marl bands/seams are present within the hardgrounds and contain echinoid spines, belemnites and brachiopods, the same fossil assemblage as in the Plenus Marls but in a different lithology to the Plenus Marls (Figure 13). This makes the marl bands here an ecological niche. There is also no flint in the marl bands because the mixing zone was not present due to the clayey nature of the marl bands affecting permeability.

Fig. 13: Marl band with echinoid spines and belemnites.

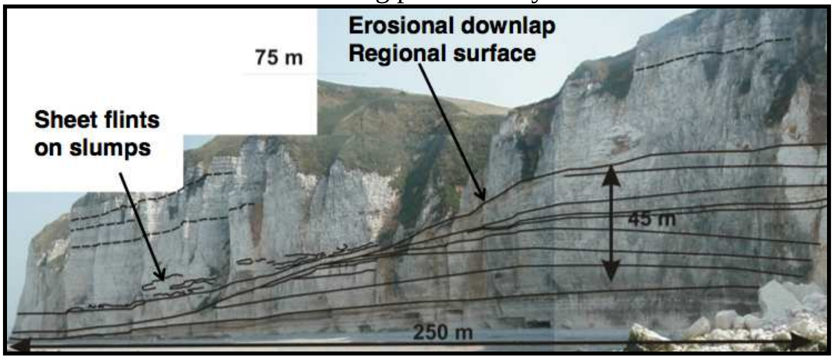


Fig. 14: Erosional downlap surfaces and onlap deposition indicating periods of uplift as local high grows during Upper Cretaceous sedimentation.

Evidence of massive scale movements is visible in the cliffs, in the form of stacked channels (creating mounds), erosion, slumping, hardground formation and faulting. Some of these synsedimentary processes can be seen in Figures 14 and 15. Split and broken flints are evidence of flint formation during slumping or vice versa also depicting large scale movements. Sheet flints occur along slump surfaces. This seabed activity stops where parallel bedding re-occurs in the cliff.

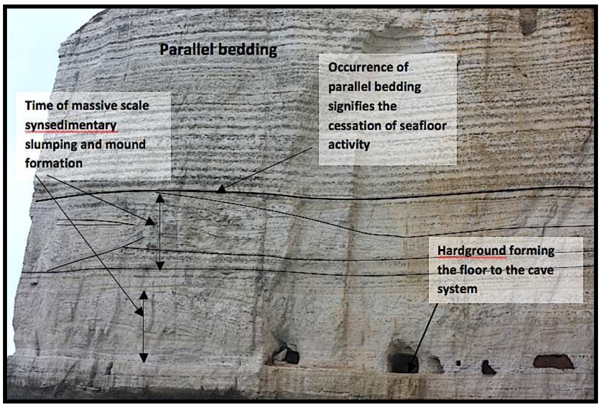


Fig. 15: Seabed activity ceases & parallel bedding resumes.

Fig. 16: Clearly visible sub-Lewes erosion.

Some areas contain pink flint, which is caused by chemical changes in the groundwater due to the presence of magnesium, possibly related to the proximity to dolomitic limestone in the area.

The trace marker fossil *Zoophycos*, which is traceable across the basin is characterized by a spiraling, tubular, black flint structure and occurs between hardground horizons. It is suggested it could be a grazing pattern of an unknown organism and represents the last trace fossil to work the sediment (Figure 17).

Fig. 17: Burrows left by *Zoophycos*, now replaced by flint.

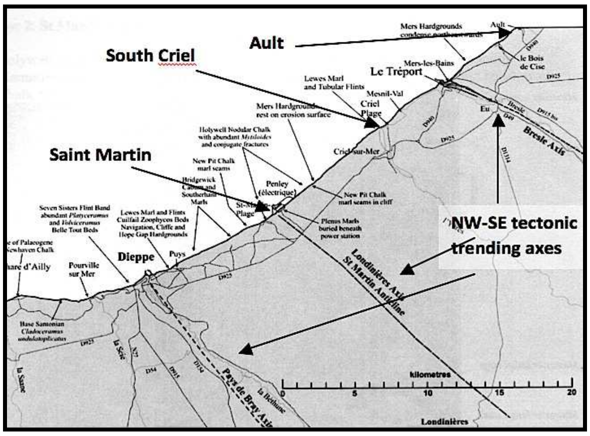


Fig. 18: Location map of St Martin, S Criel and Ault.

Day 3 – Saint Matin

The location map in Figure 18 shows the localities visited. The sequence here shows the entire rock column of the basinal succession, equivalent to the Holywell Beds in S England. The basal beds are Plenus Marls and Melbourn Formation, as Day 2, but a much thicker succession and the marl bands are further apart.

The beach is entered by a valley, on either side of which, there is fractured Chalk, indicative of periglacial fracturing. The Holywell Chalk can be seen as at Beachy Head in S England. There are many bivalves (*Mytiloides*) which are less diverse than the inoceramid assemblage. There are also giant (ca. 2m) nektonic ammonites, *Lewesiceras*, present, which indicate a deeper water environment. The smaller, nodal *Mammites nodosoides* is also present.

The rock face shows conjugate jointing (Figure 19). Shallow, obtuse angles near the base become more acute higher up the sequence. This change in fracture style within the different formations can be important from an engineering perspective. There is no flint in the Chalk here but there are many interweaving marls and bedded marls containing f-c grained intraclasts of rolled, broken chalk - an environment of constant re-working, possibly storm events, which have removed the nuclei necessary for flint to form.

To the North, the New Pit Chalk has more distinct bedded marls, which provide planes for stress slip or slides and represents a greater thickness of the basinal succession and both flint and the trace fossil *Zoophycos* re-occur.

Fig. 19: Conjugate jointing at Saint Martin.

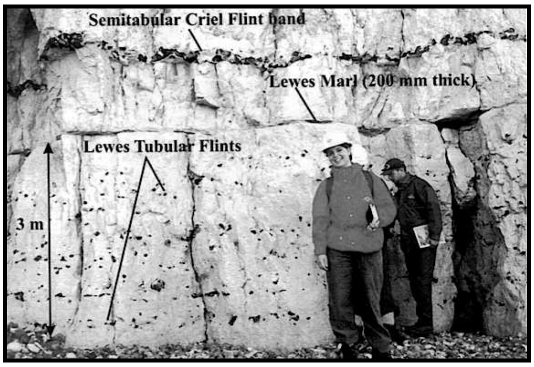


Fig. 20: Cliff exposure at Criel South.

Fig.21: Paramoudra (ca 13cm tall)

Criel South

At this location, a fault controlled river valley, with jointing parallel to the valley axis, shows stress relief with groundwater movement along orange-stained fractures. It is an excellent exposure of the Lewes Marl and Lewes Tubular Flints (Figure 20). The pumping stations and wells are all positioned along the margins of the valley, where permeability is highest due to the fractured state of the Chalk.

At beach level, there is a 3m thickness of Lewes Tubular Flints displaying non-layered, branching, interconnected tubular flint. The, often hollow, flint tubes have an inner flint core surrounded by white chalk (original size of the burrow), surrounded by an outer wall of flint (overgrowth into sediment), representing two stages of flint formation. The branching flint, the *Zoophycos* marker bed, is traceable across the basin and indicates the same conditions for deposition were present everywhere in the basin at the same time. The strata are also full of scleractinian (coral) fossils and abundant *Micraster leskei*, traceable across parts of Germany and Russia, which indicates an expanded basin and succession, allowing time for flint formation to develop.

At one end of the beach, the Breaky Bottom Flint level (marker bed) is exposed on a wave-cut platform. Large (1-4m) sometimes hollow, columnar flints with vertical cylindrical shafts (paramoudras) stand proud of the beach (Figure 21). The brown-green pyritic and glauconitic flint surrounds hard cemented chalk often with the mm-sized trace fossil *Bathichnus paramoudrae* down the middle. The mechanism of formation of these structures is unknown. Possibly they are caused by chemical changes in the water due to fluid interaction with the skin of the organism leaving the trace fossil or maybe by seismic events providing fluid escape columns carrying fluids with different chemistries.

Above the Lewes Tubular Flints is a 0.23m grey marl band - the Lewes Marl (Figure 20). The relatively low permeability of this volcanic ash/clay deposit caused the cessation of flint formation by preventing the migration of water thus the *Zoophycos* marker bed is not present above the Lewes Marl. Slickenslided surfaces are visible on the base of the marl indicating sliding has taken place. The surface of the marl is packed with Inoceramids and *Micraster leskei*. Further up, the rock face consists of chalk and tabular flint layers typically 1-2m apart. (Figure 20).

Ault

Ault is a cliff-edge town in the Department of Somme, which is gradually collapsing into the sea as a result of continued erosion and cliff instability.

Conclusions/round up of the trip

We viewed the Upper Cretaceous Chalk of the Paris Basin, from top Albian, through the Cenomanian and Turonian into the Lower Santonian (refer to Fig. 2 of Rory's talk summary). This demonstrated a marine transgression, corresponding with a global sea-level rise and continental flooding in the Upper Cretaceous, as seen across S Britain.

We noted various types of marker beds: - SSFB, hardgrounds, marl seams, trace fossils and jointing patterns, and their use as mapping criteria over long distances, particularly correlation across the Channel. We also saw how particular macro-fossil assemblages can help to 'bracket' the age of certain flint band markers (SSFB) and determine which part of the stratigraphy was being observed. We hypothesised that Milankovitch cycles were reflected in flint banding, responding to cyclical climatic changes. If this pattern is true, then the deposition and formation of flint would have occurred over long periods of time.

Columnar jointing in the Chalk at the base of the Lower Santonian and conjugate jointing in the Holywell Chalk indicate that particular fracture styles and frequencies are associated with different lithologies and formations.

The impact of hardgrounds, marls and flint bands on groundwater movement is evidenced by the extent of karst development (solutional erosion), which in turn allows the establishment of underground rivers, sediment-filled cave systems and chimney pipe structures.

Sequence boundaries produced by down-lap erosion (by channels) and on-lap deposition (channel-fill) exist within the Chalk succession. These disconformities represent a long period of erosion within the Chalk succession. Growth tectonics in the form of massive scale slumping in the Chalk and fault-controlled deposition/sedimentation has produced lateral and stratigraphic changes in the Chalk lithologies and indicates an underlying tectonic control.

We discovered that the Chalk is not a homogenous unit but that it changes laterally depending on where you are in the basin, on the margins (shelf environment), in a fault/tectonic zone or in a basinal setting. But there are some significant marker beds/horizons that are traceable and can be correlated across great distances.

The nature of the Chalk: porosity; permeability, fracturing and the varied depositional and diagenetic structures have great implications in applied geology. The cliffs visited in this trip have experienced collapse in recent times indicating just how unstable they are, as at Ault where drastic cliff falls and very rapid coastal erosion occurs.

References

The maps and many figures have been adapted from the FGS Field Handout courtesy of Rory Mortimore. Bernard Hoyez has made a video about this field trip and can be viewed at *http://craies.crihan.fr/?p=14749*.

Kola Peninsula, NW Russia: unusual Devonian igneous intrusions in the Precambrian basement – a tectonic Puzzle and a mineral extravaganza.

Summary of November 2013 lecture given by Chris Fone, Reading Geological Society

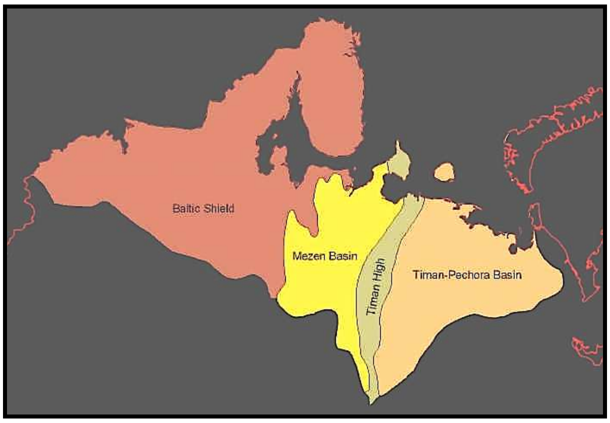


Fig. 1: The 4 geol. units which form NW Russia.

Below is background information from Maurice L.D. de Graaf's website, which contains basic information on the geology and mineralogy of Kola and maps which have been summarized below to set the scene for Chris Fone's account of his trip (go to: http://maurice.strahlen.org/). Figures 1 and 2 are from his website.

NW Russia comprises four major units (Figure 1). The Baltic Shield with exposed Archean rocks in the Kola Peninsula, Mezen Basin (Permian, Triassic and Jurassic sediments), Timan Belt fold belt and the Timan Pechora basin (thick Paleozoic sediments including coal and oil resources). The Kola province is divided into several structural units (Figure 2). Large blocks or domains, comprise mainly gneiss / granite gneiss - the Murmansk block (N coast), the Kola block (N of Khibiny and Lovozero), the Belomorian block (W, along the Finnish border), the Tersky block (S coast) and the Keivy block (central E Kola). Separating the blocks are elongate 'belts', e.g. the Murmansk block and the Kola block are divided by the Kolmozero-Voronja belt and S of the Khibiny massif lays the Imandra-Vasuga belt. There are numerous intrusions, of which Khibiny and Lovozero are two.

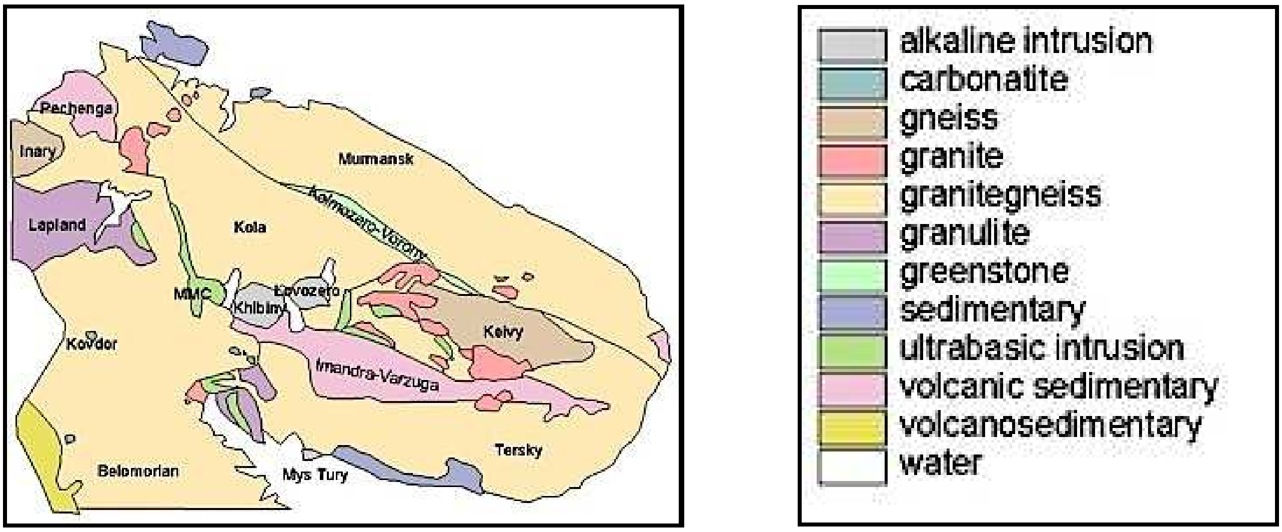


Fig. 2: L – Geological sketch map and R – accompanying legend

The Kola Peninsula in NW Russia has developed world fame for the number and rarity of minerals found in this region; more than 100 minerals were first discovered here. Three members of the Reading Geological Society were lucky enough to make a trip to the area in 2012 and, with the cooperation of the regional Geological Institute, experienced first-hand some of its wonders.

This talk explained some of the background planning, travel and local environment behind the visit. The history of the region and its development was also briefly mentioned. The overall geology which has led to the unusual suite of minerals discovered was discussed with particular emphasis on the two mountainous regions of Lovozero and Khibiny. These igneous intrusions of nepheline syenite were injected into the Precambrian Fennoscandian shield during the Devonian period. The Khibiny intrusion formed about 362 Ma and measures ca. 30km in diameter with varieties of nepheline syenite arranged in concentric circles with the centre comprising foyaite with xenoliths of carbonatite. The whole has been affected by hydrothermal activity which has created an abundance of exotic minerals.

Most mining activity developed in the S and SE part of the massif and most infrastructure occurs around the towns of Apatity, Kirovsky, Titan and Koashva.

A description of the sites visited and their geological significance was explained with the aid of photographs taken during the trip. The region is a geological puzzle and the minerals it exposes are incredible. They are a major source of income to the Russian economy and no doubt have surprises that have still to be discovered.


Fig. 3: View of lake in Kola Peninsula


Fig. 4: Minerals from the Kola Peninsula

Geological titbits from British Columbia

Summary of July2013 lecture given by Liz Aston, Member FGS

The geology of Western Canada is amazing and everyone tends to think of just the Rockies as the most spectacular thing and scenically that cannot be denied as shown by British Columbia's own spectacular chunk of Rocky Mountains – Mt Robson, Figure 1. But The Rockies are matched geologically by the dramatic geology of a different kind in British Columbia (Figures. 2, 4). As a state it has a very varied geology – and July's talk was designed to whet the appetite for this geology by tracing the course of the longest river in BC – the Fraser River which rises in the Rockies, close to the Intercontinental Divide, flows north along the Rocky Mountain Trench (RMT), Figure 3, a long (3500km) complex rift valley with a right-lateral slip component trending NW-SE. The Fraser River then makes a U-turn round the Cariboo Mountains and across the moraine covered interior plateaux.


Fig. 1: Mt Robson, part of the Classic Rocky Mountains

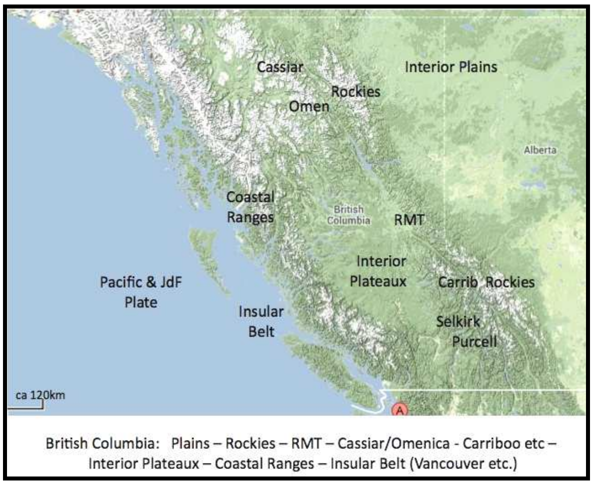


Fig.2: Compare with the geological map below

Fig. 3: (above) Lakes in the Rocky Mt Trench (RMT)
Fig. 4: (R) Ancestral North America (the large area of 3 colours in the E) includes the Interior Plains, Rockies, RMT & Cassiar/Omenica Belt.
The Interior Plateaux include the micro-continent of Quesnellia and other terranes (large green and buff colours) which docked from ca. 160Ma onwards.
The Coastal Insular & Outboard terranes are the purples along W have docked more recently & continue to dock.

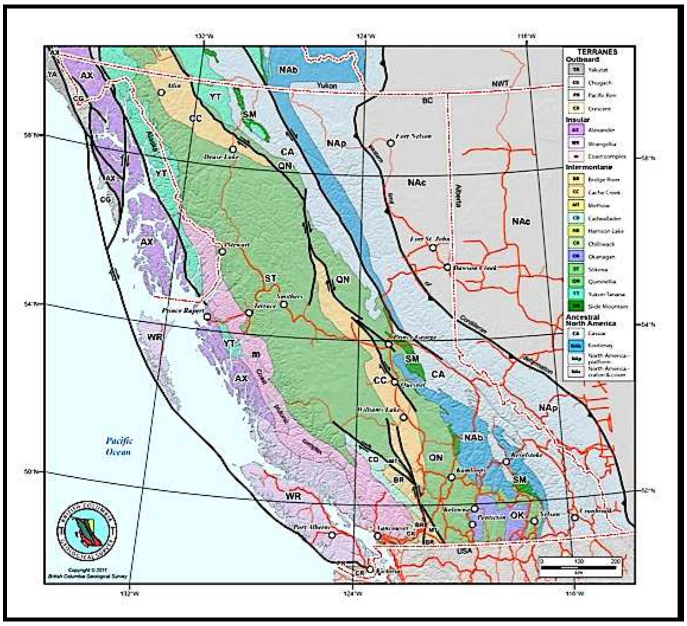


Fig. 4 – see explanation under Fig. 3

To the east lies the edge of Ancestral North America, i.e. the edge of the North American Archaean Craton, ~4.5Ga, which formed part of the Rodinia supercontinent from at ~1.7Ga. Rodinia split when NW Australia drifted away and this smaller continent was overlain by undisturbed Upper Proterozoic sediments (~900Ma onwards). During the late Proterozoic and Palaeozoic, a distinct facies change occurred which extended N-S from Yukon to the S Rockies and lasted ~300Ma. This change was from a deep water basin to the W, with thick shales, thin limestones and the famous Burgess Shale faunas, to thick shelf carbonate sequences to the E. This distinct facies belt extended along edge of the ancient craton and is known as the Kicking Horse Rim.

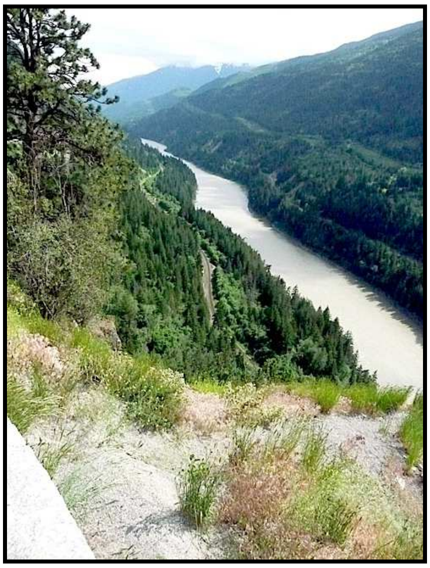
The Shuswap Area is believed to be the actual 'edge' of Ancestral North America (ANA) where the craton has been buckled and heated to form a complex of gneisses and intrusions, associated with the subduction of Quesnellia (ca. 400-180Ma) below the craton. This 'docking' of the micro continent (now the Intermontane Superterrane) caused the deep-level strong thrusting and deformation seen in the most westerly Rockies; the Rockies further east escaped a lot of intense deformation by long thrusts moving thick piles of very competent carbonates along shear zones within the incompetent shales.

The Intermontane 'Superterrane' comprises four terranes, part of a micro-continent which had already accreted before it subducted below ANA. The terranes include sections of oceanic crust, shallow water sedimentary sequences and island arc sedimentary/volcanic sequences, see Figs 5a,b from the Quesnellia terrane.

Fig. 5a (left) & 5b (right): The island arc rocks of the Quesnellia Terrane – sediementary sequences (a) and igneous (b)

To the west of the Interior Plateaux lie the Insular Superterrane and the Coastal Ranges. These are younger terranes which are believed to have accreted ~890Ma onwards. They comprise similar sequences of rocks - a mixture of volcanic island arc sequences, sea floor sediments and oceanic crust, and in the Wrangellia terrane (a sequence of island arcs and ocean plateaux with coral reefs of Paleozoic age.

The glacial features of the interior plateaux are classic – long, deep glacial lakes, eskers, kames, moraines of all types (Figure 6) and lacustrine deltas forming into ice-damned lakes, and gradually changing height, location, character as the ice melted. The Fraser River flows takes a sudden turn to E cutting the Fraser Gorge (Figure 7) through the Coastal Ranges along dextral transverse faults in a narrow, deep gorge which was deepened by waters released from the extensive ice-dammed lakes of Quesnel, Shuswap, etc.



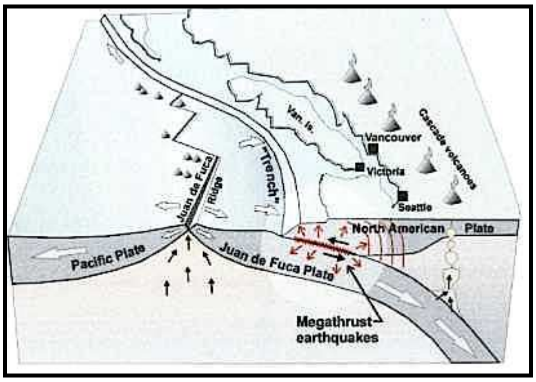


Fig. 6: (L) Thick moraine which Fraser River cuts through
Fig. 7: (centre) Fraser Gorge cuts through Coastal Ranges - Lillooet Ranges to West (RHS of photo) & Cascade Mts to East (LHS of photo)
Fig. 8: (above) Subduction of JdF Plate below North America

The current terrane which is in the process of accreting, is the small Pacific Rim Terrane exposed on Vancouver Island. This is the last section of Juan de Fuca (JdF) Plate to be subducting. The JdF Plate is a remnant of the Pacific Plate which brought the Quesnellia and Wrangellia terranes to the shores of ANA (Figure 8).

References

British Columbia, Geological Survey Website and Articles
Baird, D.M., Jasper National Park – Behind the Mountains & Glaciers
Cannings, S., & Cannings, R., Geology of BC, A Journey through time
Gadd, Ben, Handbook of the Canadian Rockies
Nasmith, H., & Yorath, C.J., A Guide to the Geology of S Vancouver Island
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FGS monthly meetings - 2014

Date	Speaker	Title of Lecture
10 January	Dr Graham Williams, Member FGS	AGM & A Geologist in Persia
14 February	John Williams Member FGS	Geohazards
7 March	Dr David Waltham, Royal Holloway College	Earth – lucky planet?
4 April **1st Friday of the month**	Jeremy Goff, British Petroleum plc	Exploring a Quaternary Volcano in Eastern Turkey
9 May	Dr Norman Moles University of Brighton	Bronze age mining in Ireland
13 June	Dr David Shilston Technical Director, Atkins Ltd	Landslides and Subsidence
11 July	Members' evening	-
8 August	No meeting	-
12 September	Dr Ted Nield, Geological Society, London	Meteorites
10 October	Dr Colin Summerhayes, Polar Institute, Cambridge	A Geological Perspective on Climate Change
21 November **3rd Friday of the month**	Dr Angus Best, National Oceanography Centre	Seafloor Methane Gas Hydrates
12 December	TBA	TBA