29th June 2012

Engineering Group of the Geological Society Field Excursion to the Upper Normandy Coast, France

Cliffs at Dieppe West – the first locality, Day 1

Leaders: **Rory Mortimore and Anne Duperret**
Organiser: **David Giles**

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Geology of the Chalk coast of France (Anglo-Paris Basin) Engineering Group of the Geological Society Field Excursion

29th June – 1st July 2012

DELEGATE LIST

Meeting Leaders
Prof Rory Mortimore (ChalkRock Ltd/University of Brighton) and Anne Duperret (University of Le Havre)

Chair of the Engineering Group
Dave Entwistle (British Geological Survey)

Meeting Convenor
Dave Giles (University of Portsmouth)

Delegates	**Affiliation**	**Delegates**	**Affiliation**
Terry McMenam	Arc	Chris Martin	BP
Darren McGrath	Arc	Arlette Cole	Crossrail
John Ditchburn	Arc	Dave Norbury	David Norbury Ltd
Geoff Heron	Arc	David Donaghy	GeoSea
Matt Free	Arup	Jesus Subires	GeoSea
Anna Morley	Arup	Judith Natanial	LQM
Ali Barmas	Arup	Ron Williams	Mott MacDonald
Romeena Haider	Arup	Catherine Rushall	Mott MacDonald
Yung Loo	Arup	Ivanka Brown	Mott MacDonald
Tom Casey	Arup	Andrew Bowden	Mouchel
Chris Bailey	Atkins	Graham Dorrell	Sladen Associates
Mark Scorer	Atkins	Sylvain Elineau	University of Le Havre
Eoin O'Murchu	Atkins	Sara Vandycke	University of Mons
Stephen Fort	Atkins		
John Perry	Atkins		
Catherine Kenny	Atkins		
Tracey Radford	Atkins		
Victoria Wanstall	Atkins		
Andy Farrant	BGS		
Jon Ford	BGS		
Joanna Thompson	BGS		
Richard Haslam	BGS		
Oliver Wakefield	BGS		
Dave Boon	BGS		
Marcus Dobbs	BGS		

Travel details:

Meet at 07.45 for a 08.00 departure from Coach Bay 1 or 2 at Ashford International Station for the 09.25 sailing from Dover to Calais.

The coach company is Diamond Travel UK. There is ample parking at Ashford International. We will be returning on the 19.55 sailing from Calais on Sunday 1st July back to Ashford International.

Accommodation is in the Hotel Aguado in Dieppe www.hotelsdieppe.com

Health and Safety issues:

Normal personal safety equipment is required (helmets, goggles, high visibility jackets); the rock, particularly flint is very hard and brittle and care with hammers is needed. Coastal cliff hazards include:

Tide – we will work around the tides and the leader knows the coastline well and issues related to tides including avoiding getting cut-off in caves. The Chalk cliffs do have cliff-falls and there are boulders to cross. Other areas of the wave-cut platform are slippery- sound walking boots are essential

The walk from Tilleul village to the beach and cliffs is about 40 mins each way. All the beaches are made of flint gravel with some boulder runs where cliffs have collapsed. Other walks are relatively short to the cliffs.

On Saturday there are toilet/refreshment facilities at the beach huts at Antifer cliffs but none on the long walk to Tilleul Cliffs.

On the Sunday most of the localities have toilets close to the beach and cafes/restaurants.

If the weather is good then sunglasses and sun protection is advisable as reflection off chalk cliffs and the sea can be severe. Sometimes the weather can be stormy and the exposed cliffs difficult and cold. Wet weather gear may be necessary. Recommend carrying water and a snack to each site.

Predicted Tides at Dieppe

Low tide on 29th June 2.29 pm CEST; on 30th June 3.43 pm CEST and 1st July High Tide 10.01 am CEST Low Tide 4.55 pm CEST.

Programme	**Location**	**Comments**
Friday 29th June 2012	Dover Eastcliff section	Seen from Dover Ferryport and Ferry
	Drive Autoroute A16 south from Calais	En route note the postion of the two Caps Cap Blanc Nez and Cap Gris-Nez The anticline of the Boulonnais
	Aire les Falaises de Widehem	The Widehem Anticline and Lewes Marl and flints
	At Abbeville take new A28 to Dieppe/Rouen	
	Either continue on A28 to Junction 10 and then the D915 to Dieppe (probably fastest route)	
	or	
	A28 to Junction 2 and then the D925 to Dieppe and Hotel (more scenic route)	
	Discussion on programme en route	
	Dieppe West Cliff	
	Park on Dieppe West Seafront: walk to sections on Dieppe west	Correlation in Seaford Chalk and Karst development in Chalk
Saturday 30th June 2012	Shopping in Dieppe for picnic lunch if weather good: Travel to Port Petrolier du Havre-Antifer and Tilleul Plage via the D925 to Veules-les-Roses, St-Valery-en-Caux, Cany-Barville, Fécamp, and Etretat to Antifer	Morning condensed sections, hardgrounds, sedimentology and tectonics in Cenomanian to Coniacian chalks on a platform: reinterpretation in terms of sequences and structure; hydrogeology Picnic lunch and afternoon on Tilleul Beach
	Depending on time and tide	Return to Dieppe
Sunday 1st July 2012		
	Drive north from Dieppe to St Martin Plage on the D925	What happens to the Turonian
	Drive from St Martin Plage to Criel Plage and Mesnil-Val	Cliffs at Criel Plage and Mesnil-Val-Plage: Lewes Marl and Flints plus valleys and floods: plus new data on cliff stability from the ROCC and PROTECT European programmes
	If possible visit Ault	Stability of cliffs
	Depart for Calais	

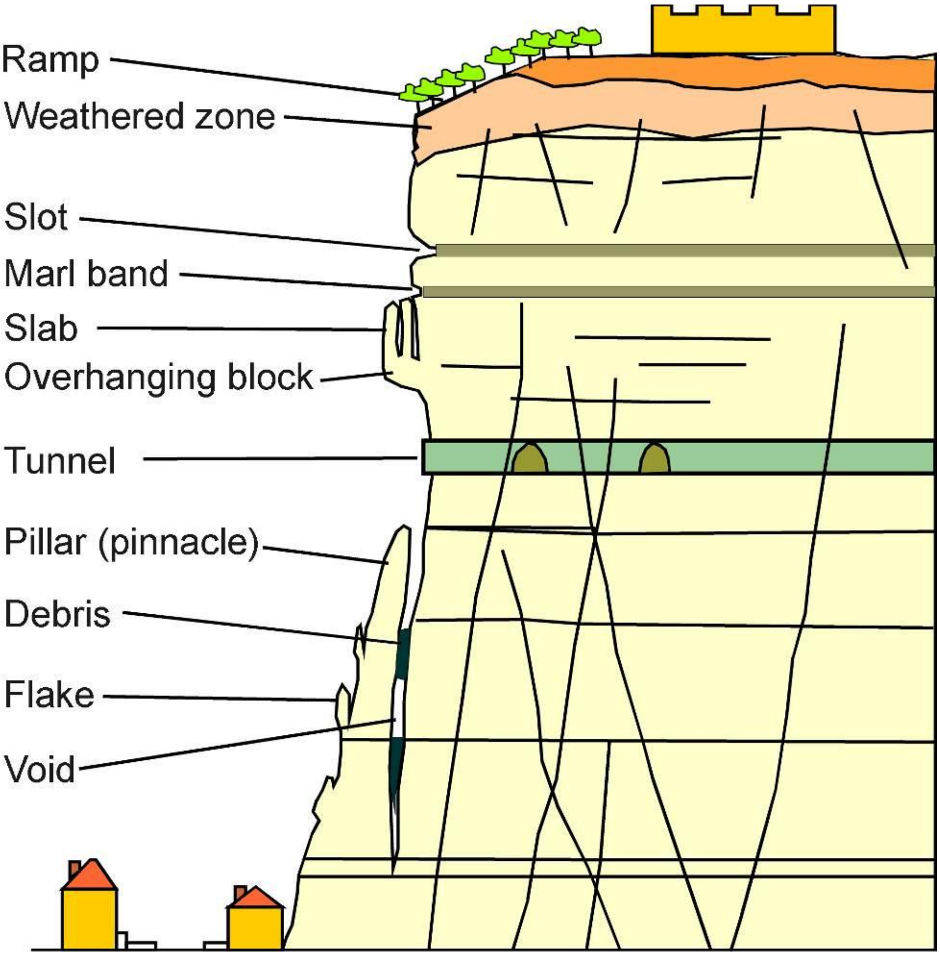


Figure 1. Schematic view of Atholl Terrace chalk cliffs, Dover

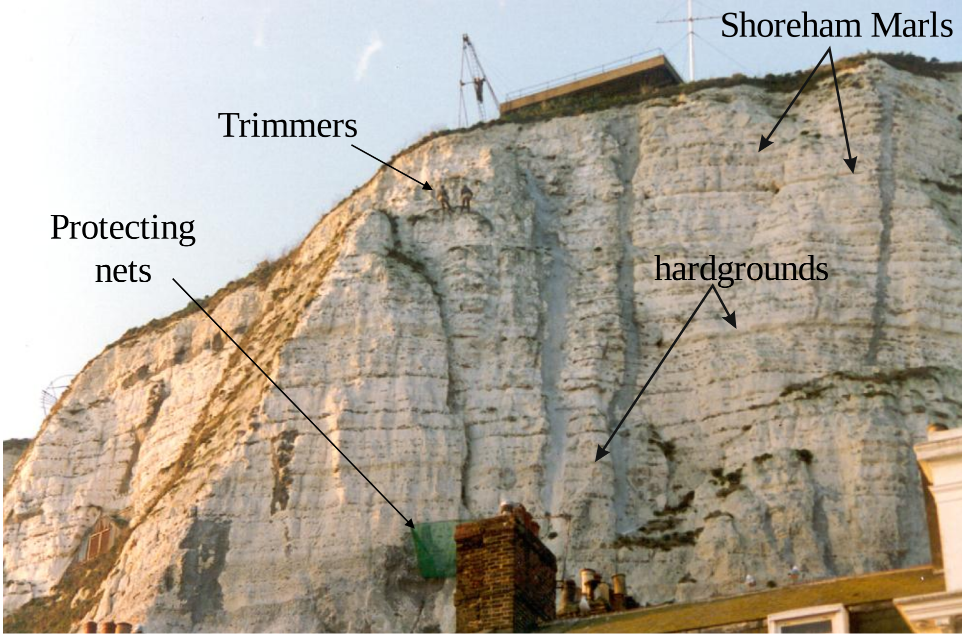


Figure 2. Trimmers removing unstable parts of the chalk cliffs at Dover Atholl Terrace

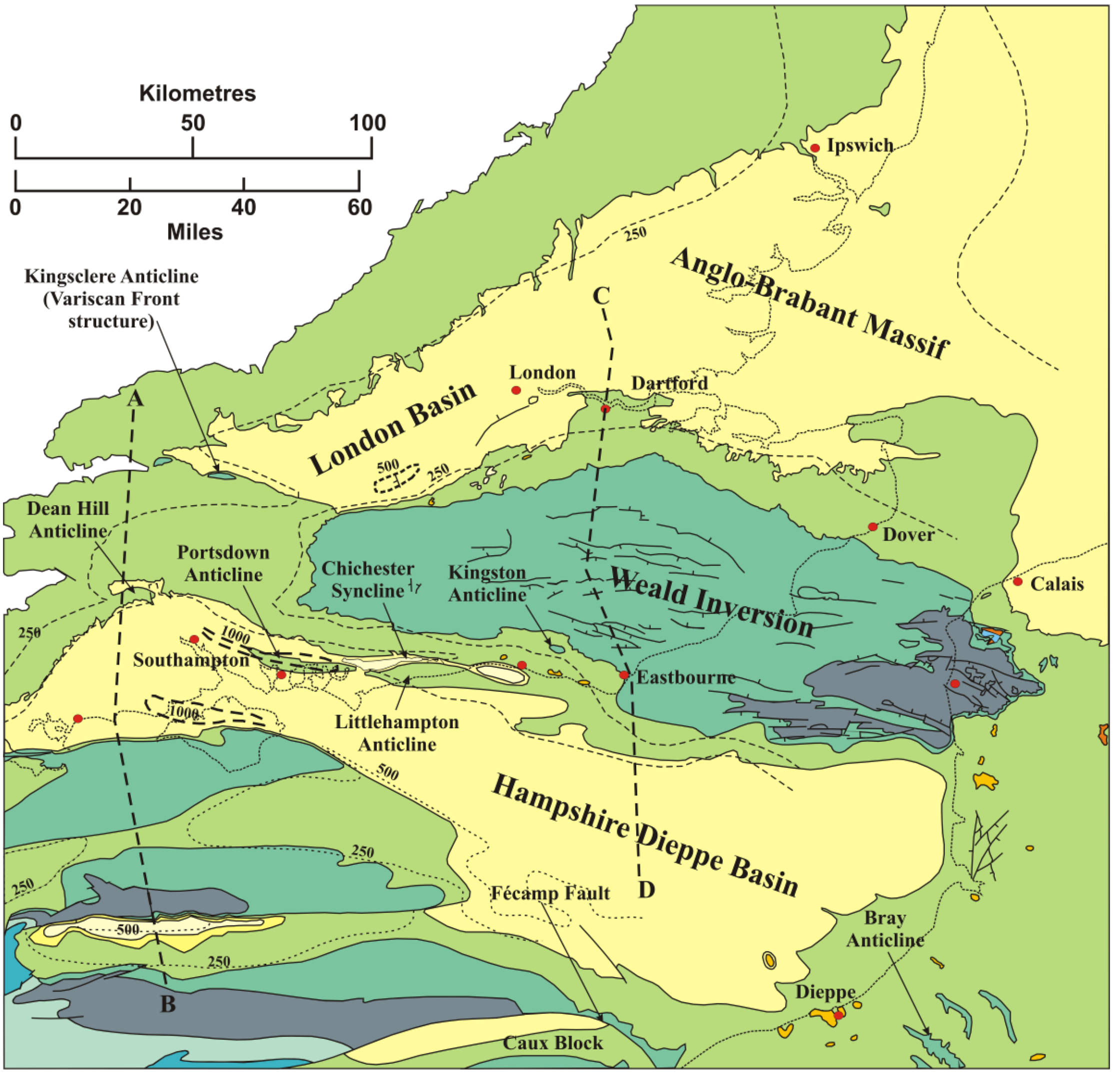


Figure 3. The Chalk continues across the Channel, partly buried beneath the Palaeogene deposits of the Hampshire-Dieppe Basin

Introduction: Why follow the Chalk?

Chalk poses many problems, not least because it appears to be so uniform, blanketing vast areas of the floors of former continental shelf seas and deep sea-floors alike. Was it formed in deep-water or shallow water, which directions did marine currents circulate, what was the impact of changing sea-levels, what criteria can be established for distinguishing between sea-level rises and falls and the influence of tectonics on sedimentation? Can intra-Chalk tectonics be used to explain the origin of many structures in the Chalk, for example:

- stratigraphic distribution of lithologies such as hardgrounds and cataclastic layers, slump beds,
- the geographic and stratigraphic position of major channels,

- vein fabrics and sedimentary dykes (pore pressure release fabrics),
- stylolitic marl seams and intra-nodule shearing (stratigraphically positioned within in one tecto-unit),
- styles and concentrations of particular fractures?

It is questions like these that have driven our research. This field excursion will attempt to answer some of these questions based primarily on field evidence.

Why Northern France? – The spectacular cliff sections between Le Tréport and Etretat provide an unsurpassed succession through chalks which exhibit complex depositional geometries including channelling, erosion features, dolomitisation, hardground formation. The sections also show distinctive flint formation which illustrates the potential for long distance correlation across the basin.

A bit about the Paris Basin

There are excellent guides to the geology of France produced under the editorship of Bernard Pomerol's father, Prof. Charles Pomerol, former Professor of Geology at Paris University. These are known as the Guides Rouge and Guide Géologiques Régionaux published by Masson, Paris. An English language version of the overview volume, ***Geology of France*** (1980), is a good introduction to the Paris Basin and its regional setting followed by the specific guide to the ***Bassin de Paris*** (1974). One of the best guides to the geology of France is provided by Charles Pomerol through the medium of ***The Wines and Winelands of France, Geological jouneys*** (1984-86; English Edition, 1989) published by BRGM, Orleans. There is a special journal for the geology of the Paris Basin (AGBP) ***Bulletin d'Information des Géologues du Bassin de Paris***.

BRGM have produced several excellent maps, one of the most useful is the Carte Tectonique de la France (Autran et al., 1980 and subsequent editions). As in the U.K there is a 1:50,000 geological sheet with an explanation booklet for each area. To see the more modern approach to mapping the Chalk in the Paris Basin it is worth looking at the 1:50,000 sheets for Courtney (Sheet 366, Pomerol, 1989 with litho and macrofauna stratigraphy by Mortimore), Blenau (Sheet 401, Pomerol 1989 with litho and macrofauna stratigraphy by Mortimore) and Arcis-sur-Aube (Sheet 262, Pomerol, 1996, with litho and macrofauna stratigraphy by Mortimore).

Like the London and Hampshire Basins, it is the Tertiary (Palaeogene) deposits that have been the focus of geological attention for the last 150 years. The Palaeogene produces a series of escarpments or cuestas and each formation a special landscape, each famous for a either wine/champagne or cheese!

The Chalk is not dealt with in any lithostratigraphical detail. Mapping the Chalk in France has been based on the Cretaceous stages and substages defined by microfossil zones. It was not until Rory and Bernard began working together that common lithological marker beds were identified across the Paris Basin from the Normandy coast to the Yonne and Aube (Mortimore and Pomerol, 1987). Subsequently the southern England Chalk formations were formally applied to the Normandy coast for BRGM (Mortimore, 2001b) and latterly in the Somme (FLOOD 1 Project).

The Chalk has increased in importance, particularly because of its aquifer potential. Each Department in France with extensive Chalk outcrops has become increasingly concerned with chalk hydrogeology. Latterly, Bernard has found a lot of his time taken up with issues related to water supply and pollution control which is now the focus of his own company.

There are several anomalous aspects to the geology of the Paris Basin. The first is the magnetic anomaly along the southern margin, through the Seine and under the Pays de Caux . This has been drilled and investigated without any conclusions. A second anomaly is the presence of channel structures in the Chalk of the Pays de Caux and beneath the Brie in the eastern Paris Basin. The Pays de Caux channels are exposed in the coastal cliffs between Antifer and Yport where they will be studied at Le Tilleul during the excursion. Those beneath the Brie were first identified on seismic sections (Hanot & Renoux, 1991; Mortimore & Pomerol, 1997; Thiry et al., 2003; Esmerode & Surlyk, 2009). Two boreholes have recently been drilled through these anomalies (for the CRAIE 2000 project, Robazynski et al., 2005) and have shown that there is up to 8 m thick dolomitic chalks similar to those present at Le Tilleul on the coast of the Pays de Caux on the surface of the channel anomalies (but at a different stratigraphic level). As part of the European funded 2004-2008 joint Anglo-French FLOOD 1 project (University of Brighton, British Geological Survey (BGS) and French Geological Survey (BRGM)) the Somme valley geology hydrogeology has been investigated and monitored. This has further illustrated regional trends in sedimentatiuon history in relation to tectonics and sedimentation (a key focus of Rory’s research).

On the French coast our field study will look at these unusual aspects of Chalk sediments and their geotectonic settings.

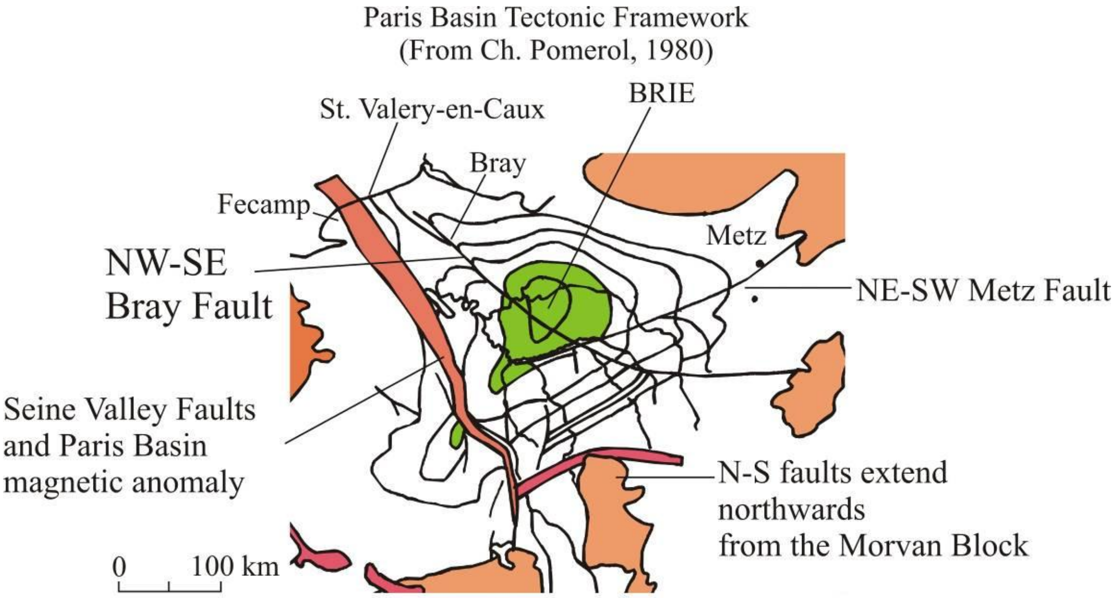


Figure 4. The outline structure of the Paris Basin (From Ch Pomerol, 1980)

Bernard Pomerol and Rory Mortimore worked together on the Anglo-Paris Basin and wider Chalk issues since 1980 but had first discussed a mutual interest in 1977 on the GA Field Excursion to the Sussex Chalk led by RNM. Our work has not been confined to stratigraphic investigations although these have formed an essential framework. We have been involved with production of Geological Survey maps and memoirs, hydrogeological and engineering studies. These have required investigation of sedimentology, structure, landscape evolution and the effects of Tertiary and Quaternary processes on the Chalk. When we started, many of the areas of study had not been seriously visited for more than 100 years and, in many cases, never studied before. There was also a very different 'approach' between French and UK geologists to this type of study and we have both benefited greatly from the co-operative research, despite national rivalries and internicine warfare within Cretaceous working groups! Absence of any other real co-operative study has led to confusing stratigraphic nomenclature which in turn reduces the effectiveness of Earth Science as a contributor to solving practical problems in engineering and hydrogeology.

This traverse of the French coastal geology is designed to introduce some of the recent ideas on the origins of chalk deposits as well as open discussion on the relevance of more pragmatic aspects such as:

(i) Lithostratigraphical divisions and mapping units; can an international lithostratigraphy work and, if so, what should we do to make it work?
(ii) What controls fracturing in the different types of chalk and can we use this knowledge to predict chalk mass features at depth?
(iii) How much karst has developed in different types of chalk and can the chalk be considered a karstic aquifer?
(iv) What are the critical factors for hydrogeological modelling and pollution problems in the basin?
(v) Can we take a basin analysis approach to engineering geology and hydrogeology rather than a single site or project approach?

In addition there have been major advances in:

(i) biostratigraphy with new microfossil and nannofossil zones recognised and being further refined currently;
(ii) better understanding of macrofossil distribution and evolution which can now be used to further subdivide the Chalk (e.g. Inoceramid Workshop at Hamburg, 1992, Freiberg 1996);
(iii) chemostratigraphy with refined use of Mn, δC^{13} and δO^{18} following Bernard's recognition of manganese (Mn), in palaeoceanography in 1976 and its link with δC^{13} (Pomerol, 1983); since then Milankovitch cycles have been applied to chalk (P.J. Felder, 1980; Gale, 1989) and chemostratigraphy applied to major events such as the C/T boundary (Pomerol & Mortimore, 1993; Gale,); for long-range correlation the work of Watkins (in press) has tested the original correlations on litho and biostratigraphy (Mortimore & Pomerol, 1987).
(iv) sedimentology with the studies of phosphatic chalks (e.g. Jarvis, 1980; 1992) and the possible tidal scour channels of the Etretat coast (Quine & Bosence, 1991) and of trace fossils related to stratigraphy and eustatics (Mortimore & Pomerol, 1991);
(v) understanding tectonic controls on sedimentation and partitioning the basin during chalk formation.

(vi) reinterpretation of many of these structures as sequence boundaries (Mortimore 2011)

These studies have illustrated the unique place of the Chalk in European and world geology. Nevertheless, for the field geologist, the engineer and the hydrogeologist it is the marker bed stratigraphy and the mappable lithological units that have the most application. Marker beds of marl seams, nodular chalk horizons and flint bands are the key for everyday correlation, geophysical borehole log and seismic section interpretation. This is where we began in 1974 and it is still the correlation of these markers that is providing us with a new understanding of previously unexplored parts of the basin. Where some of these markers disappear, then it is the macrofossil markers, primarily inoceramids, *Micraster* and *Echinocorys*, that have proved to be the most important indices, often associated with key trace fossil markers of *Chondrites*, *Zoophycos*, *Bathichnus* and *Thalassinoides*.

Investigations for the new Chalk stratigraphy in southern England, which we then applied to the rest of the basin, began in the early 1970s. This was initiated because of inadequate information available for construction of major roads in the region. Coincidentally the Geological Survey was also beginning a new mapping programme in the south Weald beginning with Lewes. For the Chalk, however, the maps were simplified with no Middle/Upper Chalk boundary being recognised. Thus the Lewes Memoir (1987), which incorporated the new information, is an advance on the map.

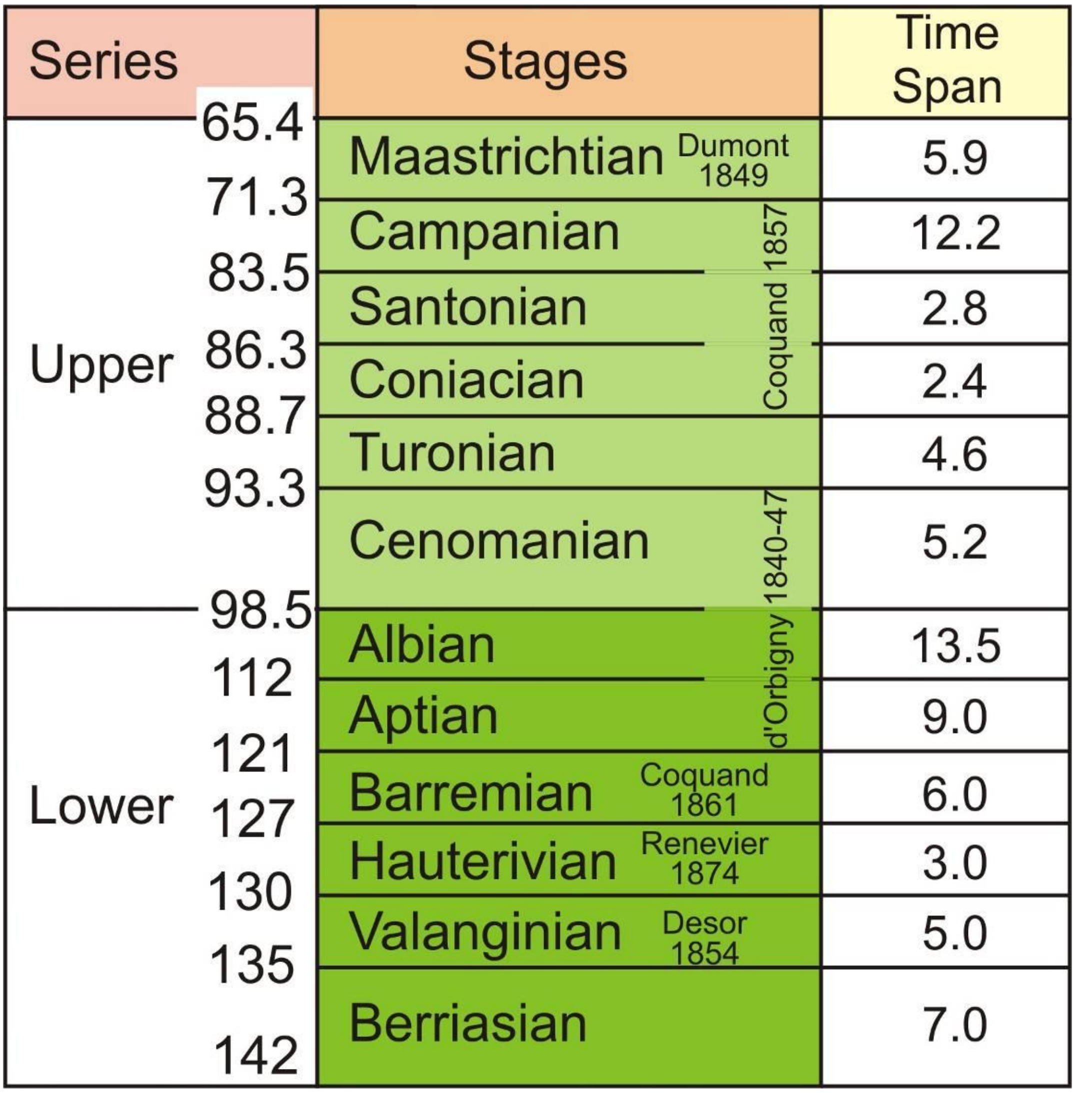
During the 1990s the Geological Survey initiated a new mapping programme from Dorset to Sussex. This programme has shown that the units other than the traditional Lower, Middle and Upper Chalk that can be mapped in southern England are those identified by Mortimore (1983; 1986). (New units were introduced in mapping the Chalk of Northern Ireland and Northern England in the late 1970s).

Lewes and the surrounding region (Fig.3) was chosen to establish a new stratigraphy because, following a reconnaissance of southern England, the East Sussex sections appeared to contain the thickest and most complete chalk stratigraphy. Marker beds such as the Meads Marls, Lewes Marl, flints in the Seaford Chalk and marl seams in the Newhaven Chalk were all present around Lewes but not in the North Downs. The numerous local chalk pits and sea-cliff exposures also provided an invaluable test of the continuity of markers and broader lithologies. The results of this joint work with BGS were published in the PGA (Bristow, Mortimore & Wood, 1997).

Co-operation across the Channel has recently increased with joint European 5th Framework and INTERREG funded projects linking the regional governments of the Somme and Seine Maritime with East Sussex, and the University of Brighton with the University of Le Harve (Anne Duperret) and BGS/BRGM. These joint projects have investigated the geohazards along the coastlines of France, England and Denmark and have investigated groundwater controlled floods in the Somme and southern England. These have been multidisciplinary studies, involving stratigraphy, sedimentology, structural geology, rock mechanics, hydrogeology, coastal sedimentologists and coastal engineers. Some of this work was published in the Geological Society Engineering Geology Special Publication No. 20, Coastal Chalk Cliff Instability based on the ROCC project, a joint venture between BRGM, Le Havre and Brighton and the PROTECT project a joint research venture between BGS, BRGM, GEUS, Brighton and

Nancy (Busby et al. 2004a). Publications of the results from the PROTECT project include Busby et al., 2004a,b; Busby & Jackson, 2006; Lawrence, 2007; Senfaute, et al., 2009.

As a result of these co-operative, cross-channel studies the French international stages (Cenomanian, Turonian, Coniacian, Santonian, Campanian) and the southern England lithostratigraphical terms (formations and marker beds) have been applied to both sides of the Channel.



Series		Stages		Time Span
Upper	65.4	Maastrichtian	Dumont 1849	5.9
	71.3	Campanian	Coquand 1857	12.2
	83.5	Santonian		2.8
	86.3	Coniacian		2.4
	88.7	Turonian		4.6
	93.3	Cenomanian	d'Orbigny 1840-47	5.2
Lower	98.5	Albian		13.5
	112	Aptian		9.0
	121	Barremian	Coquand 1861	6.0
	127	Hauterivian	Renevier 1874	3.0
	130	Valanginian	Desor 1854	5.0
	135	Berriasian		7.0
	142			

Figure 5. Cretaceous (D'Halloy, 1822) series and stages (Birkelund *et al*., 1984). Age picks (ma) based on Obradovich (1993) & Gradstein *et al*. (1996). Dates obtained using ^{40}Ar/^{39}Ar laser fusion on 50-500µg samples of sanidine from bentonites (volcanic ash/marls) interbedded with precisely dated fossiliferous marine sediments, western Interior Basin, U.S.A.

Within the onshore chalks of Europe (Figure 1, Table 1) there are four broad types of lithology, ***clean formations*** such as the Seaford and Culver chalks which are very pure (>95% CaCO3) without significant clay content or marl-seams with the highest porosities

(>40%); ***marly formations*** with a significant clay content (5-50% clay minerals measured from acid digested insoluble residues from chalk; e.g. The Cenomanian Grey Chalk Subgroup and the Turonian Holywell and New Pit Chalk formations); formations of ***pure white chalk with numerous, discrete marl-seams*** such as the Newhaven and Portsdown chalks (Tables 2 and 3) with potentially a layered prosoity/permeability (28 to >40%); and ***nodular chalk formations*** such as the Holywell and Lewes chalks (layered porosities from 5-40%) which also contain discrete marl seams. Other lithological features of the Chalk include the presence or absence of flint in the form of stratigraphically discrete bands and presence of phosphatic chalk deposits and reworked chalks. The relationship of these onshore formations to the JCR 2000 North Sea formations is shown (Table 2).

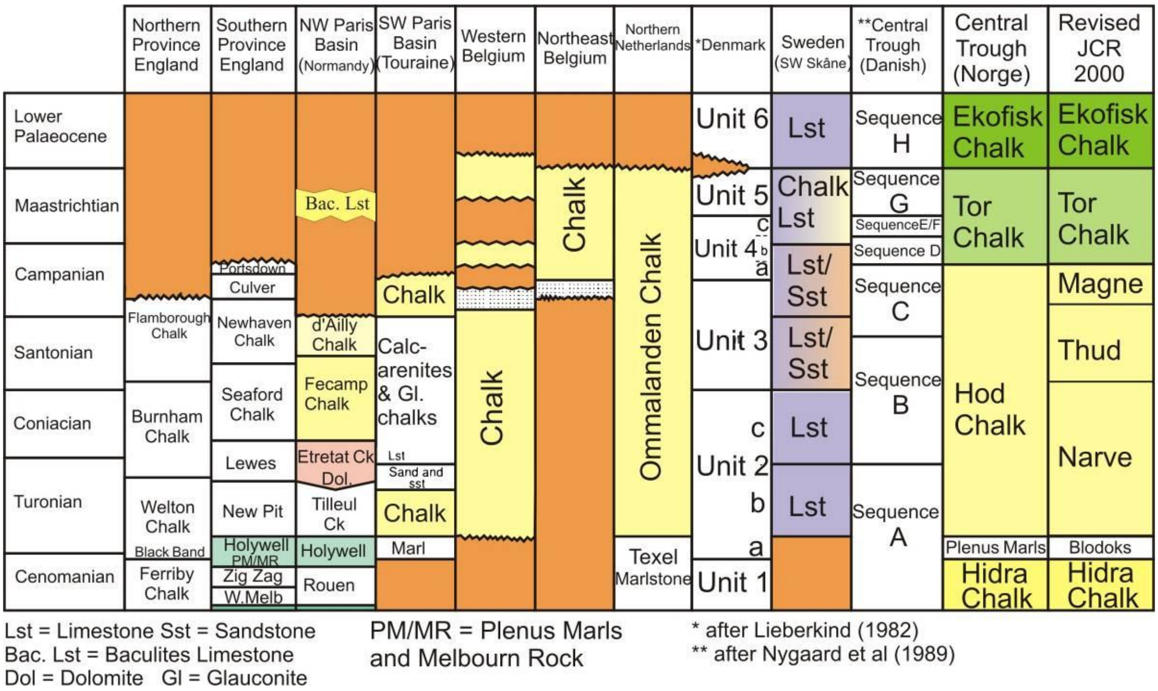


Figure 6. Equivalence of chalks and limestones in the Late Cretaceous and Early Palaeogene in NW Europe.

Investigating the origin of sedimentary, contemporaneous and post-depositional structures

There are a number of controversial issues related to the origin and hence sedimentary or burial history of the Chalk and possible loss of section: These include:

1. the synsedimentary processes producing nodular chalks
2. the origin of marl seams (are they produced by pressure-solution leaving an insoluble residue of marl or are they primary sedimentary features?)
3. the origin of the flaser or griotte structure of many marl seams
4. the origin of the vein fabrics and many intraclast beds.
5. The origin and significance of channels.

The clues to the origin of many of the above are contained in the relationship of trace fossils to each of the sedimentary structures. The Chalk commonly contains branching trace fossils on various scales, *Thalassinoides* and *Chondrites*, spiralling *Zoophycos* and other forms such as *Planolites*. Are the marl seams burrowed? Further clues are provided by the relationship of the vein fabrics and the laminated structures and slide planes.

Investigating the fracturing of the Chalk

Analyses of fractures in the Chalk of the Anglo-Paris Basin indicate a particular fracture style associated with the different lithologies/formations. Whether this ‘stratigraphic’ distribution of fracture style is controlled by lithology or some other factor such as contemporaneous tectonic movements, or the geometry of sedimentary units in relation to compaction stresses or a combination of these factors, is discussed. The frequency of fractures is also distributed stratigraphically with certain horizons containing a greater fracture frequency. These horizons include the Melbourn Rock – Meads Marls at the base of the Holywell Chalk, the Glynde Marls at the boundary between the New Pit and Lewes Chalk, and the stratigraphic interval containing the Rottingdean to Peacehaven marls in the Newhaven Chalk

In addition to the obvious brittle fractures there are many horizons in the White Chalk containing pore-fluid escape structures (**the vein fabric,** Mortimore, 1979; Mortimore & Pomerol, 1997; Mortimore, 2011) and plastic slide planes with convolute bedding. Some of the slide/slump planes have been partly replaced by sheet-flint.

Relative age of fractures

Determining the sequence and age of flint formation is critical for the relative dating of chalk fracturing. The model for flint formation developed by Clayton (1986) suggests that the initial stage of soft-flint formation began within 0.3-1.0m of sediment within the sea-bed and progressed as sediment thicknesses increased. Clayton observed an original porosity of 80% in some flints indicating an almost synsedimentary origin for the initial stages. This observation agrees with the palaeontological evidence for the excellent preservation of delicate structures in many fossils found in flint.

Clayton envisages the flint as a gel-like substance during the very early stages of formation, not becoming a ‘solid’ flint until more than 10m of sediment have formed. In this early form, flints if re-worked would not survive as discrete entities and the early forming nucleating points would be dispersed, and not reform. This would explain the absence of re-worked flints in chalks that have clearly been re-mobilised and re-sedimented and the absence of *in situ* flints in these same chalks. A good example of this is found in the Cenomanian white chalks on the western margin of the Arabian Platform at Rosh Haniqra, Israel, where chalks were episodically re-sedimented. Authocthonous chalks with flints are interbedded with allocthonous chalks without flint. Chalk turbidites (Talme Yafe Formation) on the northwestern flanks of Mount Carmel exposed at Haifa, Israel (Bein & Weiler, 1976; Sass & Bein, 1980, 1990), also show the same relationship and additionally contain sheet-flint in slip/slump scars (observations by RNM during the 1990 Cretaceous Field Conference in Israel).

In addition to these observations Bromley and Ekdale (1986) described the slightly disturbed chalks with burrows which are partly preserved by odd, out-of-place flints. This disturbance resulted from small-scale post-depositional movement of a mass of chalk rather than complete re-working. In other areas such as Downend, Portsdown, the flint bands are involved in contemporaneous slump folding and can be used to pick-out the complex box-folds (Mortimore, 1979; Gale, 1980).

In describing how flints replace chalk, Clayton (1986) emphasised (i) the degree to which the original chalk texture and fabric is retained in flint, (ii) the replacement of chalk surrounding burrows or fracture planes, (iii) and the overgrown size of flints compared to the original structure (burrow or fracture). A classification of flints is given in Table 4. Of particular importance to our study is the relationship of sheet-flints to particular types of fracture, and to adjacent nodular flints.

The itinerary for the first day is designed to introduce some of the key lithological and fossil marker beds that will then be followed along the coast. Also, interpretations of sedimentological and tectonic processes will be presented that may seem speculative with only one example. As the trip progresses the evidence will accumulate for the existence of tectonic lineaments and fault blocks which influenced chalk sedimentation. Evidence from changes in fauna and lithology, both stratigraphically and within the sub-basins, will be used to develop ideas about sea-level changes and the controls on chalk properties. A distinct fracture distribution related to both lithology and tectonic events can be seen.

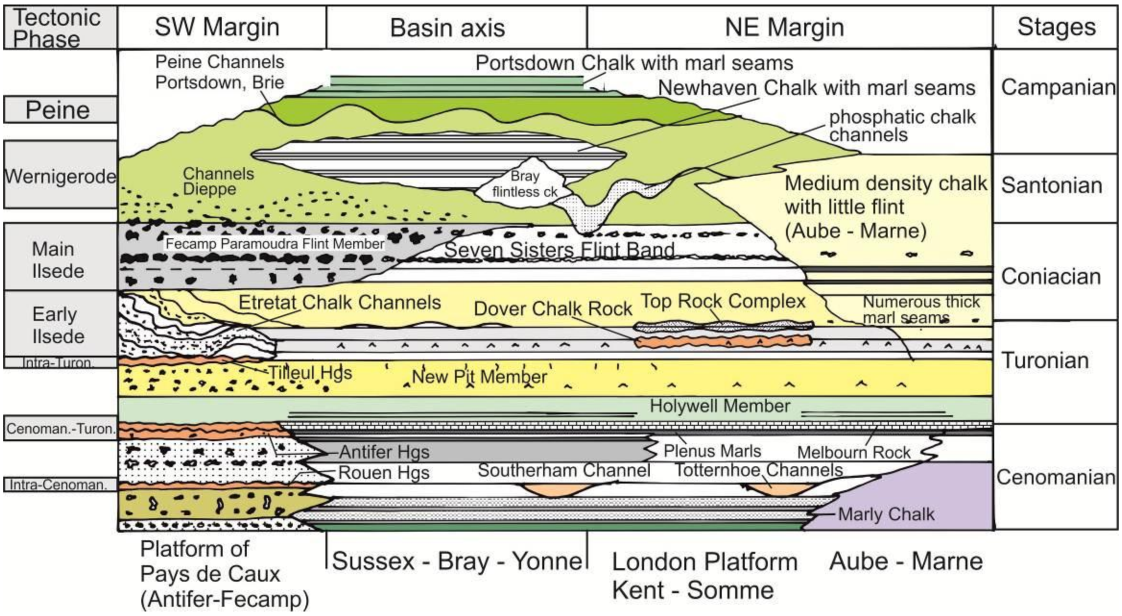


Figure 7. Schematic cross-section across the Anglo-Paris Basin (not to scale) illustrating the lateral and stratigraphical change in chalk lithologies (based on Mortimore, Pomerol & Foord, 1990).
(i)Predominantly chalks with chert/flint bands (many paramoudras) along southwest margin (area of upwelling marine water)
(ii) thicker successions of chalks with greater numbers of marl seams, reduced flint but with key marker flints – main axis of basin
(iii) largely non-flinty, thick chalk successions with thick marl seams – northeast margin (Aube-Marne); Campanian highly condensed at Vendeuil without marls or flints

Underlying tectonic framework

A further aspect of our study is the potential cause of differing fracture patterns and lateral and vertical variations in lithology and fracturing. If the cause is related to a more general process affecting the whole of northwest Europe then a study of the Chalk cliffs will be directly relevant to the North Sea. One such potential cause is the structural evolution of the region during the Late Cretaceous (e.g. Mortimore & Pomerol, 1987, 1991, 1998). Even a more local cause, such as lateral variation in lithology within the basin, may have a primary, underlying tectonic control.

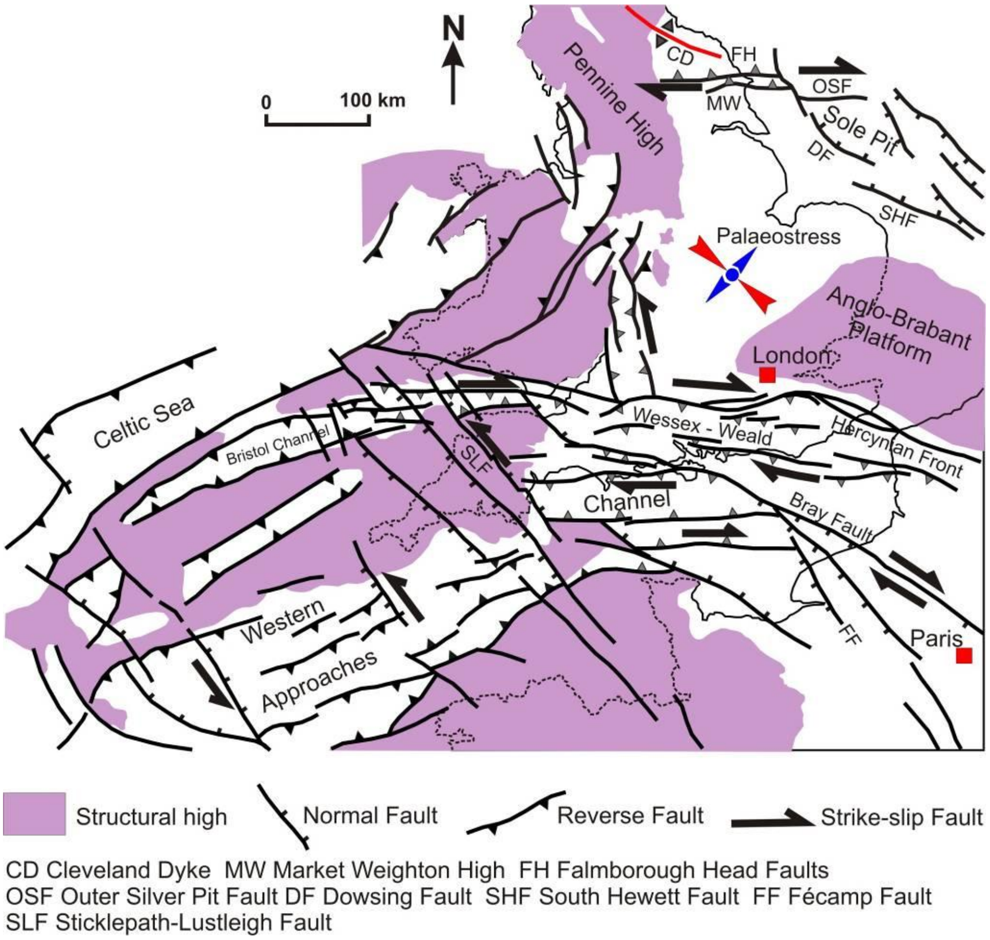


Figure 8. Results from palaeostress studies (Hibsch et al., 1995) and regional geological studies (Lake & Karner, 1987; Zeigler, 1990,1993; Mortimore, 2011) support the idea of strike-slip controlled local basins in the Late Cretaceous and Palaeocene.

The Late Cretaceous of the Anglo-Paris Basin has a NE margin defined by the Anglo-Brabant Platform, a SW margin defined by (i) the Start -–Cotentin line and (ii) the massifs to the south (Armorica), and southeast (Morven, Massif Central) with the Gulf of Poitou between. Within the basin there are a number of tectonic axes, some expressed as platforms (Pays de Caux, Upper Normandy) or as en-echelon fold belts. Underlying these fold belts and platforms are a number of long-lived fault systems generated during the Hercynian and exploited by all subsequent tectonic episodes.

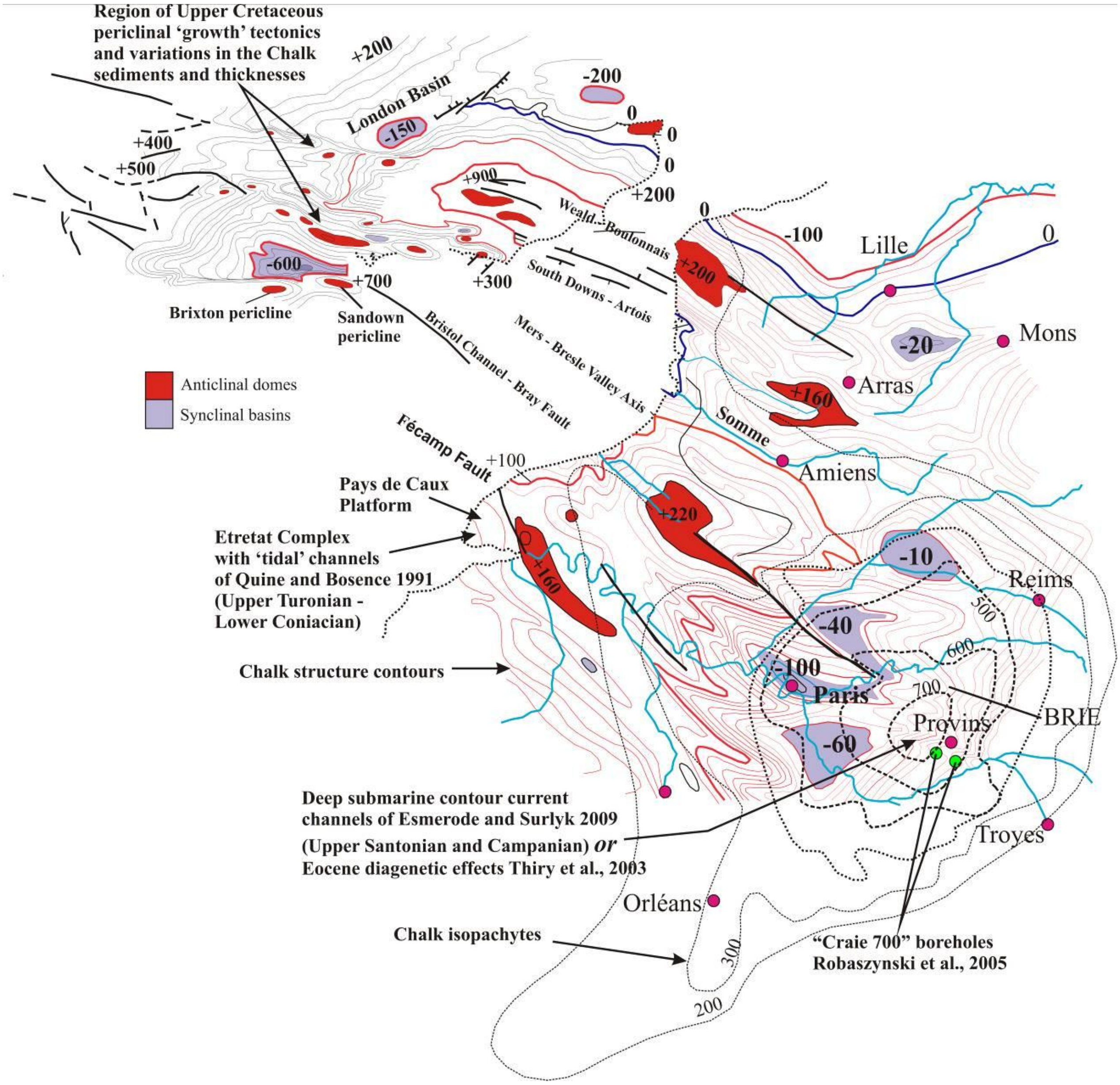


Figure 9. Northwest trending structures in the Anglo-Paris Basin – French coast a dip section; English coast an oblique strike section. Structure contours on the sub-Palaeogene surface (metres) pick out anticlinal domes and show difference in size of features between England and France. The UK coast is an east-west strike section whereas the French coast is a northeast-southwest dip section. Based on Dolfuss (1890, 1910), Wooldridge and Linton (1955), Jones (1972, 1980) and the BRGM Tectonic Map of France. Chalk isopahcytes for the Paris Basin show the deep structure within the Brie, eastern Paris Basin, where the Craie 700 boreholes were drilled (Robaszynski et al., 2005).

Day 1 Friday 29th June 2012

At the western end of the Dieppe seafront the Chalk cliffs expose a section in the Seaford Chalk Formation

Loc. 1 Dieppe West (drive to Dieppe West Seafront (close to Castle)

West cliff at Dieppe has a marvellous exposure of deep karst developed along the Seven Sisters Flint Band, including filled-cave systems and an underground river. The Seaford Chalk exposed here contains many of the features also seen in core along the line of CROSSRAIL.

See if you can identify the evidence used to correlate this flint with the Seven Sisters Flint Band.

Also note the spectacular Dieppe hardground developed along an erosion surface in the Santonian, cutting down into the Coniacian. We are at the western end of the Pays de Bray Fault controlled pericline.

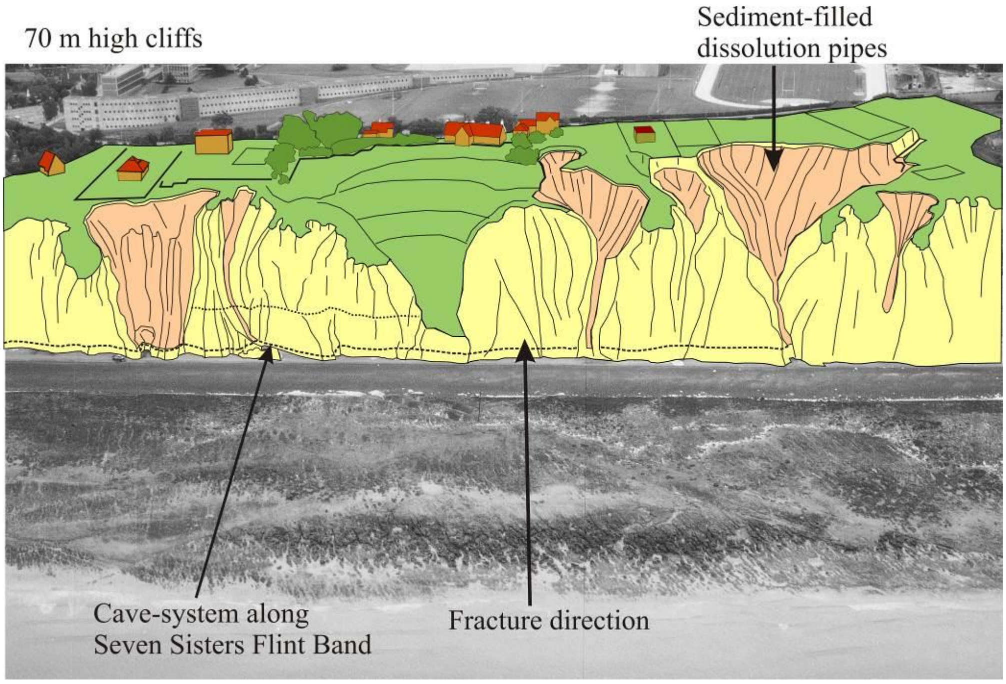


Figure 10. The cliffs of Dieppe west showing the Seven Sisters Flint Band near the base of the cliff acting as a local aquiclude along which water has concentrated developing a range of karst features

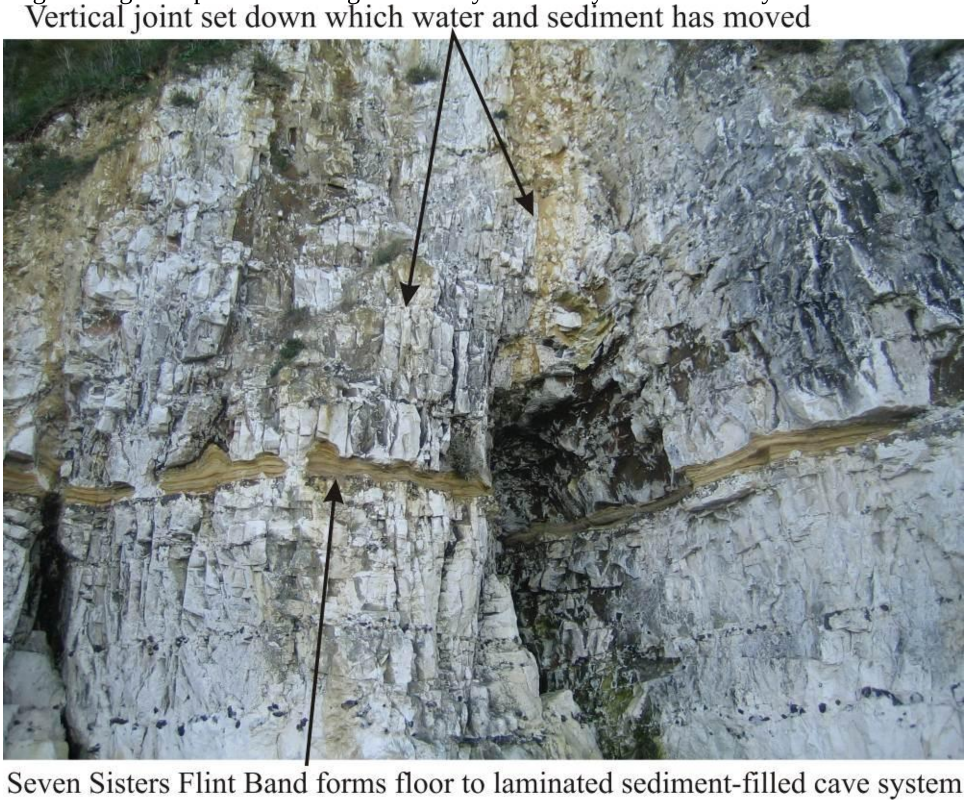


Figure 11. Sediment washed down from the cliff-top via vertical fractures.

Figure 12.

Day 2 Saturday 31st June 2012 Antifer, Tilleul, and Fécamp , Coast of Pays de Caux

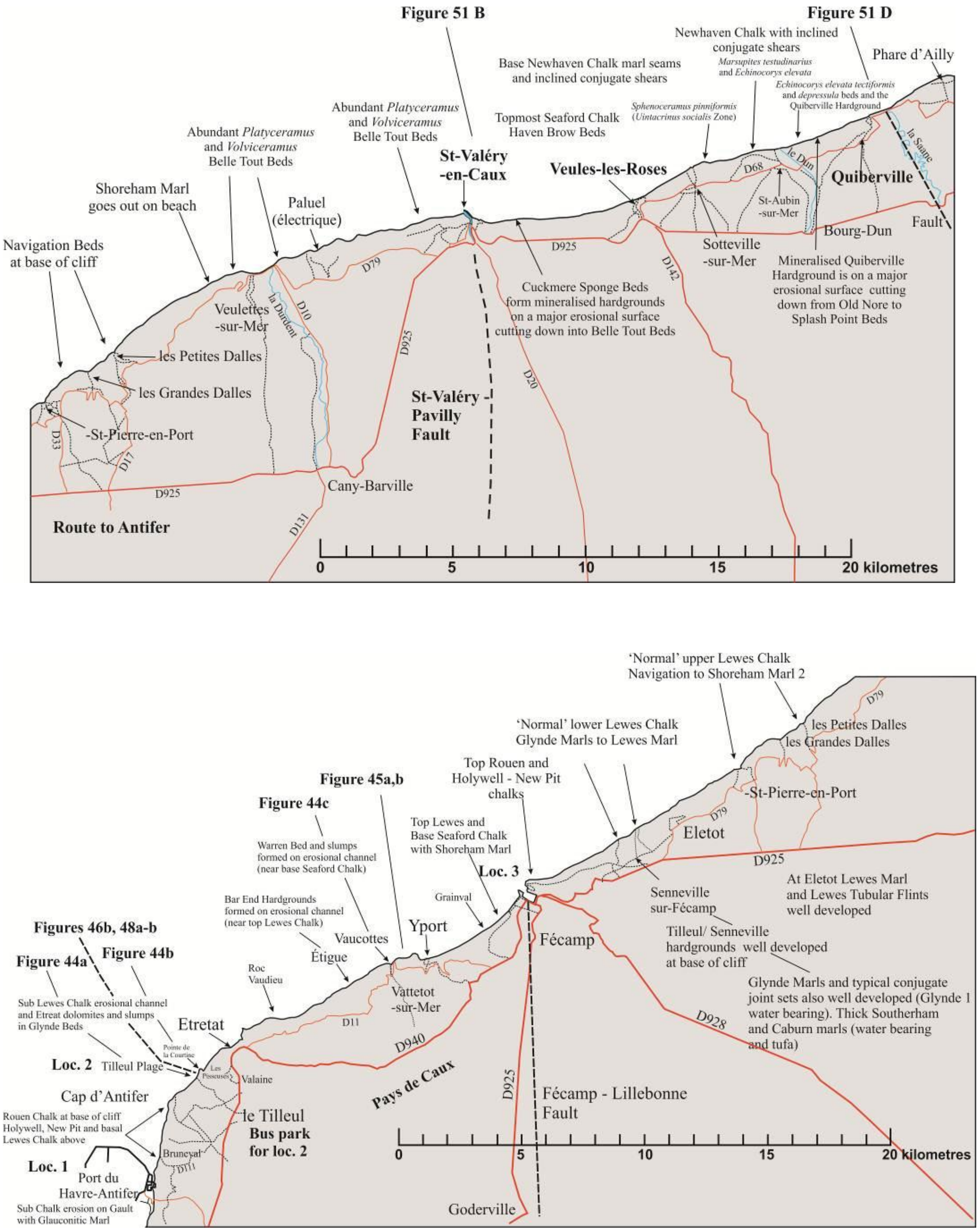


Figure 13. Route to be taken, locations to be visited and position of key features of the geology in the coastal cliffs for Day 2 (Port du Havre-Antifer (Loc 1) and Tilleul Plage (Loc 2)). The figure numbers in bold refer to figures in Mortimore 2011.

Take the D925 out of Dieppe to St-Valery-en-Caux and Fécamp travelling through Veules-les-Roses, St-Valery-en-Caux (now bypassed), Cany-Barville (where we may stop for a loo visit and any extra water/food etc), then on through Fécamp along the D940 to the junction with the

D139 (to St-Jouin-Bruneval). At this junction (with statues of horses and paniers for gallet) go round the roundabout and take the acute right to Port Pétrolier du Havre-Antifer (we may stop to take photos of the horse). Follow this road down to the junction with the D111. Cross the road heading down the hill on the Alpine switchback (three lanes for petrol trucks) to beach level Turn left to the beach parking area (toilets and refreshments may be open – not always)

Loc. 1 Port Petrolier du Havre-Antifer

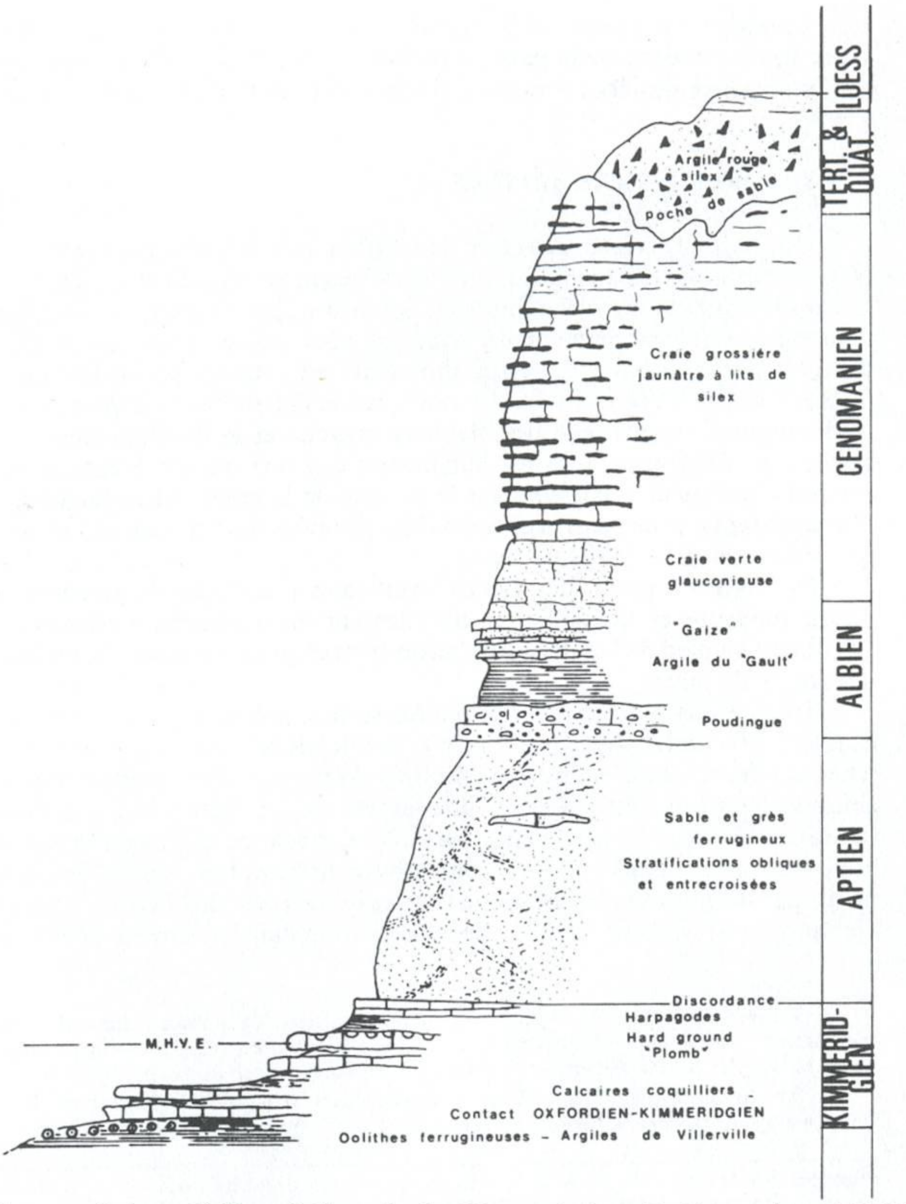
This petroleum port, constructed in the 1970s following the Arab-Israeli War of 1973 and the strategic need for oil supplies delivered by super tankers, exposes Jurassic Kimmeridge, Cretaceous Albian, Cenomanian and Turonian - Coniacian strata at the top of the cliff. It is the intention to start at the southerly end of the section at the base of the Cenomanian. Here, instead of a typical Glauconitic Marl there is a dark, glauconitic silt with abundant quartz pebbles, wood and glauconite fragments resting on well bioturbated, light-grey silty clay with abundant weathered quartz pebbles. There is a dark black, phosphatic nodule bed a little way above the base Cenomanian contact with the Albian.

Juignet (1974) proposed that the Antifer section should be a parastratotype of the Cenomanian in chalk facies (cf Stratotype at Le Mans where there is no good section and the lithofacies is very different (top Cenomanian is sand Sables du Perche)). This section is not complete as it contains several horizons of condensation. The basal pebble bed is not at the real base of the Cenomanian and is probably in the *Mantelliceras saxbii* Zone. In the Middle Cenomanian the Rouen Hardgrounds represent condensation at the *Turrilites acutus/M. dixoni* boundary. The Antifer Hardgrounds are all that is left of the Plenus Marls, the belemnites rest on Antifer 2.

A feature of the Cenomanian on this coast is the presence of chert/flint bands compared to the main axis and northern flank of the basin. Hardgrounds and flints are not known elsewhere in the Plenus Marls. Even though this Cenomanian section is condensed some trace fossil horizons survive (e.g. the Asham Zoophycos Beds and Kennedy's Scratched Horizon). We will be able to studyexamples of both flint and chert in this section.

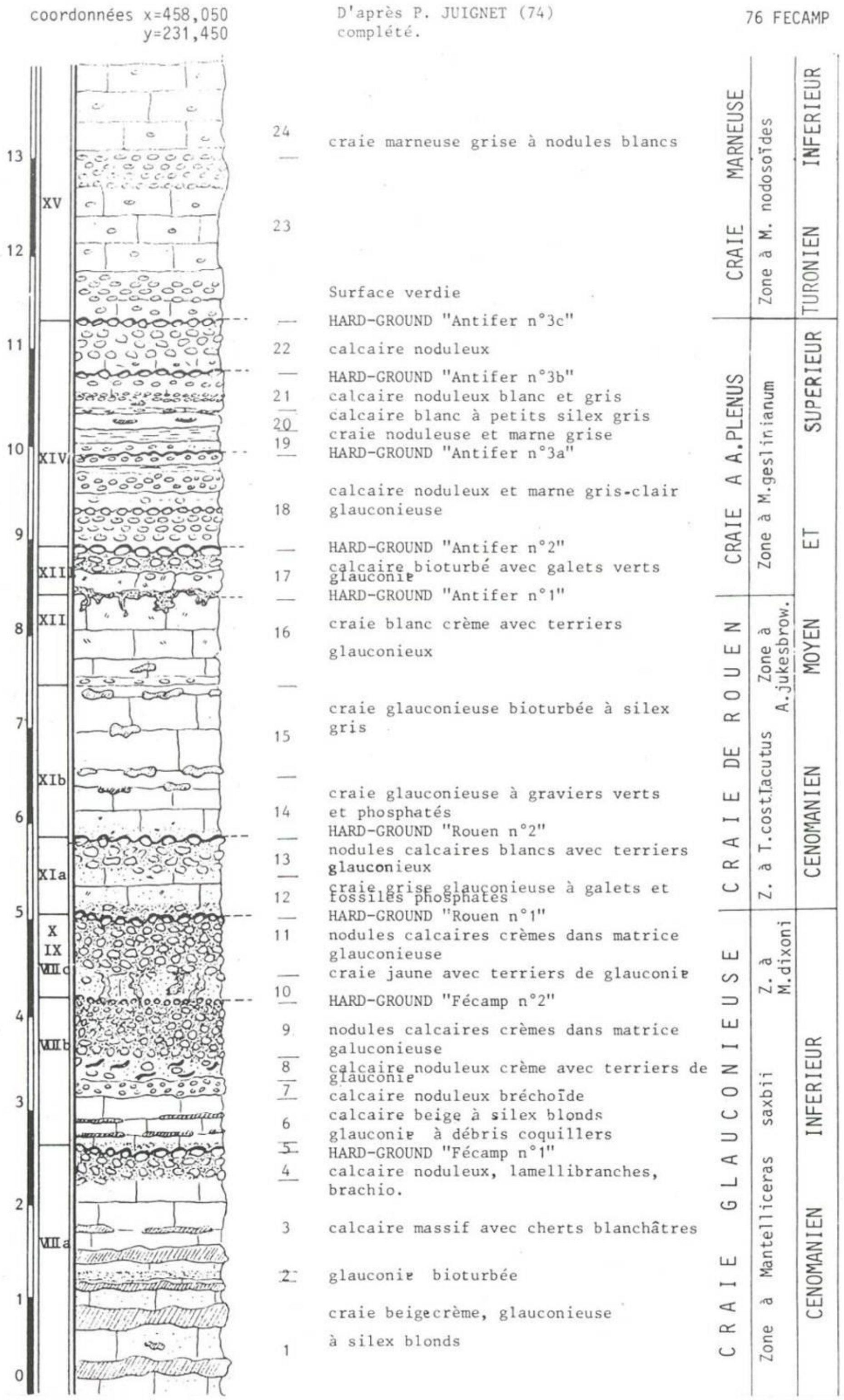
Anne Duperret and her research team at the University du Havre have been investigating the stability of the cliffs particularly in relation to the communes Ste-Adresse near Cap de la Hève (just north of Le Havre) and along the coast to Tilleul etc. The cliff sections from Antifer to Cap de la Hève comprise Jurassic, Kimmeridge and a thin Lower Cretaceous Gault overlain by Upper Cretaceous Cenomanian-Turonian chalks.

On the bus journey back up the road note the Rouen Hardgrounds, Antifer Hardgrounds, Holywell Nodular Chalk and New Pit Chalk formations.



Geology of the cliffs of Cap de la Heve (after J. Guyader, 1978)

Figure 14. The section exposed along the cliffs from Port d'Antifer to Cap de la Heve



Stratigraphy of the Chalk at Cap Fagnet (after Juignet, 1974)

Figure 15. Juignet’s 1974 PhD section of the Cenomanain Chalk cliffs at Cap Fagnet (Fécamp – similar to Antifer and Le Tilleul).

Loc. 2 Tilleul Plage

Take the same road back to the roundabout with the statues of horses. Take the left exit back towards Etretat. The first village is Le Tilleul. In the centre of the village is a cross-roads. We will park the bus at the new coach parking area and then walk along a small lane identified as to the beach (la plage). Continue straight along the lane (i.e. bear a bit to the right following the La Plage signs). At the next road junction you will see a parking area used for cars and minibuses etc (too small for a coach). It is a 20-30 min walk down the Valleuse d'Antifer to the beach. We will take packed lunches and plenty of water. There are no loos here! If anyone is desperate try the village centre at Le Tilleul which may be open (turn right rather than left off the D940 in the centre of Tilleul; about 100m down on the right is the Marie and village hall and gardens; not always open – or ask at the restaurant at the cross-roads)

Figure 16. South side of Tilleul beach where the Grey Chalk (Rouen Chalk Formation), Holywell and New Pit Chalk formations are exposed and the sub-Lewes Chalk erosion can be seen.

Tilleul Plage provides access to the top Cenomanian and the transition into the Turonian (i.e. from the Grey Chalk into the White Chalk and through the Holywell, New Pit, Lewes and Seaford Chalk formations). In addition to features seen at Antifer there is the marked concentration of gritty, nodular Holywell Chalk with bands of *Mammites nodosoides*. The first *M. nodosoides* were found resting on the Antifer 3c Hardground of Kennedy and Juignet which makes it equivalent to the Melbourn Rock (sensu Sussex, Mortimore, 1986). The entry of flinty chalk is again earlier on the southwest flank of the Paris Basin in the Turonian than the central axis or northeast margin (Mortimore & Pomerol, 1987). Several trace fossil markers are, nevertheless, still present (eg. the *Zoophycos*, *Bathichnus* at the New Pit to Glynde marl seam equivalents, Mortimore & Pomerol, 1991a). Also the *Conulus* abundance levels are especially well developed in these sections.

This section is also important for the development of chemostratigraphy as Bernard Pomerol (1976) was the first to identify the manganese 'accident' in the Plenus Marls equivalent, the Antifer Hardgrounds, and subsequently correlated this signal with δC^{13} signal that is now widely used as an index of Oceanic Anoxic? events and as a correlation marker signal.

Tilleul Plage provides easy access to the spectacular so-called mounds and channels in the Etretat Chalk Complex which begin around the base of the Lewes Nodular Chalk in the Late Middle Turonian (difficult to date as the key lithostratigraphical markers have gone cf. Senneville - Fecamp sections). These mounds and channels have been interpreted as sedimentological bioherms (Kennedy & Juignet, 1974) and as tidal scour channels (Quine & Boscence, 199…). Their tectonic setting on the southwest margin of the basin, which here was probably a tilted fault block, was considered important to their origins (Mortimore & Pomerol, 1987). These sedimentary structures begin during a well documented period of Late Turonian tectonics seen in many places in Europe. This also coincided with a period of regression and corresponds to the UZA-2 and UZA-3 Sequence boundary of Haq *et al*., 1987. The stratigraphical interval in which these sedimentary features are developed is also coincident with the early Ilsede phase of tectonic movements recognized in northwest Europe and responsible for reactivating faults, fault blocks and adding a further pulse to the growth of folds.

Any well preserved fossils collected from the basal parts of the Etretat Chalk will be appreciated (especially Late Turonian ammonites).

Lunch will be taken on the beach depending on the weather. The view of the Chalk arches was made famous by the French Impressionist artist Monet (paintings now in the National Museum of Canada, Ottawa). Note the contrast between the flat Tilleul Hardgrounds and the inclined bedding of the Etretat Chalk. *Zoophycos* finger flints are present in a special bed below the Tilleul Hardgrounds. In this section it is easy to study the beds of slumped and shattered flints around the Turonian - Coniacian boundary.

Key issues that can be investigated on this beach include:
1 Origin and timing of flint formation including pseudoflint and sheet flint
2. Synsedimentary processes including hardground formation, sea-bed mineralisation, erosion, faulting and slumping in chalk
3. How to use macro-fossils and trace fossils for correlation and investigating origin of structures
4. Chalk sedimentation on a fault controlled shelf
5. Controls on groundwater flow within the Chalk
6. Scales of cliff failure

Figure 17.Synsedimentary growth of slump folds

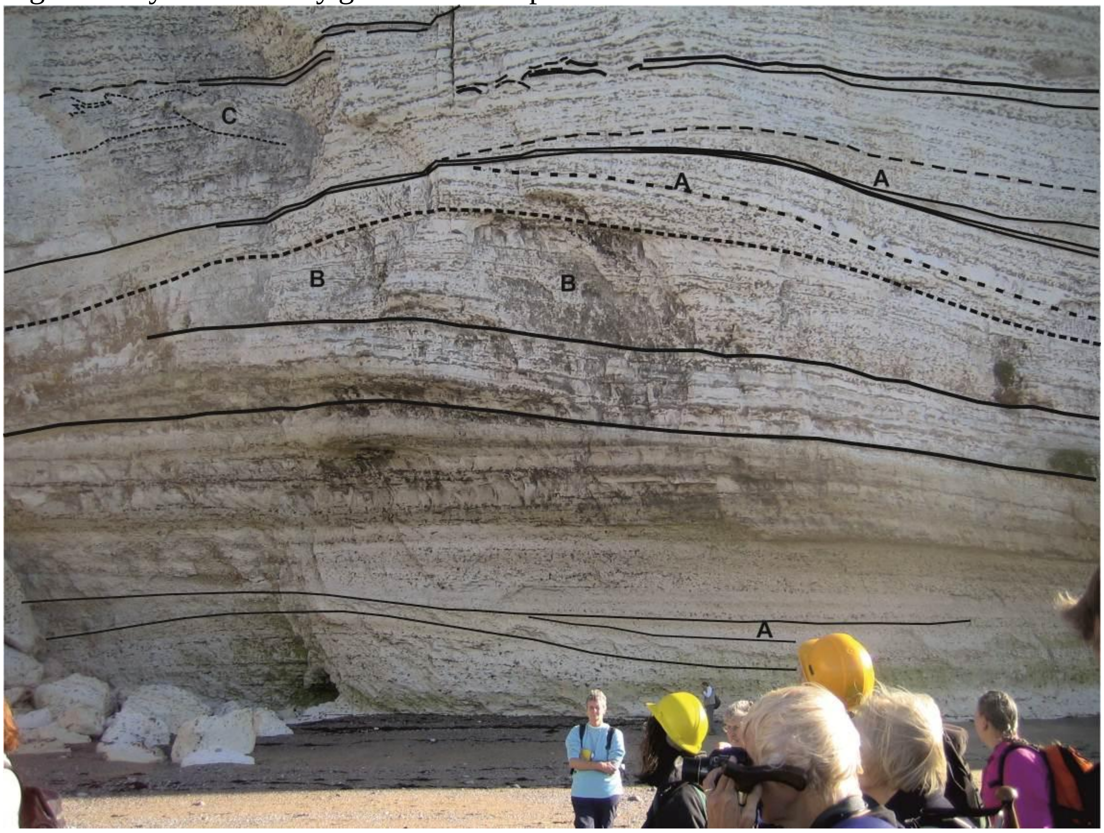


Figure 18. Details of the onlap relationships of beds over 'mounds'.

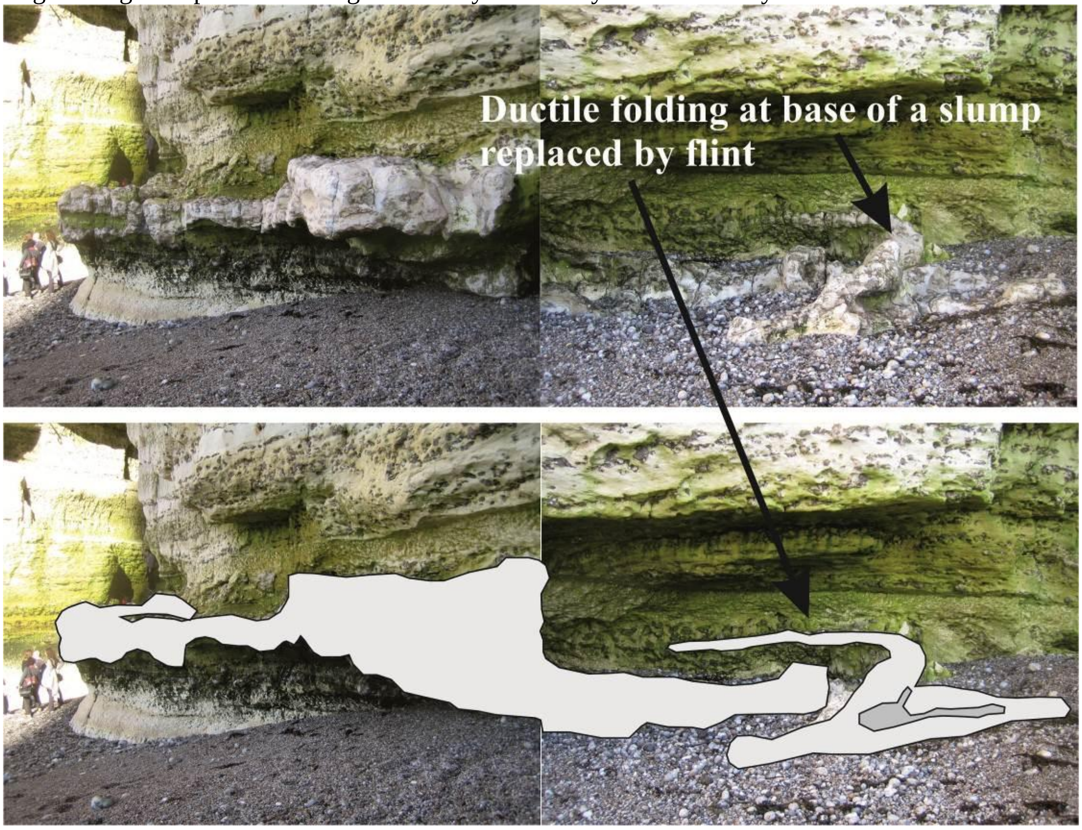


Figure 19

Figure 20a. The view from the tunnel onto the cliffs of Etretat showing the complex stratigraphy in the Turonian and Coniacian chalks with flint bands and hardgrounds.

Figure 20b. Detail from Fig. 20a showing a synsedimentary slide with the slide plane replaced by a sheet flint

Figure 20c. Detail from Fig. 20a showing the large vertical column of flint (Paramoudra)

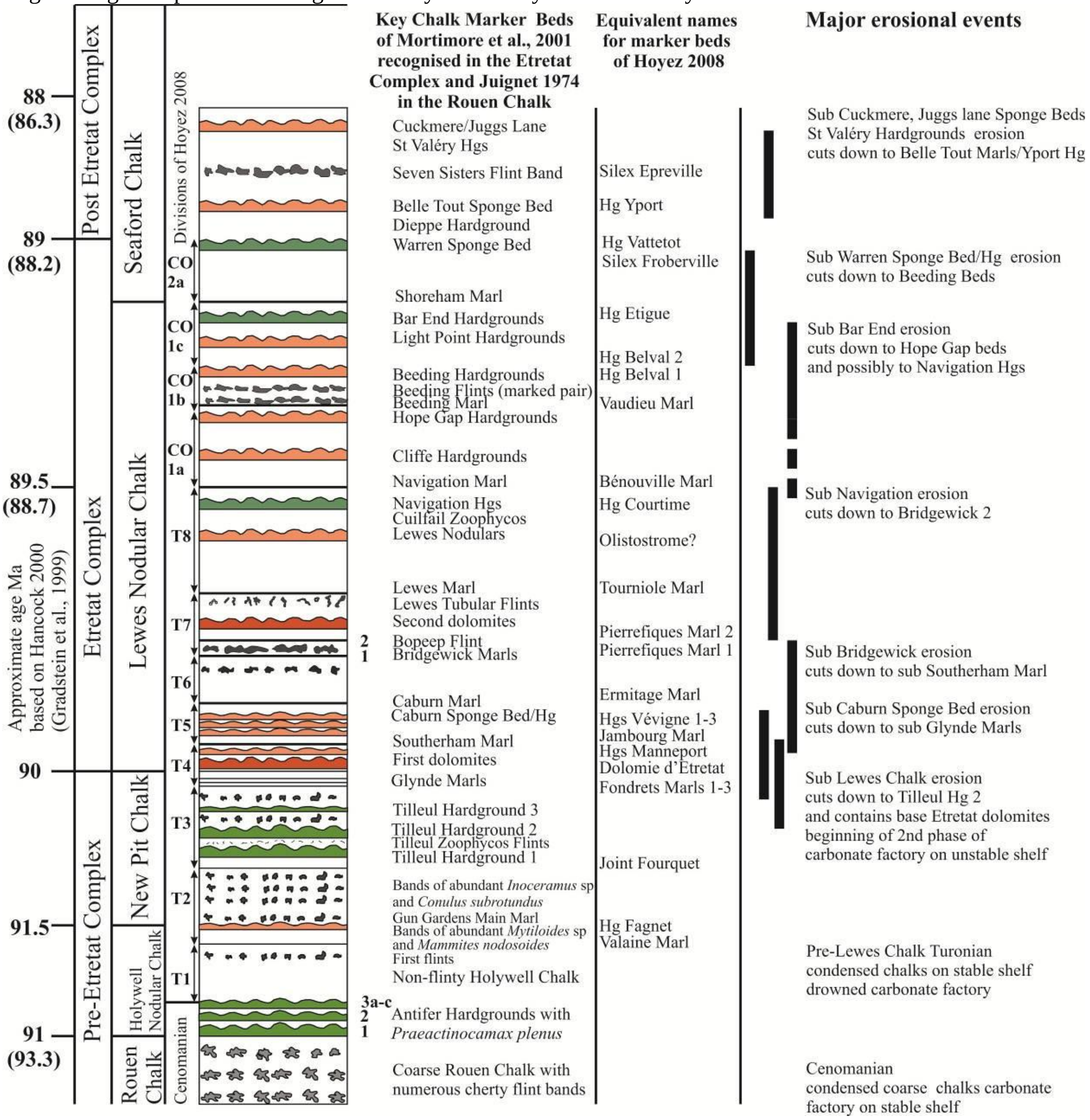
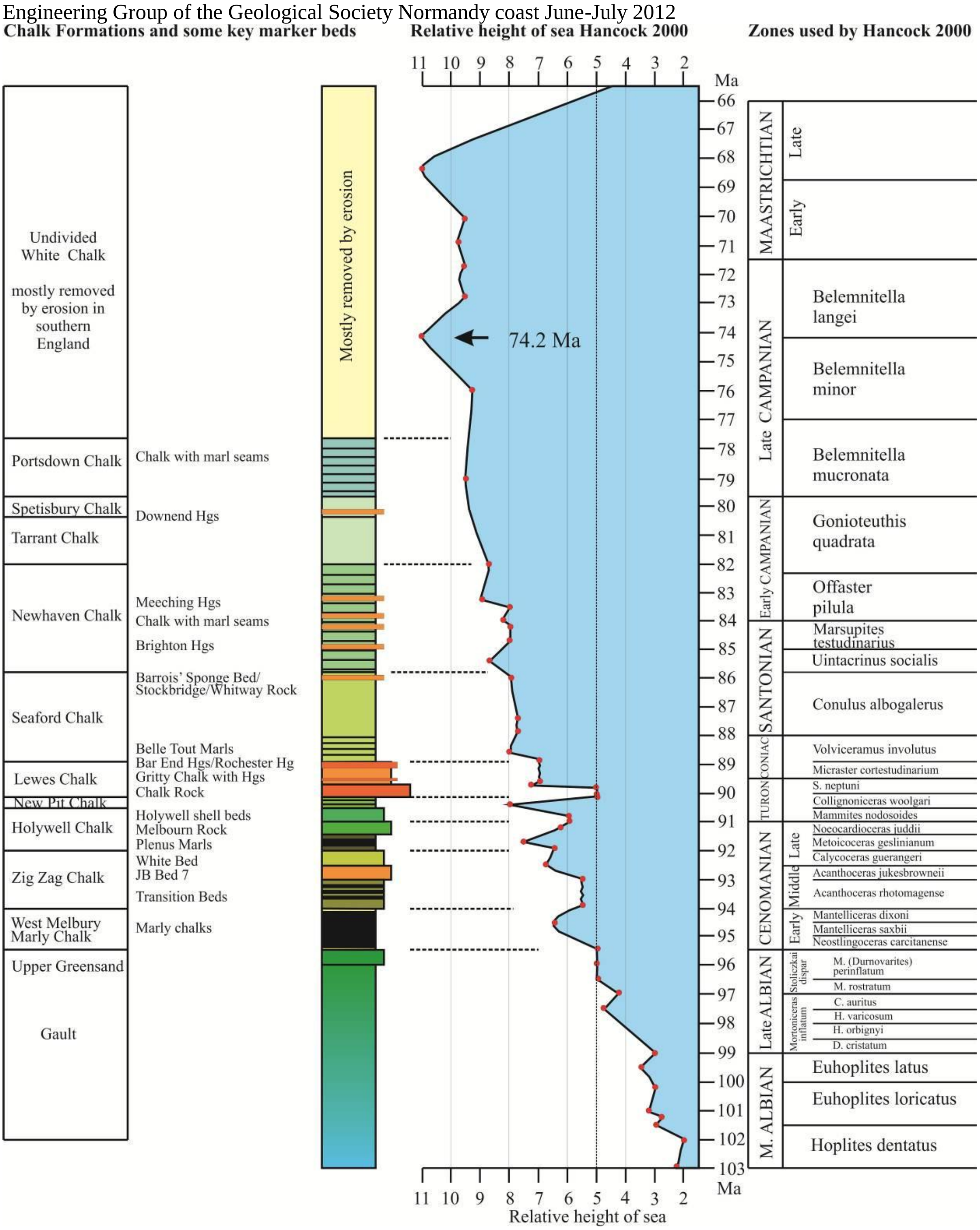


Figure 21. Schematic stratigraphy for the Chalk on the Pays de Caux platform



Chalk Formations and some key marker beds

Relative height of sea Hancock 2000

Zones used by Hancock 2000

Figure 22. Relative sea-level curve for the Upper Cretaceous (based on Hancock, 2000)

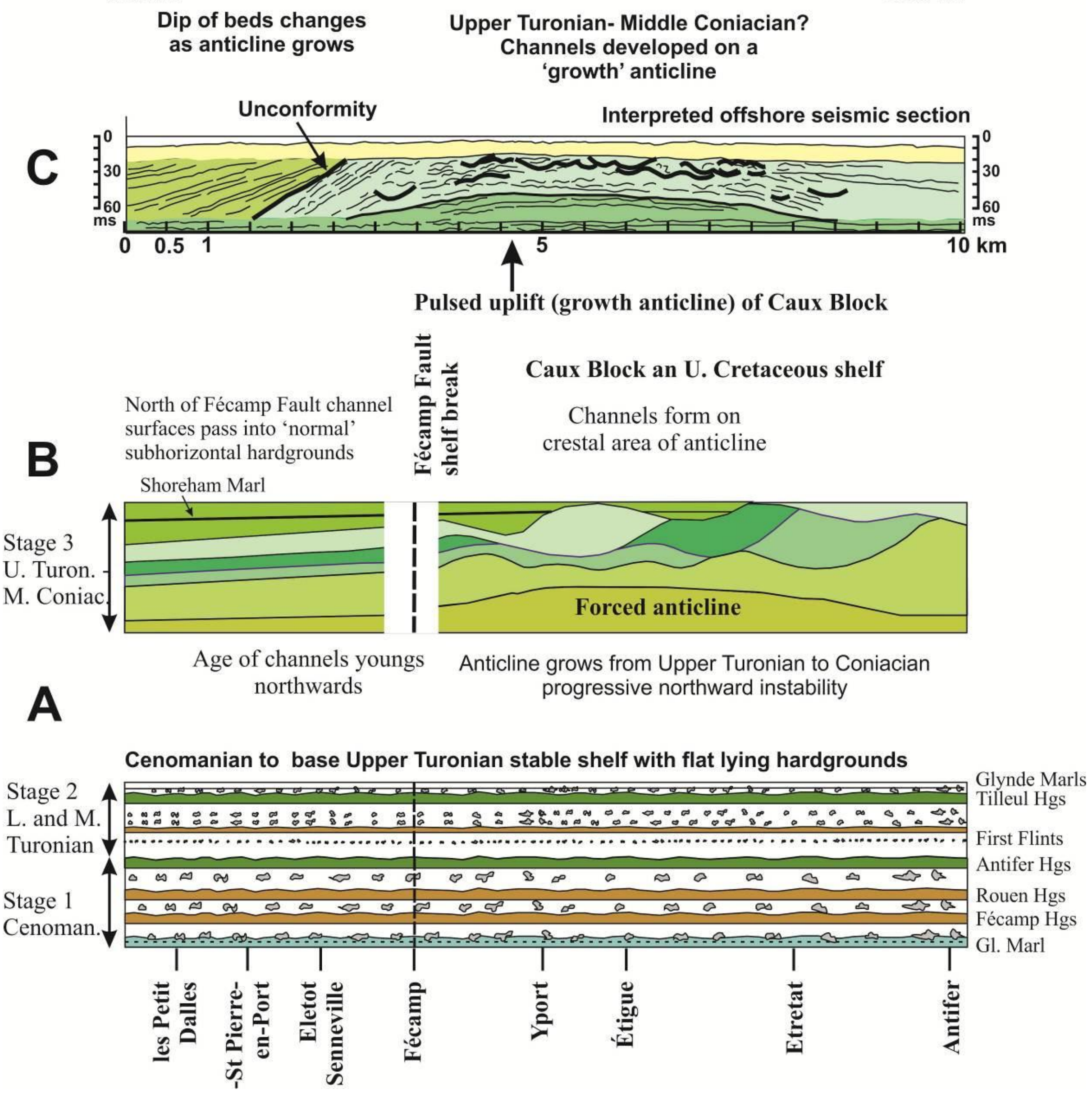


Figure 23. Schematic model for the origin of the Etretat Chalk channel complex.

Loc. 3 Cap Fagnet (Fécamp) (we will stop here only if there is time)

A large fault controls the harbour at Fécamp with Coniacian - Santonian chalk on the south side and Cenomanian - Turonian on the north side. There will not be time to look at the conspicuous bands of Paramoudra flints which enter above the equivalent of the Shoreham Marls. These will be viewed from a distance later at Eletot. On the north side of the harbour the contact between the Cenomanian and Turonian is well displayed and the utility of the Holywell Beds as a general mapping concept in the Anglo-Paris basin is evident.

Figure 24. Cliffs at Fécamp on the north side of the Fécamp Fault

Figure 25. Cliffs at Senneville – water flows out of the cliff along the Southerham Marl creating the vegetated slope in the lower part of the cliff

Day 3 Sunday 1st July 2012
Dieppe East cliffs; Puys to the Bresle Valley area and Ault; Picardie Coast

General Geology:

From a shelf setting in the Pays de Caux (previous day) to a basinal setting crossed by strongly developed NW-SE tectonic axes (Figure…). Correlation of key interbasinal marker beds that are better developed in the 'more complete' basinal successions, return of 'normal' chalks; development of the Mers Hardgrounds and erosional base to Lewes Chalk across the Bresle Valley axis with occlusion/loss of marker beds (similar to Chalk Rock of Chilterns-Berkshire Downs); fracture characteristics of different formations; coastal cliff instability issues and an experimental site for monitoring cliff collapse.

Loc. 1 Dieppe East Puys

Puys provides a spectacular section in the Late Turonian-early Coniacian Lewes Nodular Chalk Formation. In Puys bay the Lewes Marl and Flints are conspicuous and the typical forms of *Micraster* (including *corbovis*, *leskei* and *normanniae*) are abundant. This is probably the type section for *M. normanniae* (Bucaille) which, in the absence of consistently collectable ammonites and inoceramids, is an excellent stratigraphic marker for the Turonian Coniacian boundary in chalk facies of NW Europe.

Puys, although lying close to the Bray Axis, is nevertheless in a more basinal setting and each marker marl seam recognised in Sussex can be traced into these cliffs. This is best seen by walking northwards towards St-Martin-Plage and the Penly Nuclear Power Station where the Cenomanian - Turonian boundary with typical Plenus Marls (cf Antifer) was formerly exposed but now covered by construction works. This makes the Dieppe - St Martin Plage sea-cliff section the best section of the Turonian in the Paris Basin because the key marker bands are more easily recognisable than in the type Turonian of Touraine. As in Sussex the flints enter above the Glynde Marls in contrast to the Senneville - Tilleul sections. Excellent unsilicified Cuilfail Zoophycos are present but the Navigation Marls do not occur. Instead there are several conspicuous, phosphatic and glauconitic hardgrounds in the equivelant of the Navigation - Cliffe - Hope Gap section of the Lewes Nodular Chalk Formation.Each of these hardgrounds correlates with the erosional events seen in the Etretat Complex (Mortimore, 2011).

It was along the cliffs to the north of Puys that Anne Duperret and Albert Genter and co-researchers witnessed a cliff collapse at first hand and were able to analyse the failure (Duperret et al., 2002a). A key feature of this collapse and most others was the way stratigraphic integrity was retained with the oldest beds and biggest blocks transported furthest from the cliff base. The Puys collapse was a two stage process and the role of marl seams and water held up along the marls seems to have been important to the failure mechanism.

Day 3: Dieppe to St Martin, Criel Plage, Mesnil-Val Mers-les Bains & Ault

From the hotel at Dieppe West: we will take the D925 to St Martin Plage take the road past the castle heading back uphill to the 'Auchan' roundabout; we may decide to shop for 1hr for shopping/fuel as the tide will be high at this roundabout take the left following signs to Eu and Le Treport out of Dieppe going north on the D485 and then D925; continue through the villages of Graincourt, to St-Martin Plage roundabout take left turn towards St Martin Plage - we may have difficulty with the coach so this section may be abandoned.

Return to the St Martin Roundabout turn north to Eu, go through the village of Tocqueville-sur-Eu and be ready to turn right off the D925 as you go downhill and on a bend (the turn is nearly blind but is a feed off right). At the junction with the D222 turn left and on into the village of Criel-sur-Mer; in the centre of the village take the awkward sharp left at the crossroads to La Plage and Criel Plage. About 2 km down this road a bend to the right brings you to the seafront with a single house and car park on the right: stop on the road/gravel edge; the sections we will study are on the cliffs to the left; (If the bus is too large we will continue on the D222 into Criel Plage

Return to coach and travel on into the centre of Criel Plage (toilets if needed); quick stop to look at the cliffs on north side of Criel Plage Then take the small road (D126E) to Mesnil-Val. Park where possible on seafront or nearby. Walk round concrete groyne onto the beach where we will study the PROTECT experimental site (about 1-2 hr)

Depending on time we will decide whether to continue to Mers-les-Bains and Ault. Ault has huge cliff instability problems along its seafront and contracts have been let to investigate how to solve these problems. Then return to Calais.

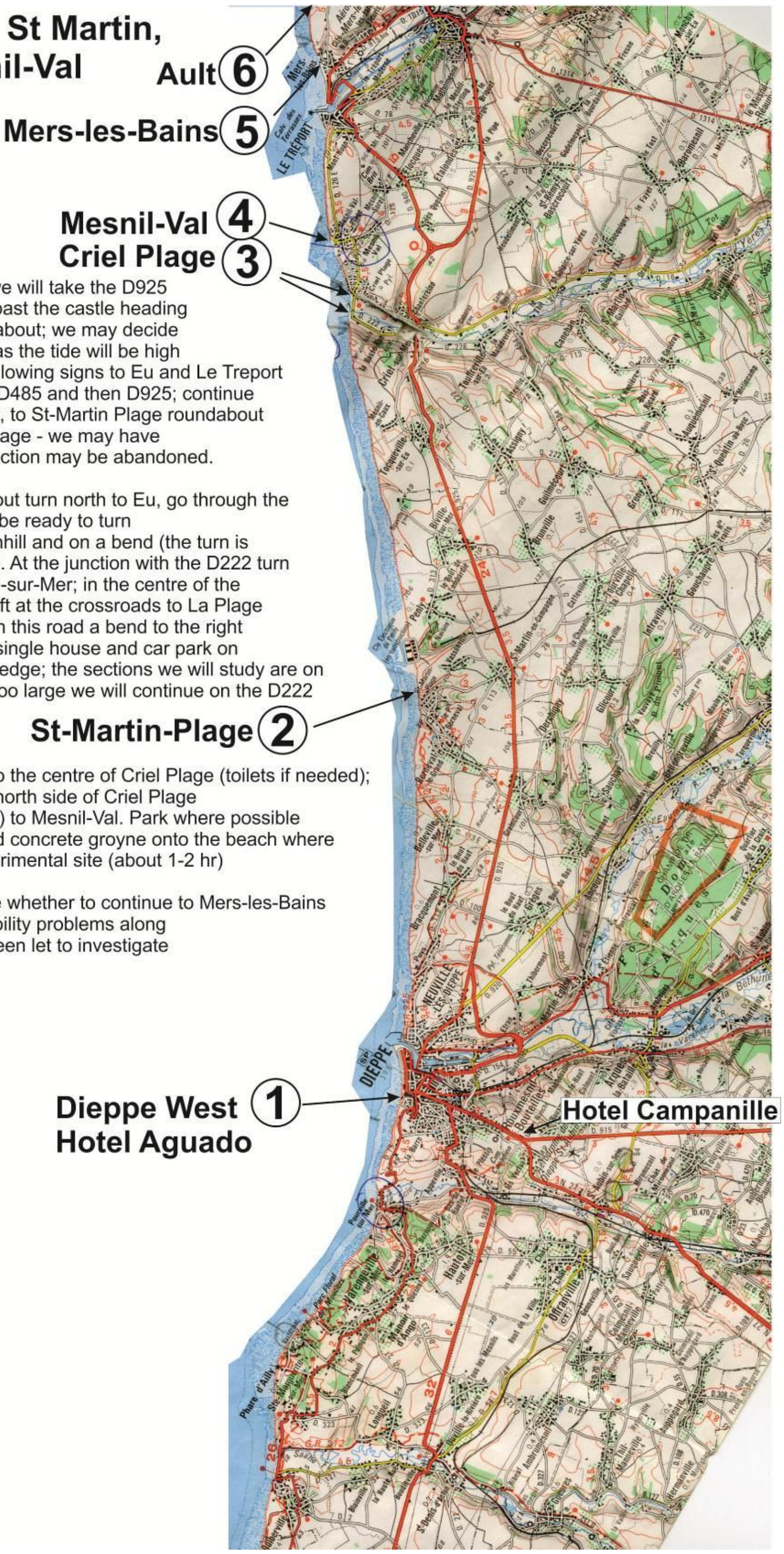


Figure 26. The Itinerary for Day 3 on the Normandy coast north of Dieppe to the Somme.

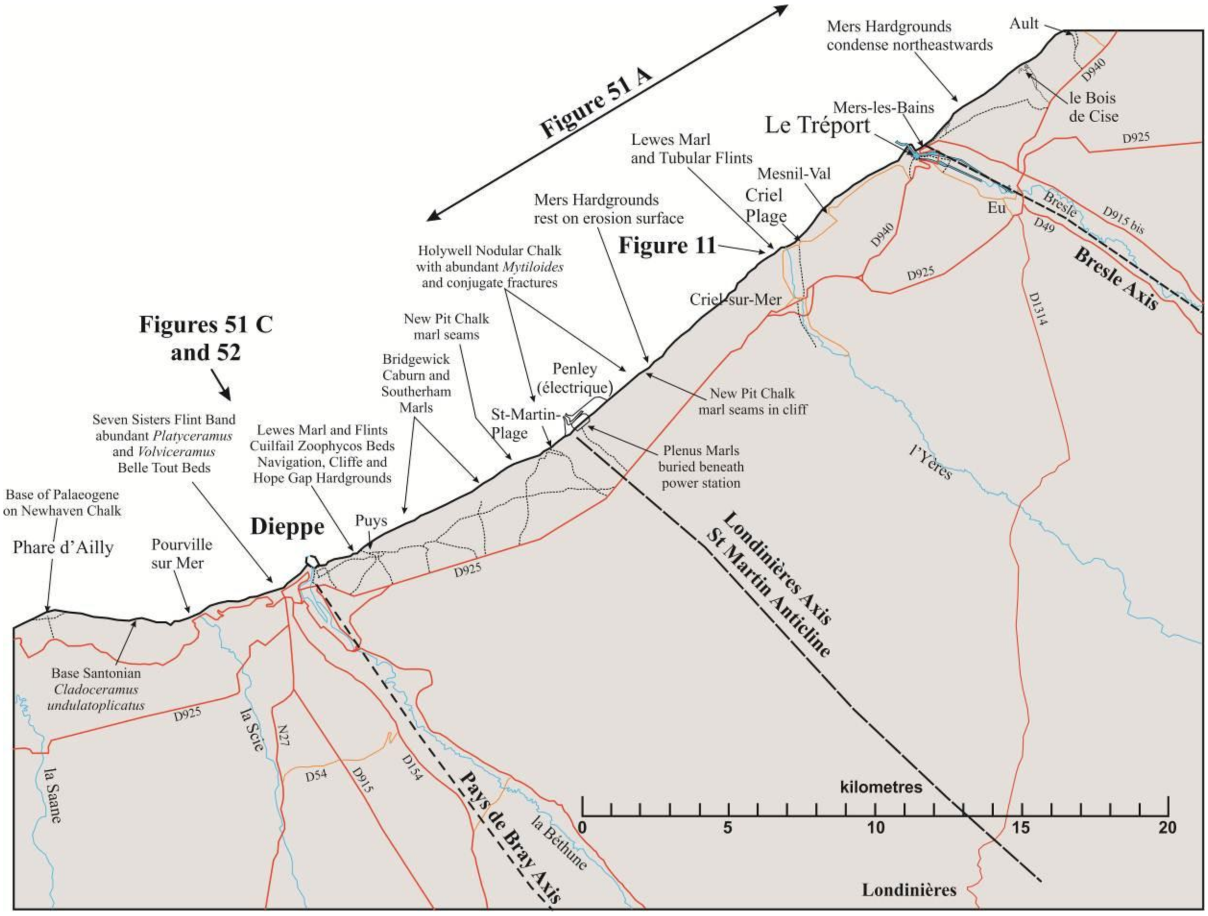
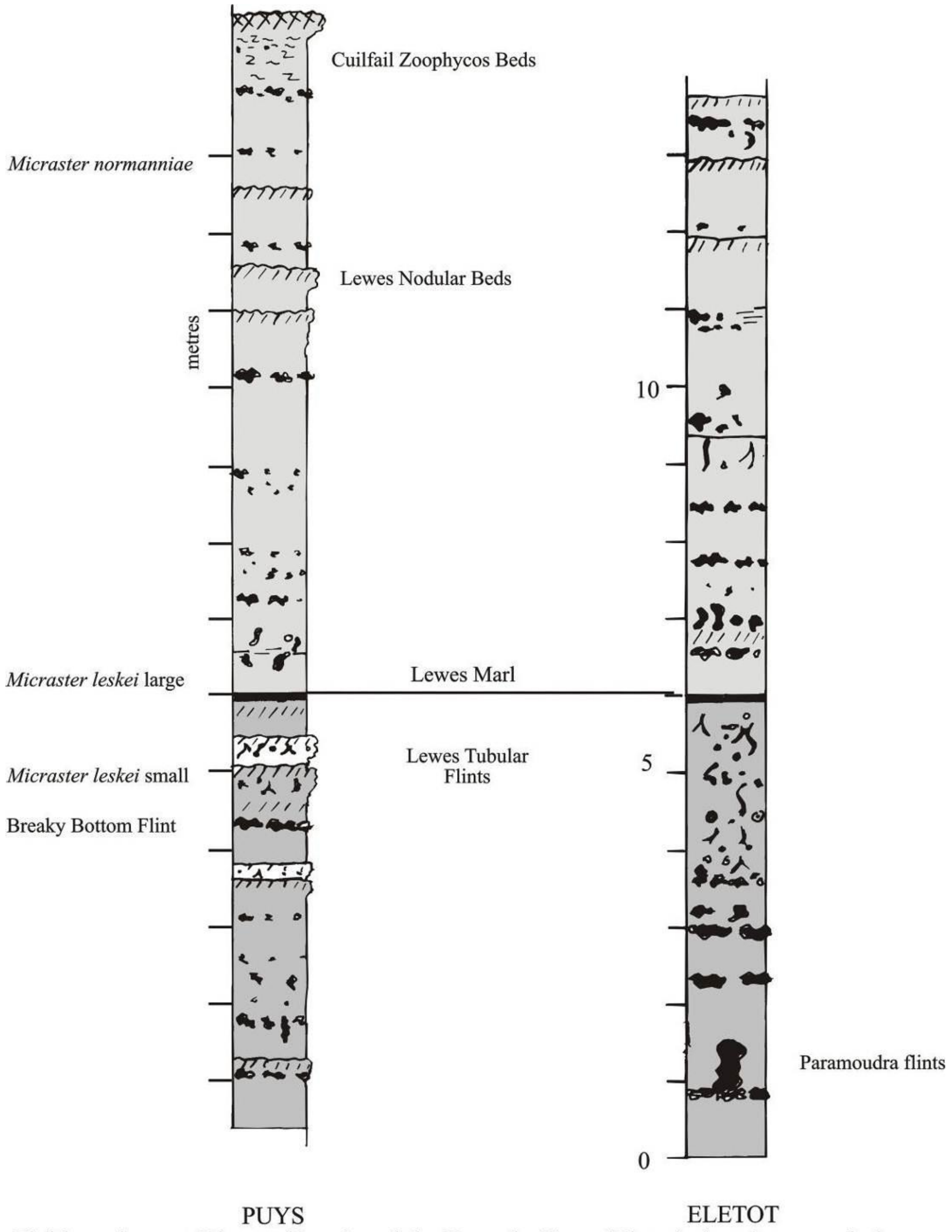


Figure 27. The localities to be visited on Day 3 showing the trend of NW-SE tectonic lines, the location of key marker beds in the Chalk and the position of illustrations given in Mortimore 2011.



Field sections at Dieppe (Puys) and the Pays de Caux (Eletot) showing correlation of the Late Turonian Lewes Marl and flints.

Figure 28. Compare this figure with the cliffs at Criel Plage below.

Loc 2. St Martin Plage

Holywell Chalk lithology and fracturing – *Mytiloides* shell beds with the ammonite Mammites nodosoides – intraclast beds, marl seams in the New Pit Chalk and sub-Lewes Chalk erosion.

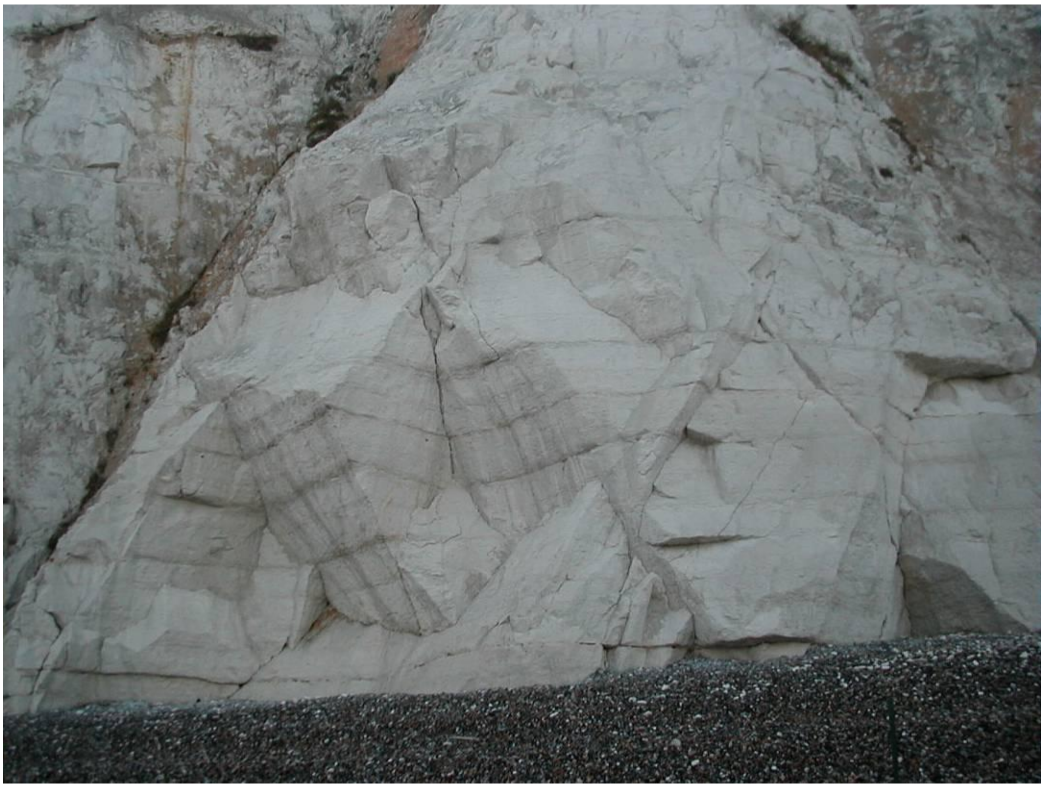


Figure 29. Inclined conjugate fractures in the Holywell Chalk at St Martin Plage

Figure 30. The beach and cliffs at St Martin Plage

Loc. 3 Criel south

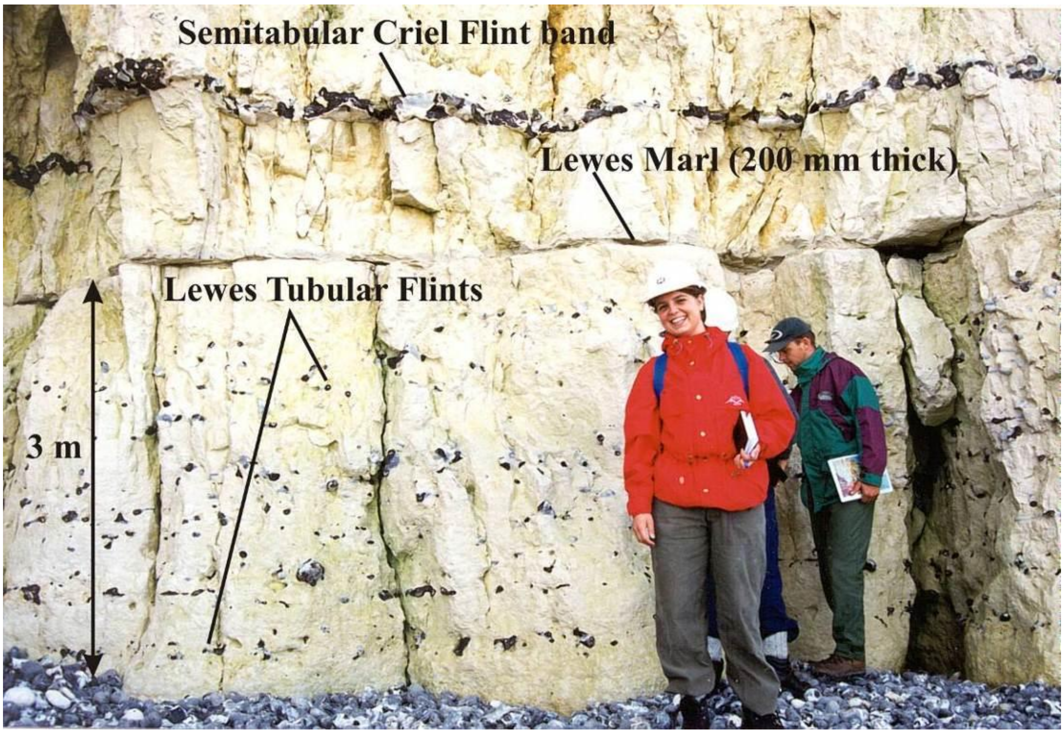


Figure 31. Cliff exposure at Criel South

It was a great surprise on first visiting Criel to find such a remarkable development of the Lewes Tubular Flints and Lewes Marl. This confirmed the importance of this level as a key marker in the axis of the Anglo-Paris Basin. This key marker is also always conspicuous on geophysical borehole logs which provide the major subsurface correlation framework. *Bathichnus paramoudrae* hardened-chalks form pinnacles on the wave-cut platform at the Breaky Bottom Flint level. \there are wonderful examples of massive, branching Thalassinoides flints in circles (fairy rings of Norfolk) on the wave-cut platform in the beds below the Lewes Flints. Also on this south side of Criel the Cuilfail Zoophycos are well developed and abundant *Echinocorys*, *Micraster* and *Conulus* occur. Heavily orange, iron-stained fractures parallel to the river valley illustrate CIRIA Grade B and C chalks in this geological setting.

Criel north

On the north side of Criel, beds below the Lewes Marl are formed along the surface of a mound-like structure with a long wave-length. This allows the different mode of preservation of trace fossils to be seen. Down slope of the mound some vertical traces are preserved in glauconite whereas elsewhere the same traces are grey, burrow-fills. Note the correlation of the Lewes Tubular Flints, the Lewes Marl and the Criel Flint. Also note the weathering associated with the valley and downslope creep. Note the style of fracturing (persistent conjugate joints with a small apical angle), which control formation of caves. Also note the unit of weaker, high porosity chalk above the Lewes Marl that causes increased weathering. This demonstrates the layered nature of chalk porosity.

Loc. 4. Mesnil-Val

Mesnil-Val was chosen as the site for the PROTECT experimental station, based on the geology that had been explored and identified over the previous two decades. Towards the base of the cliff the Lewes Tubular Flints, Lewes Marl, and Criel Flint can be identified. A weaker/softer unit in the Chalk between the Lewes Marl and the Navigation Beds forms a conspicuous weathered-out concave horizon. This weaker horeizon is traceable all the way from Dieppe East to Le Tréport and probably into the Somme (FLOOD 1 Project). Conspicuous primary conjugate fractures with an acute apical angle typical of the Lewes Nodular Chalk Formation transgress the entire cliff (slickensided/striated). Note other fractures are typically bed related and control some of the cave systems below the Lewes Marl.

Figure 32. Drilling horizontal boreholes at Mesnil-Val for the PROTECT Programme

Several research projects have investigated the stability of the Chalk coastal cliffs of the U.K. and northern France. A key site for this work has been the Mesnil-Val to Criel cliffs of France. A European INTERREG II funded project, Risk of Cliff Collapse (ROCC, 1999-2001) brought teams from the French Geological Survey (BRGM) and the universities of Brighton & Le Havre together for a two year investigation of the nature and scale of collapses along the Channel coastline. The outcomes from the ROCC Project have been published as a Geological Society Engineering Geology Special Publication (Mortimore & Duperret, 2004). ROCC was followed by the European funded 5th Framework PROTECT project (PRediction Of The Erosion of Cliffed Terrains, 2001-2004) which investigated new ways of determining and predicting time dependant fracture development and cliff instability in chalk coastal cliffs at sites in southern England, north-west France and the Baltic coast of Denmark at Møns Klint. The results indicate that the techniques and methods employed have the potential to provide an early warning of impending cliff failure. PROTECT was undertaken by the national geological surveys of Denmark and Greenland (GEUS), France (BRGM) and the U.K. (BGS) and the University of Brighton, supported by the French Geotechnical Laboratories at Nancy (INERIS). BGS were the co-ordinating partner and the project was supported by the Isle of Wight Centre for the Coastal Environment (IWCCE), the Direction Departementale de L'equipement de la Seine Maritime (DDE76), Urzad Morski w Gdyni (PMA) and Consorzio Ferrara Ricerche (CFR).

A wide range of scientific results were obtained from all the working partners in the PROTECT Project:

- University of Brighton: the engineering geology of the sites including rock mass characteristics, strength testing and external influences on the chalk cliffs.
- The British Geological Survey (BGS): the application of azimuthal apparent resistivity (AZR).
- The Bureau de Recherche Géologiques et Minières (BRGM): the seismic velocity characteristics of the rock mass and
- the Institut National de l’environement Industriel et des Risques (INERIS): the mechanical behaviour and acoustic emission characteristics of developing cliff failures
- The Geological Survey of Denmark and Greenland (GEUS): the control field survey.

The site to be visited during the field meeting will be at Mesnil-Val where the cliffs were instrumented by INERIS, geophysical surveys were carried out by BRGM and BGS and the characterization of the geology and engineering geology was investigated by the University of Brighton.

Figure 33. Impact of climate on cliff collapse Automatic micro met station at Mesnil-val wind speed and direction temperature precipitation

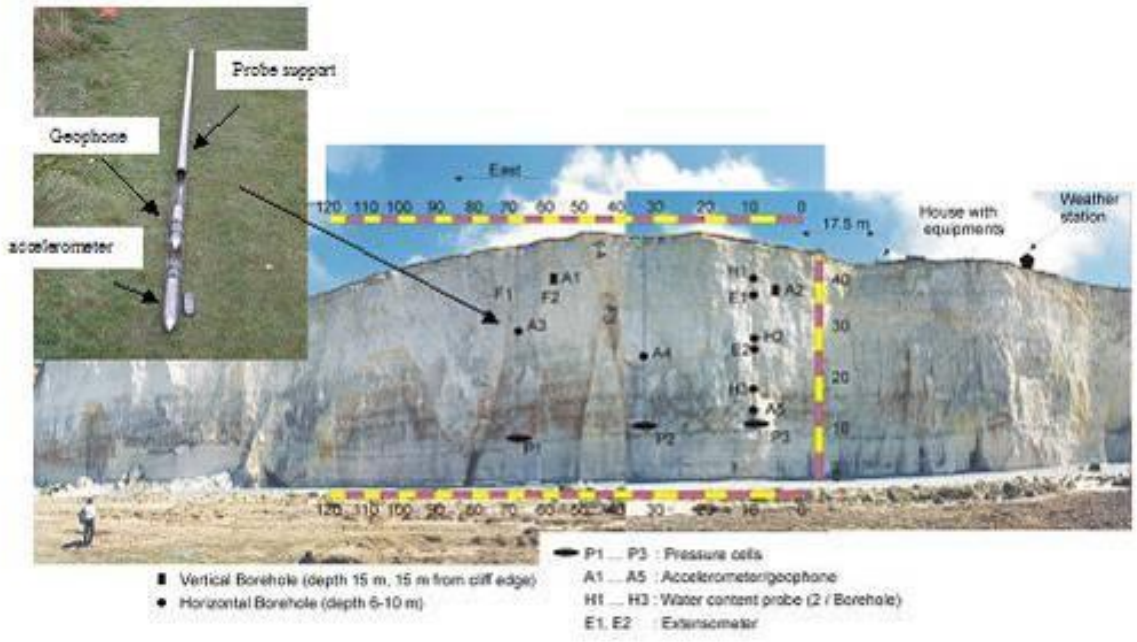


Figure 34. PROTECT Mesnil-val site: experimented with a range of different types of instrument; installation methods & monitoring networks

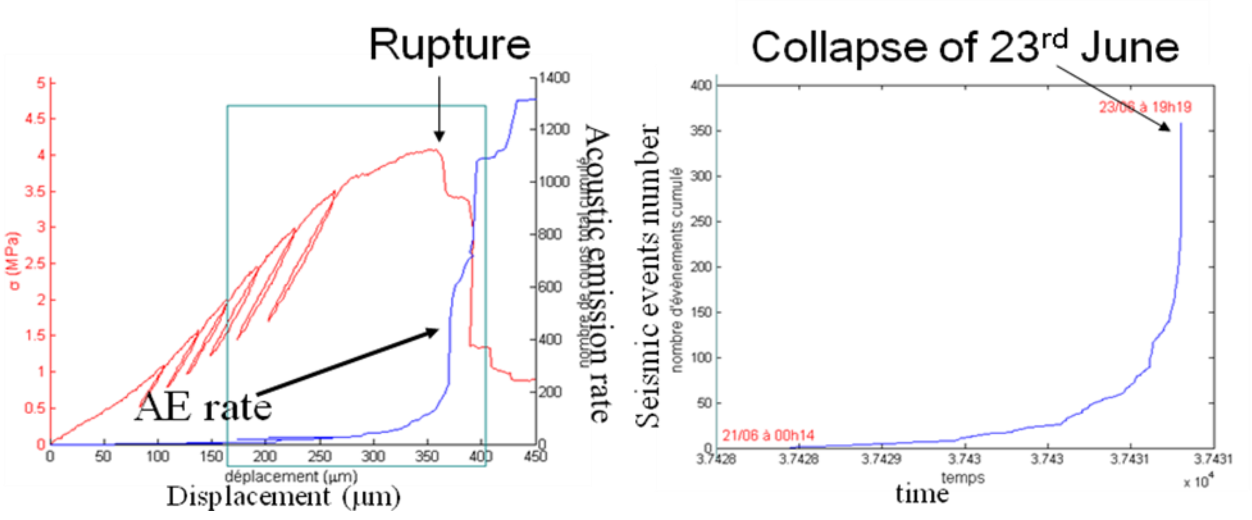


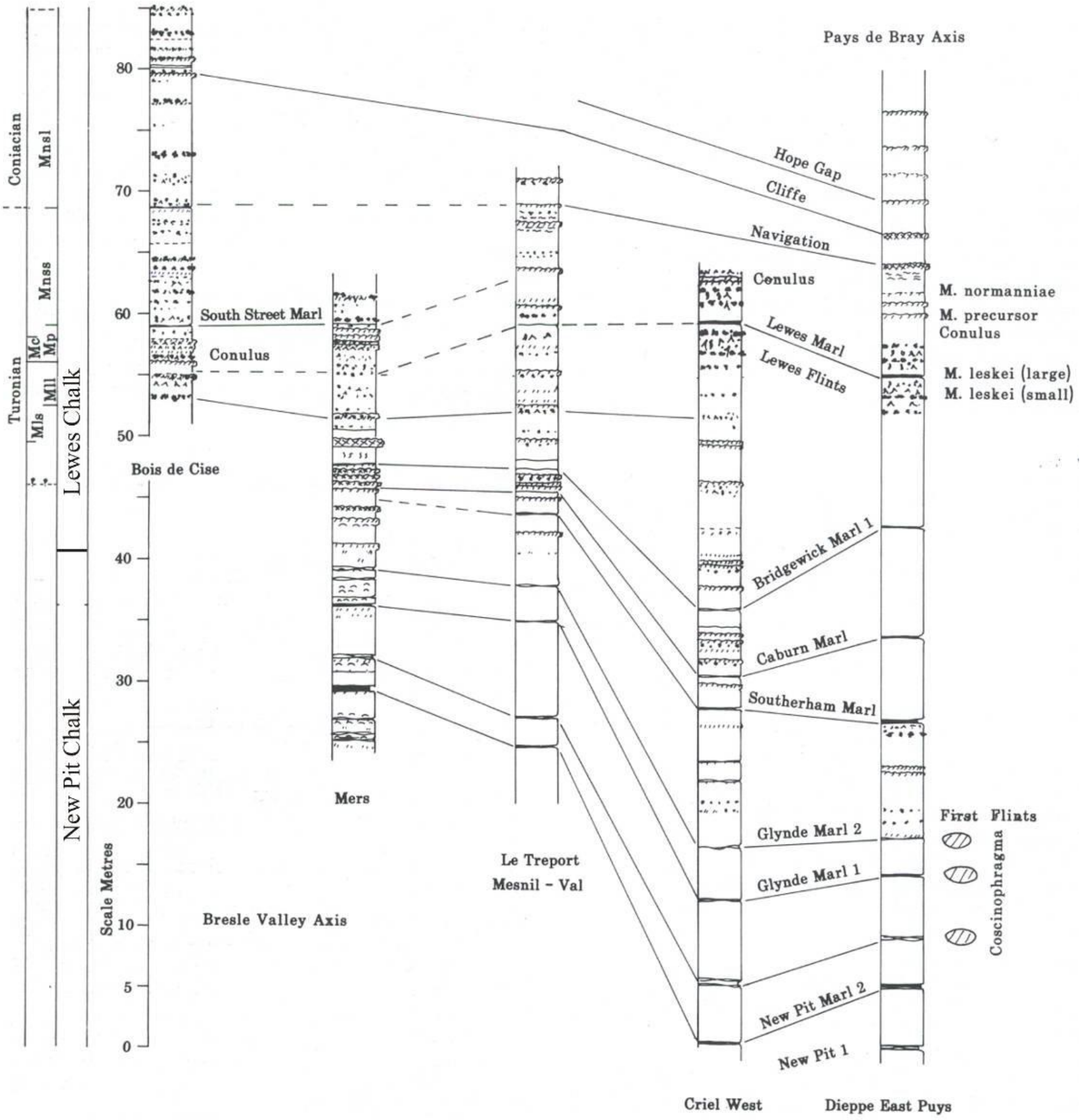
Figure 35. Site and laboratory rupture and acoustic emission, Mesnil-val experimental site

Loc. 5 Le Tréport and Mers-les-Bains

The Bresle Valley Axis comes out at Mers-les-Bains and has a great influence on chalk sedimentation, bringing the Turonian up again at Le Tréport and Mers (Mortimore & Pomerol, 1987). This creates the environment for the condensation seen in the development of the Mers Hardgrounds. These hardgrounds represent the chalk between the Glynde and Lewes Marls (Lower Lewes Chalk) but the marker marl seams, Southerham, Caburn and Bridgewick, have all been attenuated. It is another example of the Late Turonian movements but with a different expression compared to the Etretat Chalk. This condensation also results in *Micraster* occurring in abundance at some horizons e.g. *M. leskei*.

This section gives the opportunity to review the problems of chalk correlation in areas which were tectonically active during sedimentation and reinforces the need for detailed palaeontological studies alongside the lithostratigraphy.

Figure 36. En route from Mesnil-Val a stop will be made at a viewing point at the top of the cliffs at Le Tréport with an excellent view of the Bresle valley axis.



Sections between St. Martin Plage and Bois de Cise
From Mortimore and Pomerol, 1987.

Figure 37. Dieppe to Mers-les-Bains coastal cliff sections illustrating attenuation towards the Bresle Valley axis in the Late Turonian represented by the Mers Hardgrounds (Mortimore & Pomerol, 1987)

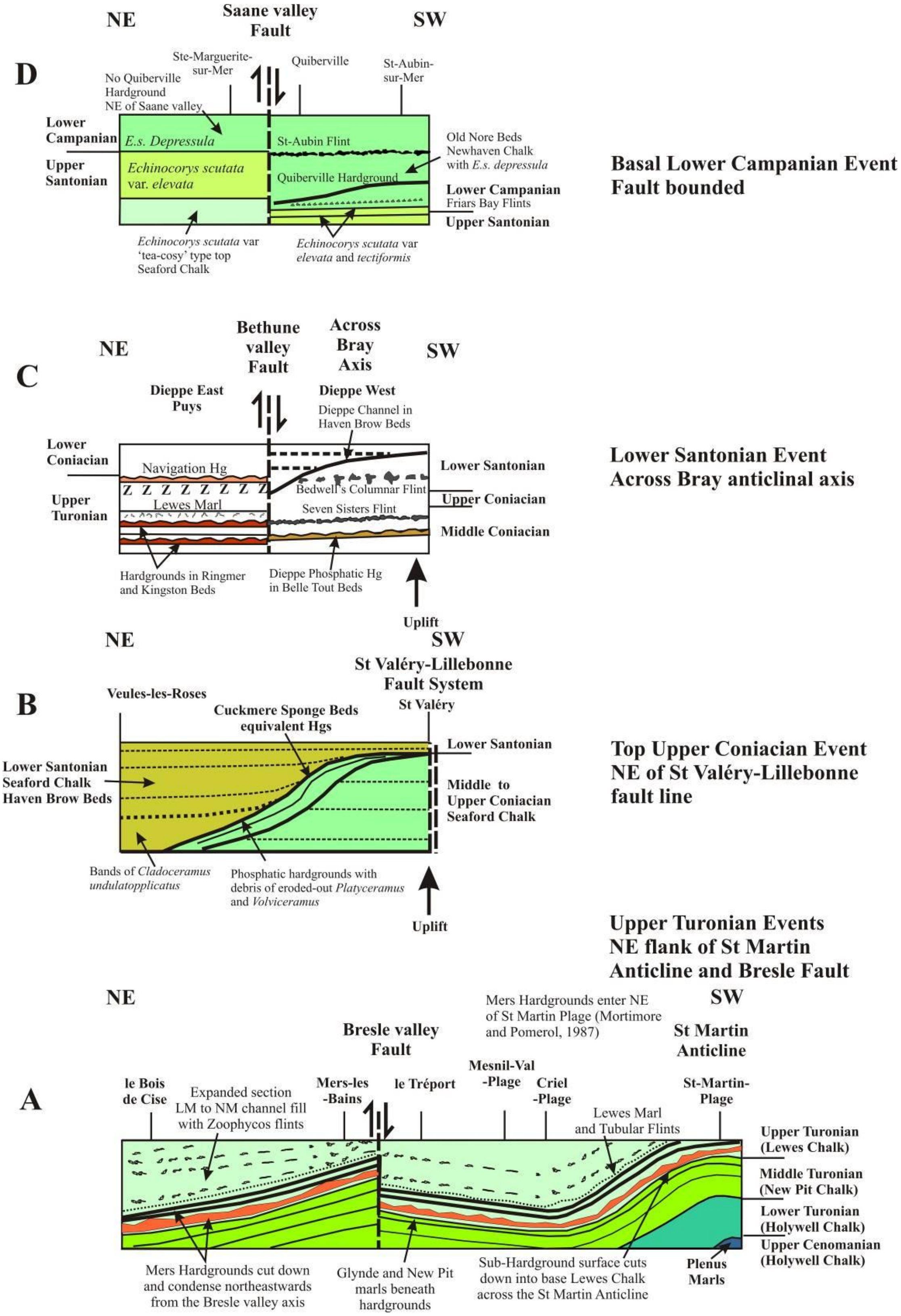


Figure 38. Schemnatic models for sedimentation across various tectonic lines, Upper Normandy coast.

Loc 6. Ault

The final Locality, Ault is in the Department of Somme and shows the extreme problems related to a town built along the cliff tops.

Summary

Day 1 introduced the idea of cross-Channel correlation of marker beds and formations, supported by the macro-fossils; the presence of erosion surfaces within the Chalk (sequence boundaries), and the range of karst features to expect in chalk.

Day 2 illustrated the lateral changes in chalk sediments that take place on an isolated fault controlled platform where gritty lithologies predominate and where sea-level changes and tectonics combined to produce erosion events and slumping (growth tectonics).

Day 3 illustrated the return of interbasinal marker beds in the more complete 'basinal' sequences, and the condensation of beds with associated occlusion of marker beds over tectonic axes and a fracture stratigraphy for the Chalk. Coastal cliff instability studies illustrated some of the mechanisms causing different types of failures and the methods being developed to monitor instability. Other research on chalk strength related to water chemistry (salinity) was also discussed.

The controls on groundwater exerted by lithologies such as hardgrounds, marl seams and flint bands, as well as the primary fractures and valleys, has also been observed over the three days.

The French coast, more than the English coast provides illustrations of all these aspects of Chalk geology and applied geology. Nevertheless, the examples seen here over the three days can be applied to southern England as well.

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To all my French colleagues who have helped me understand the geology of the Paris Basin and how things are done in France, especially Bernard and Charles Pomerol and their families, Anne Duperret, Albert Genter, Pierre Watremez, Christian Naill and Frank Hanot and the proprieters of Le Coq Hardi in Criel Plage.

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Coastal cliff instability figures from Duperret et al. 2004

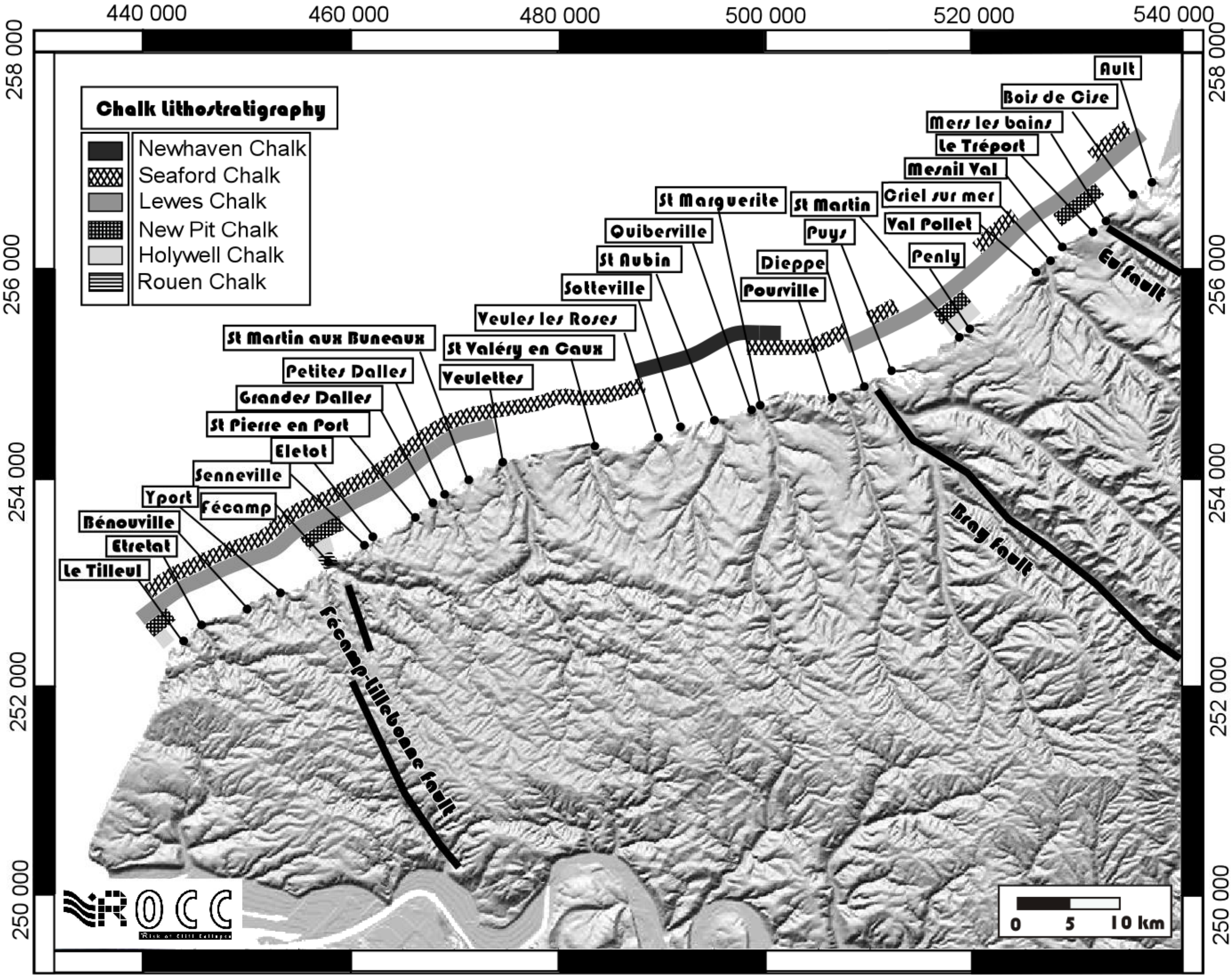


Figure 39. DTM map produced by BRGM and showing the distribution of Chalk formations along the coast of Upper Normandy

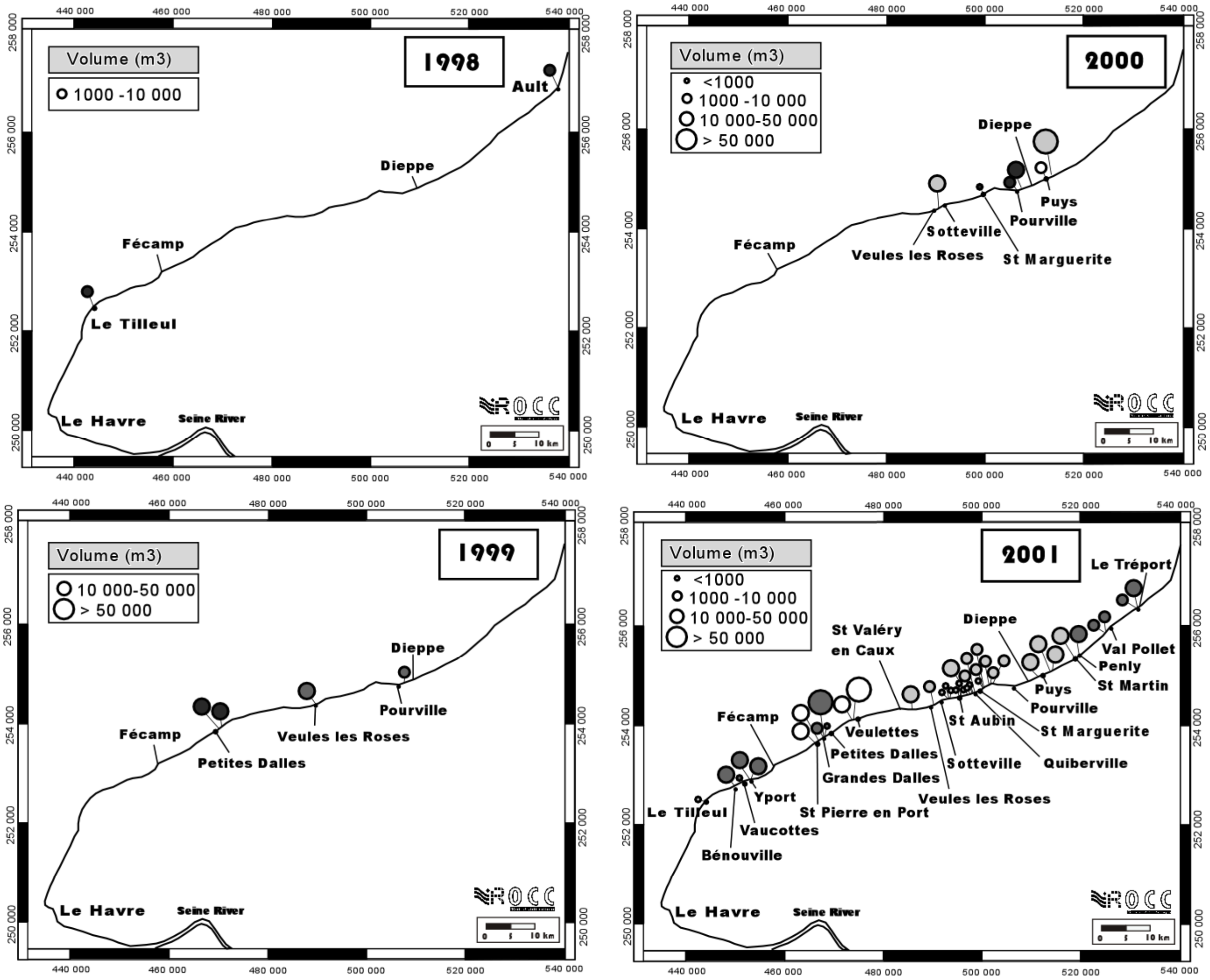


Figure 40. Frequency and size of cliff collapses by year for the 4 year period 1998-2001.

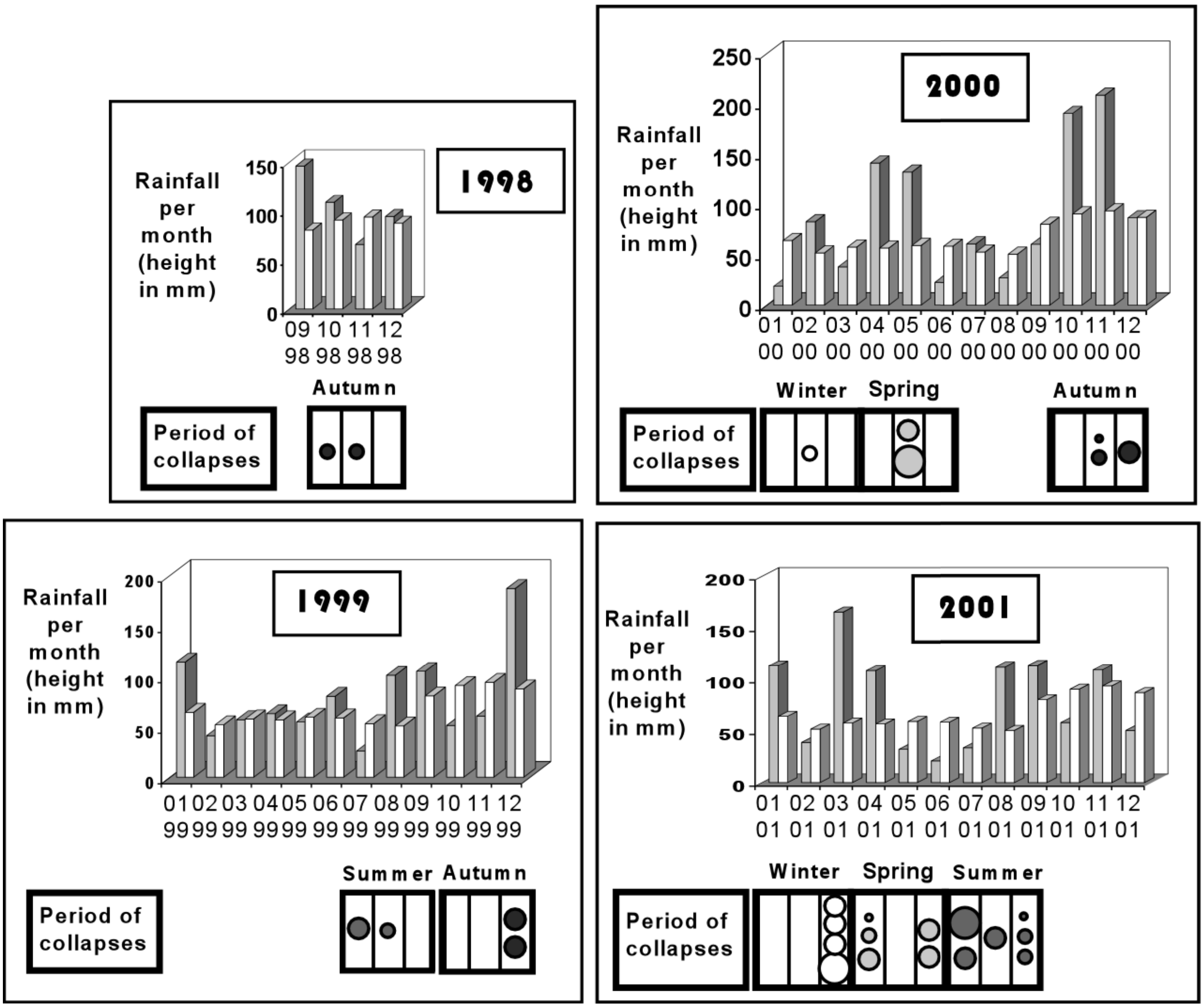
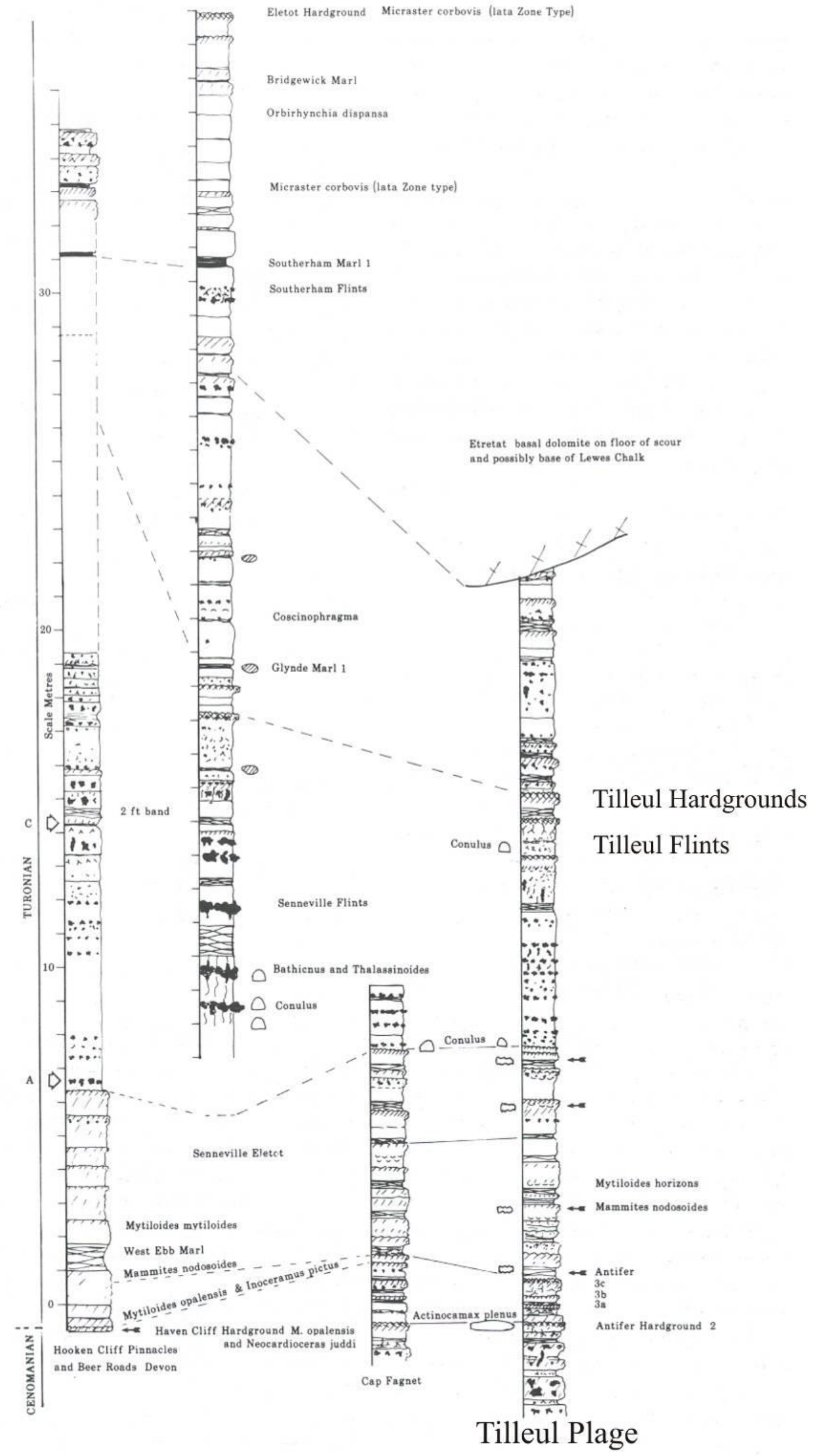


Figure 41. Rainfall recorded along the cliffs per month for the 4 year period 1998-2001



Sections between Tilleul Plage and Eletot (From Mortimore & Pomerol, 1987)

Figure 42.

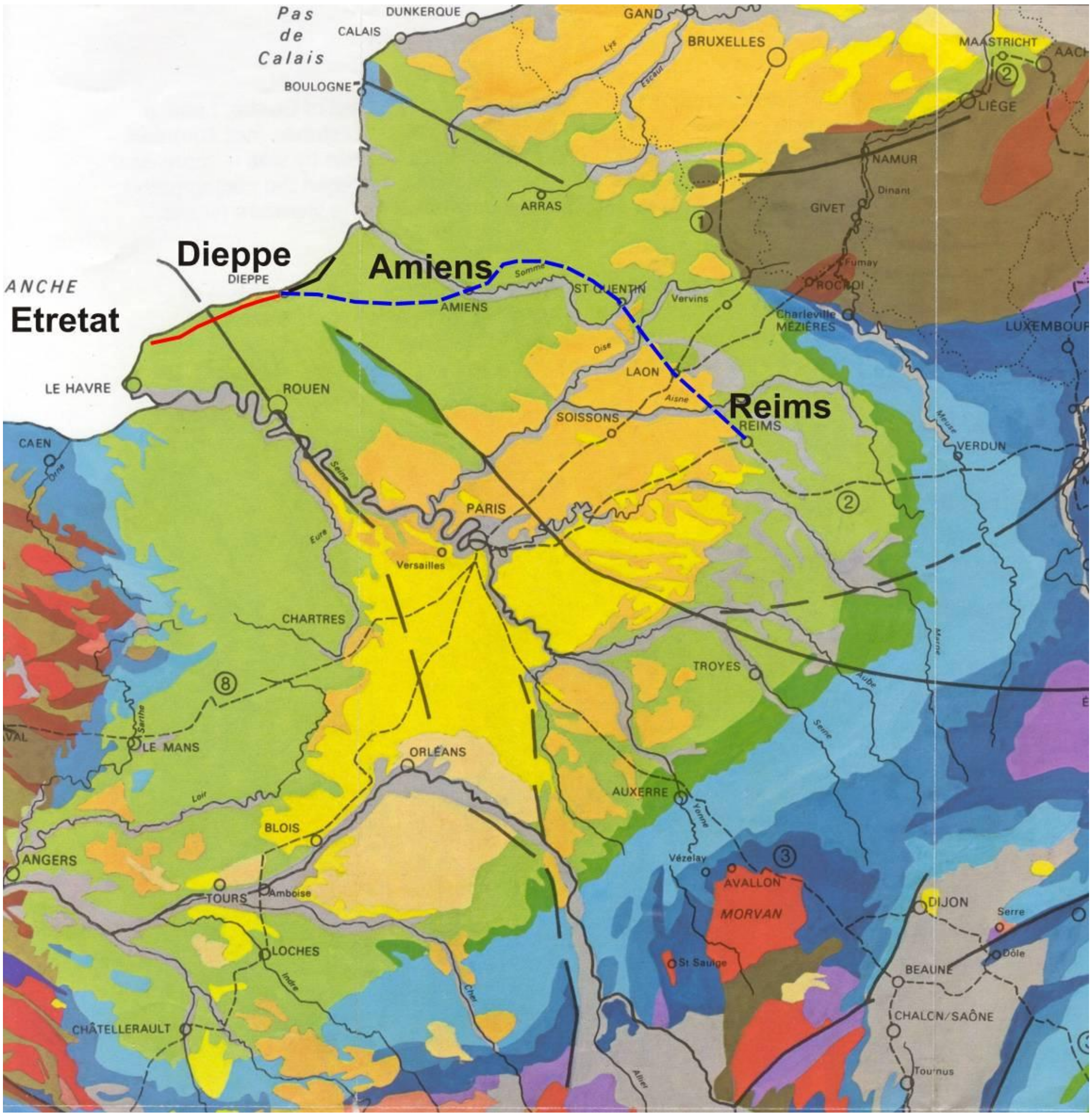
STRATIGRAPHY OF THE BOULONNAIS

QUATERNARY	Holocene	Marine and estuarine sands Dunes
Last 1.8 million years	Pleistocene	Raised beach deposits
CENOZOIC	Pliocene	Diestian - Marine sands, locally cemented
65-2 million years	?Eocene-Landenian	Brackish water sands and clays
MESOZOIC		
Cretaceous 142-65 Ma	Cenomanian - Maastrichtian	Chalk
	Albian	Gault Clay
	Aptian	Sables de Wissant
	Berriasian - Barremian “Neocomian”	“Wealden”
Jurassic 213-142 Ma	? Volgian? “Purbeckian”	Calcaire des Oies
	Portlandian	Gres des Oies
		Assises de Croi
	Kimmeridgian	Argiles de Wimereux
		Argiles de la Creche
		Grès de la Creche
		Argiles de Chatillon
		Grês de Chatillon
		Calcaires du MoulinWibert
		Argiles du Moulin Wibert
		Calcaire de Brecquerecque
	Oxfordian	clays passing up into limestones
	Callovian	and sandstones
	Bathonian	Clays and Limestones
		Caicaire des Pichottes
		Oolithes de Marquise
		Oolithes de Rjnxent
		Marnes d ‘Hydroquent;
		Sables d ‘Hydroquent
	Bajocian	(?) only in borings
	Lias	only in borings
Triassic 248-213 Ma	Rhaetian	clays- and sands
PALAEOZOIC		
Carboniferous 360-286 Ma	Westphalian	Houiller (Coal)
		Gres des Plaines
	Visean	(Calcaire Carbonifere)
		Dolomie du Hure
	Tournasian	Calcschistes de la Vallee Heureuse
Devonian 408-360 Ma	Famennian	Gres de Ste. Godeleine
	Frasnian	Schistes de Fiennes
		Calcaire de Ferques
		Schistes de Beaulieu
	Givetian	Calcaire de Blacourt
		Gres et Poudinque de Caffiers
Silurian 438-408 Ma	Ludlovian	Schistes a *Monograptus colonus*

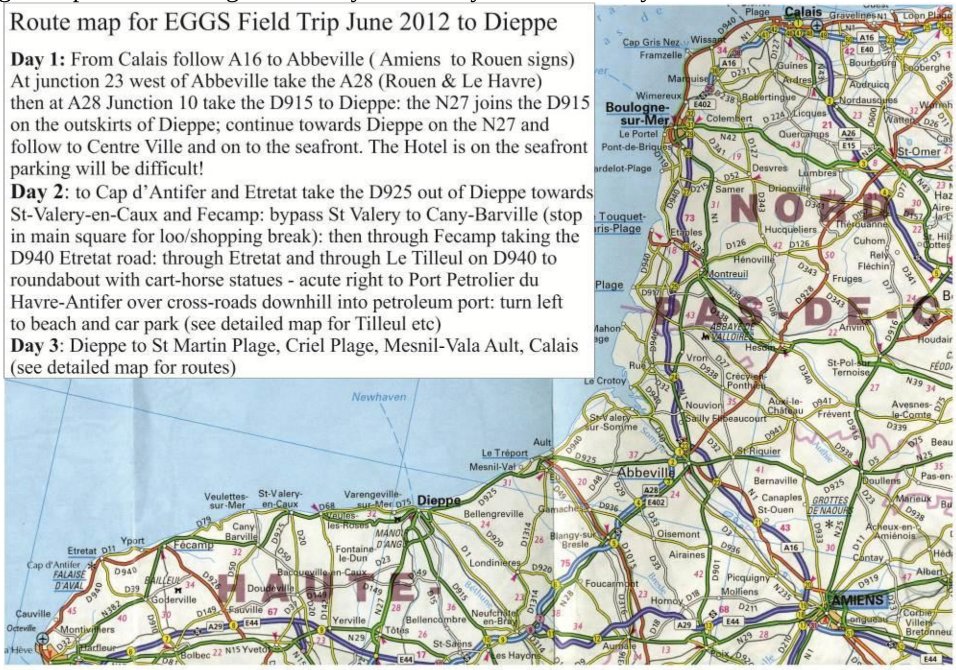
Geology of the Ferques Inlier. Location and subcrop map of Hercynian thrust belt beneath Mesozoic cover and cross-section across Ferques inlier. (From Cooper, Garton and Hossack, 1983)

Schematic profile of the duplex structures in the Basse Normandie Quarry, Ferques Inlier. (From Cooper, Garton and Hossack, 1983)

Coastal sections between Boulogne and Cap Blanc Nez. (From Ager and Wallace 1966)



Figure….Simplified geology map of the Paris Basin (Based on Ch. Pomerol, 1980)



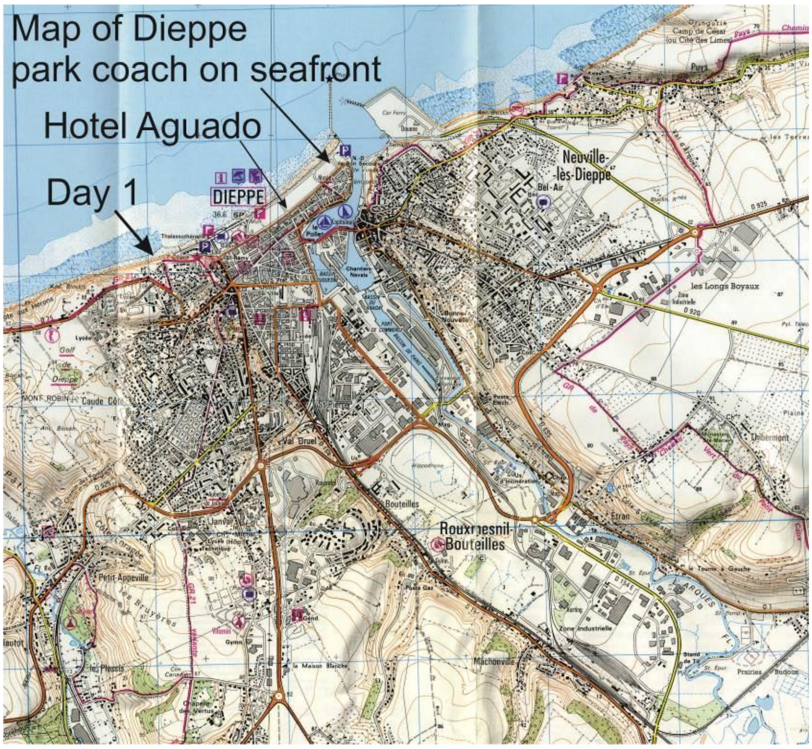
Route map for EGGS Field Trip June 2012 to Dieppe

Day 1: From Calais follow A16 to Abbeville (Amiens to Rouen signs) At junction 23 west of Abbeville take the A28 (Rouen & Le Havre) then at A28 Junction 10 take the D915 to Dieppe: the N27 joins the D915 on the outskirts of Dieppe; continue towards Dieppe on the N27 and follow to Centre Ville and on to the seafront. The Hotel is on the seafront parking will be difficult!

Day 2: to Cap d'Antifer and Etretat take the D925 out of Dieppe towards St-Valery-en-Caux and Fecamp: bypass St Valery to Cany-Barville (stop in main square for loo/shopping break): then through Fecamp taking the D940 Etretat road: through Etretat and through Le Tilleul on D940 to roundabout with cart-horse statues - acute right to Port Petrolier du Havre-Antifer over cross-roads downhill into petroleum port: turn left to beach and car park (see detailed map for Tilleul etc)

Day 3: Dieppe to St Martin Plage, Criel Plage, Mesnil-Vala Ault, Calais (see detailed map for routes)

Map 1: Route from Calais to Dieppe following motorways (A16, A28) and main roads (D915) to the Hotel at Dieppe

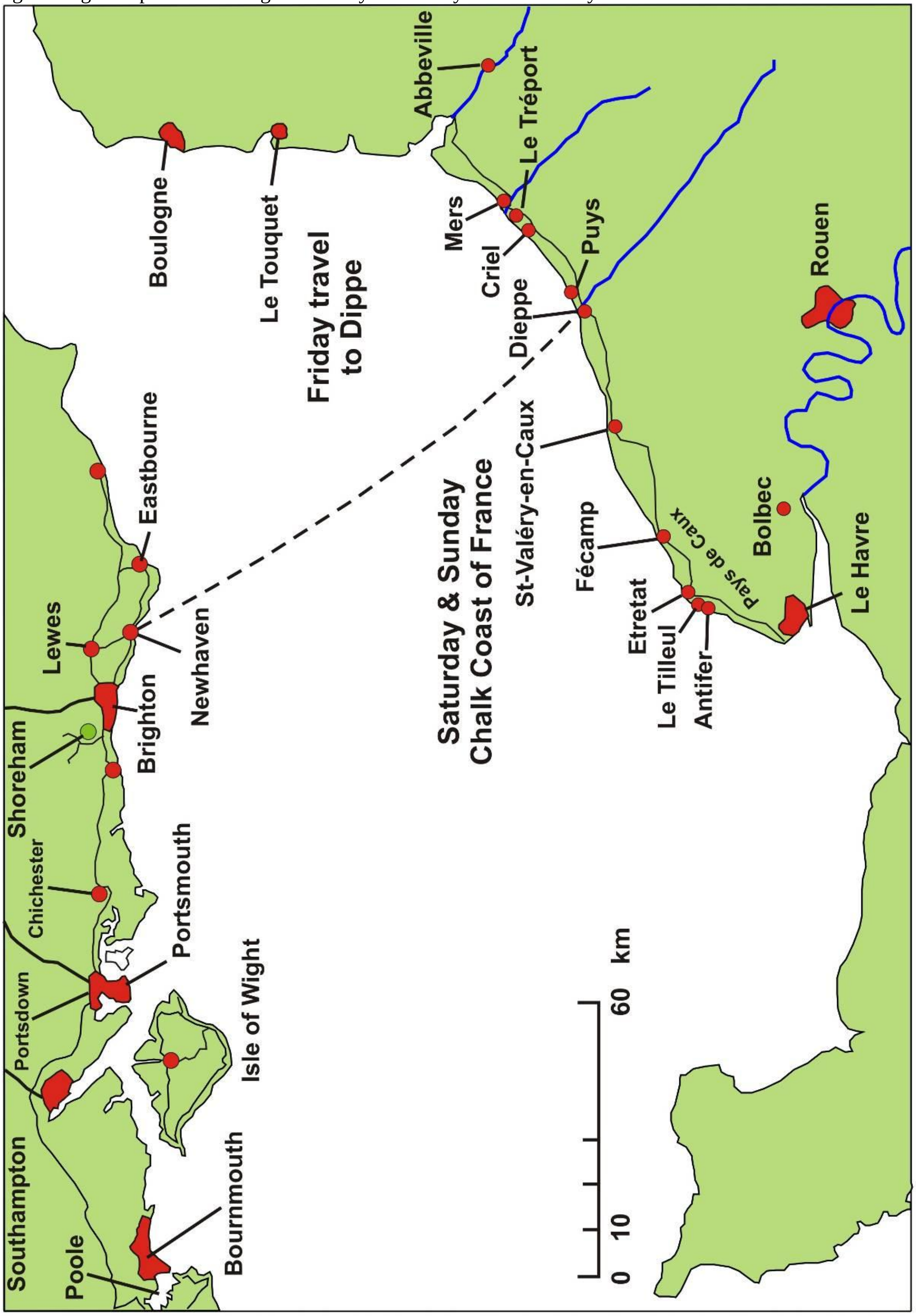


Map of Dieppe
park coach on seafront

Hotel Aguado

Day 1

Map of Dieppe showing location of the hotel and the seafront section for Friday 29th June


Southampton
Poole
Portsdown
Chichester
Shoreham
Portsmouth
Isle of Wight
Bournmouth
Brighton
Lewes
Newhaven
Eastbourne
Boulogne
Le Touquet
Friday travel
to Dippe
Saturday & Sunday
Chalk Coast of France
Abbeville
Le Tréport
Mers
Criel
Puys
Dieppe
St-Valéry-en-Caux
Fécamp
Etretat
Le Tilleul
Antifer
Pays de Caux
Bolbec
Rouen
Le Havre
0
10
60
km