Farnham Geological Society

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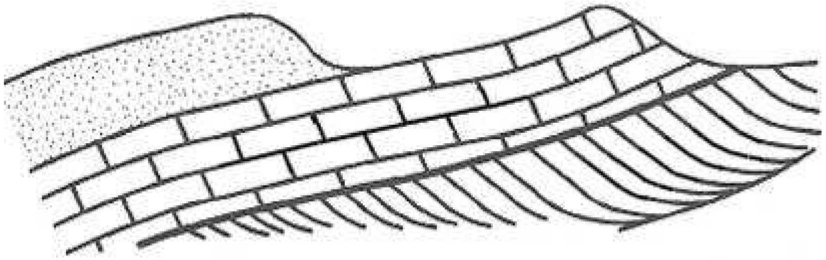

A local group within the GA

Vol. 12 No.1

Newsletter

February 2009

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Editorial

The study of geology is seen by many as a narrow specialist subject of interest only to "professionals." As we know, this is not a true picture and many examples can be quoted to demonstrate the "long arm" of geology.

In this newsletter there are several examples of the interaction between geology in its technical context and in its wider aspects. It is right that our newsletter should embrace related subjects, either as separate articles such as Mike Rubra's account of the archaeological aspects of the field trip to Brittany and Normandy; or as articles such as the report of Ruth Siddall's lecture on "The Geology of Paintings". Before this lecture many members could not understand what could be the connection between fine art and geology; in the event this fascinating talk opened our eyes to the importance of rocks and minerals in the making of pigments for use by painters.

The best example of the wider aspects of geology contained in this newsletter is the summary of Peter Worsley's talk on Darwin. He underlined the fact that Darwin, highly renowned for his work on "The"Origin of the Species" was, throughout his life, a keen observer of the influence of geology on the development of human communities and of fauna and flora species. He was, for example, fascinated by the development of coral reefs when the Beagle was visiting islands in the Indian Ocean. A whole section of his journal concerning the Beagle's exploration is devoted to this topic.

To round off these observations one should note the extent to which natural history and suchlike programmes on television touch on aspects of geology. One can find fault with the sometimes shallow interpretations but nevertheless it is good to see that the underlying geology is thought worthy of mention It gives us the opportunity of providing further enlightenment to our friends!.

Peter Cotton

Programme of lectures January to April 2009

Date	Speaker	Title
9th January	John Williams, FGS	*Building Stones of London – a Historical Perspective*
13th Feb	Di Smith Open University	*Flint*
13th March	Duncan Pirrie Helford Geoscience LLP	*Forensic geoscience; the role of geology in serious crime investigation*
17th April *Note:3rd Friday of the month*	Dr Hazel Rymer Open University	*Low Cost Volcano Monitoring*

Field excursions April to June 2009 - see page 14 for details of entire year

Date	Field trip	Leader
April 3 – 6	St. Austel granite	Dr Alan Bromley
May 10 - 16	Isle of Man	Dr Bill Fitcher
June 7	Avebury to Swindon	Dr Graham Williams and Mike Rubra

Diamonds through time

Summary of November lecture given by Andrew Fleet, Natural History Museum

On the human timescale diamonds were first known in southern and eastern Asia two thousand or more years ago. Their rarity made them symbols of power and they remained the property of royalty and the elite. Most came from river gravels of southern India. A few stones found their way to classical Greece and Rome but in Europe disappeared from view until the 14th or 15th century. The supply was still from Asia but by about 1700 this supply was drying up and became replaced by one from diamond-bearing river gravels in South America. The supply of South American diamonds in turn became limited in the early 19th century but in the 1860s diamonds began to be discovered in river gravels in southern Africa. These discoveries led to the ultimate source of diamonds being recognised in pipe-shaped volcanic deposits that came to be called kimberlites after the birthplace of the South African diamond industry.

Understanding of the reasons why diamonds are so rare stemmed from this discovery. Firstly their main region of formation is under areas of the continents which have remained geologically undisturbed for 2,500 million years or more (cratons). Here the diamonds formed at temperatures of ~1000°C and pressures 45,000 times atmospheric, mostly at a time of three billion years ago. Secondly they needed to be transported rapidly from the depths at which they form (140-200 km) so they do not transform to graphite as pressure was released the shallower they got. It was the magmas which give rise to kimberlites and lamproites, another volcanic rock, which provided this rapid transport system at various times throughout the Earth's history. They originate at depths of 150 km or more and are rich in carbon dioxide. They move through fractures and near the surface have explosive power as their gas content comes out of 'solution'. However kimberlites are rare, only about 6000 pipes are known and furthermore only about one in 200 pipes contain diamonds in economic quantities, added to which only about 20% of diamonds mined are of gem quality.

Andy Fleet

Charles Darwin, Mercian Geologist

Summary of December Lecture given by Professor Peter Worsley, Reading University

Professor Worsley started his lecture by explaining why he described Charles Darwin as a Mercian Geologist. Darwin was born in Shrewsbury where he attended Shrewsbury School and his family was related to the Wedgwood family; this part of the country had been within the old kingdom of Mercia. With regard to the description of Darwin as a geologist. the speaker was at pains to point out throughout his talk that Darwin was as knowledgeable about geology as about fauna and flora for which he is better known.

After Shrewsbury Darwin went to Edinburgh University at the age of 16 to study medicine, which he hated, and spent much of his time attending lectures on natural science. His father was not happy about what he regarded as a lack of application by his son and then took the unusual step of sending Charles to Christ's College, Cambridge, to study theology. Once again Darwin spent most of his time pursuing his real interests of botany and geology, amassing specimens of both. In these pursuits he was encouraged by Adam Sedgewick, who was the Professor of Geology, and also by John Stevens Henslow who was the Professor of Botany. It was the latter who was instrumental in obtaining for Darwin a berth on the Royal Navy's exploration ship, HMS Beagle, commanded by Captain Fitzroy. Before joining the Beagle however, Adam Sedgewick took Darwin on an extended field trip of Wales and the Borders in order to acquaint him with the practical aspects of field geology.

At the age of 22 Darwin joined the Beagle and spent the next five years travelling round the coasts of South America and the Galapagos Islands. Here he spent most of his time on land investigating the fauna, flora and geology of the coastal regions. It is not often realised that the time he spent on the Galapagos Islands was relatively brief although his investigations there are the most publicised as contributing to his great work “The Origin of the Species”.

In southern Chile and Argentina he found the immense glaciers a constant source of amazement. He was also intrigued by the vast forests and areas of lush vegetation which he described as a “cold jungle”. Another phenomenon which fascinated Darwin was the building of coral reefs; it was as a result of his observations that he began to appreciate the effects of relative movement in land and sea levels. After his return to England he struck up a friendship with Charles Lyell whose book “The Principles of Geology” was read by Darwin when on the Beagle. Darwin was particularly interested in Lyell’s visit to Pozzuoli near Naples where, by observing how far up the columns of an old temple marine creatures had eaten into the stone, he concluded that the level of the sea in this area had fallen dramatically.

One result of Darwin’s friendship with Lyell was for him to be appointed as the Secretary of the Geological Society in 1838. From 1842 Darwin lived in Down House at Downe in Kent where he continued his observations of the local fauna and flora, writing innumerable booklets;such as “The formation of vegetable moulds through the action of earthworms”. It was at Down House that Darwin brought together his thoughts about evolution which he published in his magnum opus “The Origin of the Species by Means of Natural Selection”.

Peter Cotton

The nature and origin of ferruginous “*Carstone*” development at Mellow Farm Quarry (Dockenfield), Western Weald, Hants

Introduction

The study was carried out at a disused roadside pit known as Mellow Farm Quarry located in a sunken lane (Heath Hill Lane) at a small section of Lower Greensand escarpment in the Dockenfield district of the Western Weald close to the Surrey/Hampshire boundary (OS Sheet 186 grid: 821388). The pit is located to the west side of Heath Hill and extends from north to south for ~100m with a worked face of ~20m. It was initially excavated for sands, building stones and gravels along a junction of the Folkestone Beds and contemporaneous Sandgate Beds which outcrop to the south and west of the area. The north of the quarry is believed to have been worked in the extraction of ferruginous ironstone known locally as ‘carstone’, and to the south the loosely consolidated white silica sandstones sometimes referred to as ‘silver sands’. These aggregates were used for cements and mortars while the colourful reddish/brown and dark/grey carstone was worked as a (poor) building stone and decorative chips known as galletting - indeed the quarry is thought to have supplied many of the materials used in the construction of the nearby 12th century Waverley Abbey. The Folkestone and Sandgate Beds are dated to the uppermost division (Late Albion) of Cretaceous Lower Greensands formed in shallow marine near-shore environments. To the south of the pit the silver sands are well exposed and were extracted for use in calcium-silicate brick production and as a ‘fixer’ in the manufacture of clay bricks and tiles.

Geological Setting

The gently inclined variable N/NE-dipping exposures (~15^o to ~30^o) exhibit S/SW trending of bedding planes with a degree of cross-bedding and expansion measured at ~335^o - this bearing is similar to concurrent lithologies laid down elsewhere in the NW Wealden district (Narayan 1963). In the northern part of the quarry the bedding planes are indistinct and the sediments become highly limonitic (Fe_2O_3,H_2O) with conspicuous exposures of rusty/dark tabular and cylindrical ferruginous veins which vary in thickness from a few millimetres in places to roughly five centimetres (2 inches) overall (Fig 1). The in-situ slabs or wedges of contorted veins vary in character, length, density and colour, from soft and brittle with a distinctive reddish-brown tinge, to hard and strong with a dark-grey metallic sheen - clearly an age dependant anomaly. Ironstone ‘chunks’ of all shapes and sizes litter the quarry floor intermixed with vegetation and sand masses. While the thin ironstone ‘beds’ express a tenuous sinuosity, this is countered by solidity and strength from the thicker protrusions. The latter seemingly provides stability to the escarpment face and is known to be a common geomorphological feature of the so-called Surrey Hills in this part of the Western Weald. On the other hand the thinner (younger) more ferruginous veins represent weaknesses evidenced by a rock fall that occurred in January/February 2006. There is a noticeable tendency for the thin brittle veins to rupture with marked conchoidal fracturing thereby generating minor radiating surface faults to parts of the facade. Further inspection suggests the recent rock fall was the result of freeze/thaw weathering to obtruding seams together with confined root penetration, remnant faulting, and more probably vandalism verified by graffiti to parts of this slowly deteriorating rock face – or indeed a combination of all these conditions. A series of dip measurements taken across a number of protruding veins alternated between ~10^o to ~45^{o}W/SW (inward facing) might also contribute to structural weaknesses. Although the general strike trends east-west and the dip is largely to the north, a direction which suggests long term stability to the escarpment face, periodic (natural) rock falls are thought to be rare. To the south of the pit the silver sands are well exposed and were extracted for use in calcium-silicate brick production and as a ‘fixer’ in the manufacture of clay bricks and tiles. The Folkestone Beds are dated to the uppermost division (Late Albion) of Cretaceous Lower Greensands formed in shallow marine near-shore environments.

Ferruginous Development

Formation of the iron-cemented sandstones sometimes referred to as ‘ferricrete’ elsewhere in the Wealden District can be interpreted from existing cross-sections in the quarry face as emanating from incipient meteoric surface precipitation migrating via accessible pore spaces in the loosely packed sediments. This long-lasting seepage of fluids generates striped diffusion patterns of superficial iron-stained curves or ‘drapes’ referred to as *Liesegang rings,* known from chemical reactions (Hedges 1932). In effect the oxidised drapes or curvatures are produced by gravity induced water transportation and the settling-out of oxide minerals from circulating groundwaters contained within the iron-rich lithology (Fig 2). Where the phenomenon of precipitation reactions occurs to form Liesegang rings, abundant ferruginous minerals such as glauconite, $(K(fe^{3}+,Al)_2(Si,Al)_4O_{10}(OH)_2)$, a complex hydrous silicate of iron and potassium plus aluminium, magnesium and calcium, together with leached decayed mineral substances from sub-surface organic matter, is transported to irregular spaces of containment within the sediments. As a result abundant iron-rich solutions become intermixed with alumina and calcareous minerals which cement a plentiful supply of unconsolidated quartz grains to complete the ‘ferrugenetic’ process. Isolated pockets of sediments are also formed, sometimes with bleached sandstone centres, which then develop into a variety of contorted solidified veins and cylinders delimited within the horizons – this assortment of ferruginous seams are termed *festoons* or *festooning structures* since they appear to hang like loose metallic chains between formations (Fig 3).

It can readily be deduced that the assorted configurations of ironstone developed in the highly oxidised Folkestone Beds form relatively quickly (several hundreds to thousands of years) as the sediments become subjected to diagenetic alteration. The controlling factors are an essential supply of migrating groundwaters which significantly contributes to oxidation of ferrous compounds ($FeO^{\text{-iron II compounds}}$), not least the intrinsic glauconitic minerals themselves. Reliance must also be placed on subtle internal variations over relatively long periods of time. It should also be noted that ferruginous development does not take place at depths greater the ~8m because diagenetic conditions become impeded. These include; pore space limitations, mineral constraints due to leaching restrictions, temperature variations, inadequate water migration channels and compressional dynamics. Ferruginous development of carstone results in an iron content of ~60% ($Fe_2O_{3,}H_2O^{\text{-iron III compounds}}$) which can be regarded as a limonite rock rather than a rock with constituent limonitic minerals (Read 1970).

There has always been controversy as to how the Folkestone Beds uniquely develop ferruginous variations leading to iron cementation. It was originally thought that oxidation was derived from the presence of glauconite which is common to marine sandstones. W. E. Smith (1957) disputes the notion that glauconite was the prime source because it was too fresh; moreover the variability of ferruginous development within the Folkestone Beds precludes glauconite as being a major source. Smith pointed to the importance of pyrite alteration as a more likely cause while investigating pyrite nodules in the Hythe Beds. He concluded calcium phosphates had been dissolved from percolating rainwater following removal of the Gault Clay capping. On the other hand Padgham (1970) suggested a penecontemporaneous early diagenetic process from the remains of soft parts of molluscs termed *molluscite* by Gideon Mantell (Topley 1875). However such remains are rare in the Folkestone Beds and insufficiently widespread within the succession to be a source. While the origins of iron-cementation has yet to be fully established, the stratigraphic proximity to the Gault Clay deposits with their abundance of fossilised bones and shells, provides a more productive and ready source of iron and calcium phosphates than that afforded to the stratigraphically older Hythe Beds where iron cementation is less pronounced. It is likely therefore that Smith’s (1957) work points to the alteration of pyritic nodules as the main oxidation source for variable ferruginous development in the Folkestone Beds.

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Fig 1: Early development of contorted ironstone veins known locally as 'Carstone', Folkestone Beds

Fig 2: Diffusion patterns of iron staining referred to as 'drapes' and*Liesegang rings* (chemical reactions) in marine sandstones of the Folkestone Beds

Fig 3: Ferruginous sandstone exhibiting dark-grey ironstone development known as *festoons* or festooning formations

John Gahan

The geology of Brittany – FGS field trip to Brittany & Normandy, October 2008

Regional Geological Interpretation - the Celtic Ocean and the Cadomian Orogeny

Denis Bates, joint leader of the trip, demonstrated that Brittany is a complex area geologically, and I think it is easiest to put the rocks and localities visited into their regional context, based on interpretations from the 1990 Special Publication on this area. The Brioverian rocks of northern Brittany (ranging from 626-575Ma) were originally thought to be a normal stratigraphic sequence of lower (older) volcanic rocks underlying upper (younger) sedimentary rocks. However they are now interpreted to have formed in an orogenic zone, to the south east of a major subduction zone running down the English Channel (then the Celtic Ocean). A volcanic island arc complex offshore passed through a back-arc sequence of volcanics and sediments, shoreward to coastal terrigenous beds. These facies zones were then progressively thrust as 'terranes' upon each other and onto the edge of the Icartian Continental Plate (2000 Ma). These broad domains are shown in Fig 1 (from Rabu et al).

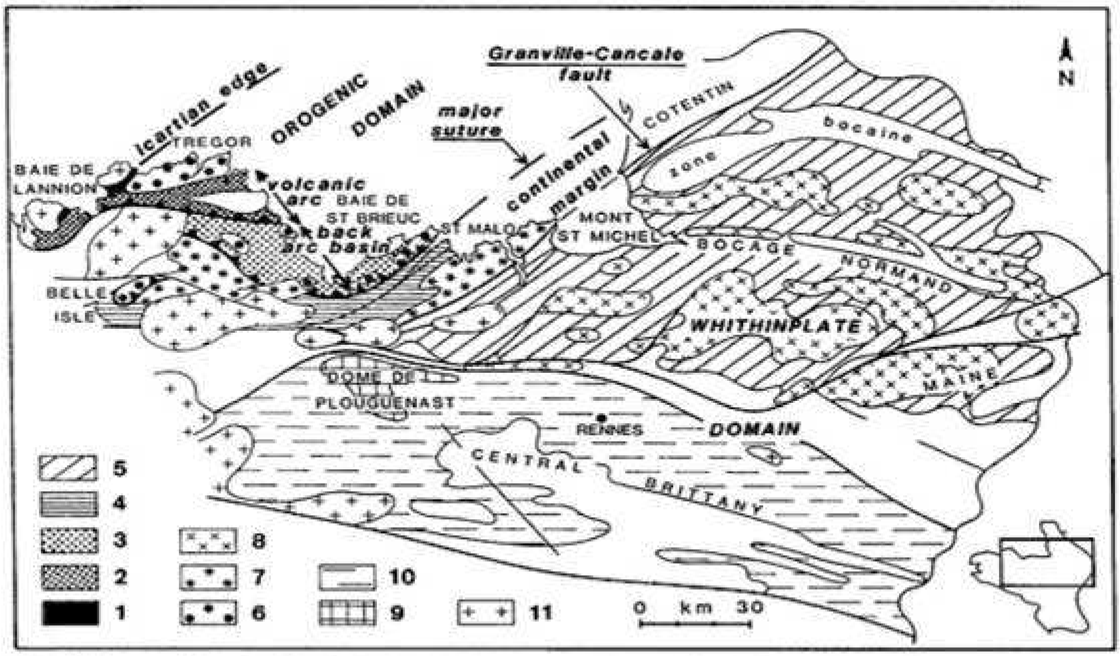

Fig. 2. Structural sketch of the Cadomian belt in the orogenic area (North Brittany) and the intraplate domain (Bocage Normand and Central Brittany). 1, Basement; 2, 3, Cadomian orogenic domain (2, island arc; 3, back arc basin); 4, 5, Cadomian continental domain (4, interbedded black chert; 5, reworked black chert); 6, Trégor granites; 7, St Malo migmatites; 8, Mancellian granitoids; 9, Dome de Plouguenast; 10, Central Brittany Brioverian; 11, Variscan granites; Unornamented, Palaeozoic cover and basin

Figure 1: Note the position of the volcanic arc and back arc zones of Baie de St Brieuc lying within the Orogenic Domain, between the subduction zone (the Icartian Edge) to the NW and the continental margin to the SE.

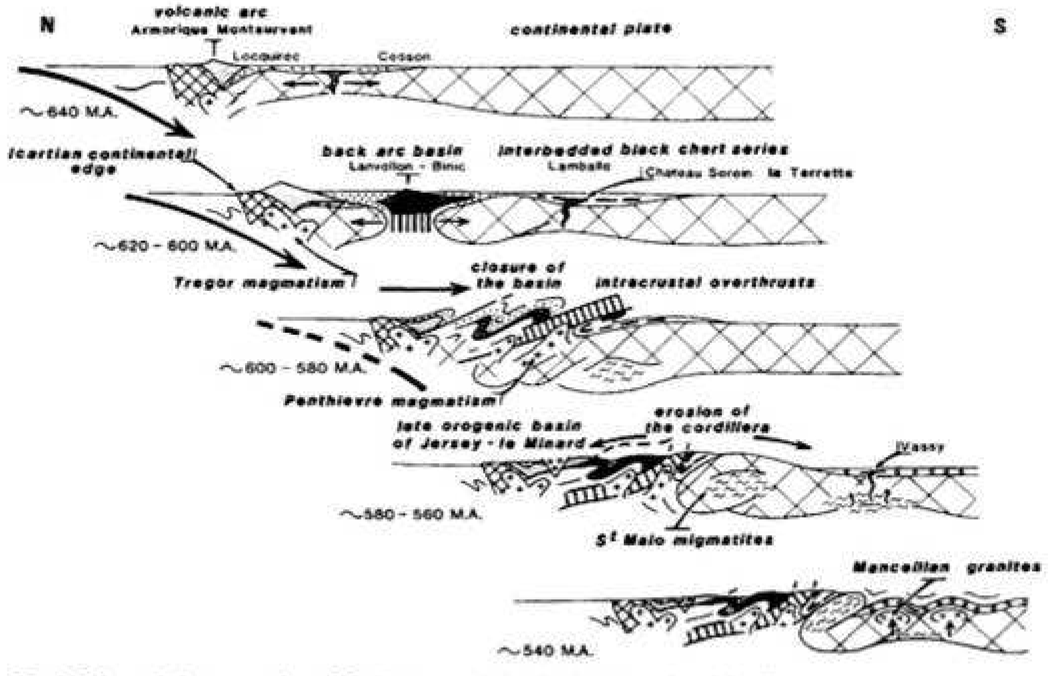

Fig. 4. Schematic interpretation of Cadomian evolution in the Armorican Massif.

Figure 2: Note how the different zones are adjacent to each other at the time of their formation (top figures) and are then gradually thrust one on top of the other, and onto the continental margin, as the mountain building progresses.

Fig 2, (also Rabu et al), attempts to show the gradual closure of this area of the Celtic Ocean during the Cadomian Orogeny – from approximately 640 to 540Ma. This sequence of events was complicated further by the oceanic plate (to the north) sliding sideways clockwise relative to the continent (to the south) along a deep vertical suture (transverse fault).

If we put the rocks we saw into this setting, then the basic volcanic rocks and ultrabasic serpentinitic rocks seen at Erquy probably represent ocean floor sequences, formed in a back arc extensional basin (see 620-600Ma in Fig 2); where the medial and proximal slope fan deposits, as at Moulin Plage, Binic and Cesson, overlying coarse pebbly debris flows (Cesson) also formed. The debris and turbidity current flows were generated by the frequent earthquakes associated with this environment. The diorite at Saint Quay represents the roots of a volcano from the island arc, seawards of this back-arc (~640Ma in Fig 2).

The continental red beds of Cap Frehel represent the undisturbed continental deposits whilst the heavily folded and contorted St Jacut migmatites represent sequences which were severely deformed during the earth movements. Note, the St Malo migmatites of St Jacut peninsular are not true basement as they are of similar age to these sequences (<650 Ma) whereas the true basement rocks are 2000 Ma (outcropping further west at Baie de Lannon).

The Jersey rocks were not visited but are part of this same basin, although interpreted to be part of a later orogenic phase (see above 580-560Ma). The Jersey Volcanic Group have been interpreted as calc-alkaline andesites and rhyolites of an island arc setting and the Jersey granites their associated magma chamber sequences, whilst the Jersey Shale Formation represents outer to medial fan turbidite deposits.

Summary of Brioverian Localities

St Jacut Peninsular - The St Malo Migmatites (Figs 3 and 4) are a series of migmatites (a mixture of foliated high grade metamorphic rocks mixed with bands of granitic igneous rocks generated by the partial melting of the metamorphic rocks to create a melt from which the granitic rocks crystallised) formed under intense heat and stress during the severe earth movements. Ptygmatic folds appear random and disconnected – they are thought to form when the rocks are very warm (hence not brittle) and non-homogeneous. The folded material represents the more viscous band and the surrounding material, being less viscous, flows around the fold. There was also good evidence of a large vertical fault; could this be a transverse fault?

At Plage de Quatre Vaux (4 valleys) there were migmatites similar to St Jacut but with thick quartz pegmatitic veins of multiple phases, which appeared to have been emplaced as a crystal mush, and now deformed, also present were possible boudinage structures.

Figure 3: Ptygmatic folds in the migmatites of St Jacut Peninsular (west).

Figure 4: St Jacut East – more St Malo migmatites

Saint Quay lies at the northern end of the western side of the Baie de St Brieuc and the sequences here include a dioritic igneous intrusion of Cadomian age, 559 Ma, with many good examples of xenoliths, and later cross-cutting granitic veins and patches (Fig 5)

Moulin Plage – steeply-dipping thick sandstones are, as Graham demonstrated, locally overturned to S. In Fig 6, these thick sandstones young from left to right. The left hand bottom corner of the picture comprises the laminated top of one turbidite, this has been cut into by the following thick proximal turbidite which occupies most of the photograph. Rip-up clasts of dark shale are just visible along the lowest part of this turbidite which is some 1.5-2 m thick. They were laid down as medial and proximal turbidites (dense flows of sand, silt and mud which flow downhill under gravity in turbulent conditions and the turbidite deposits form fans such as at the bottom of a submarine canyon. Sediment may gather on the shoreline and then flow as a mass when the earth is shaken by an earthquake, as at Aceh, Indonesia on Boxing Day, 2004, or when it becomes unstable under its own weight as at Aberfan, 1966).

Figure 5: The grey diorite intrusion at Saint Quay shows pink granitic areas and pale pink cross-cutting veins (do the pink granitic areas represent chemical alteration of the diorite, i.e. the addition of K^+ (potassium ions) to change the feldspars to orthoclase?).

Figure 6: Boudinaged quartz vein at Moulin Plage cutting through sub-vertical sandstones

Thick turbidites are normally associated with submarine fan systems, which develop along tectonically unstable coasts, often associated with subduction trench systems, such as along the modern day coast of California. Here tongues of igneous rocks similar to those seen at Saint Quay were present. Also boudinaged quartz veins were apparent (boudinage structures were common throughout the area). Boudins are formed by extension in a non-homogenous series of rocks. The rigid tabular rock (here a quartz vein within sandstones, but often a bed of sandstone within shales), is stretched and deformed within less competent rocks. The competent bed is sheared to form sausage-shaped 'boudins' (French for sausages).

At Binic there were similar subvertical, but relatively undeformed, sands of proximal turbidites again with shales, often contorted, forming lenses and possibly slumped, but without the tongues of igneous rocks.

Cesson – here, thick pebble layers (Fig 7) were originally interpreted as a basal conglomerate of shallow marine origin. However, if you look more closely, the pebbles lie in a mud matrix and the mud supports the pebbles, they do not support themselves, so have not been winnowed. I prefer to interpret this as a debris flow, which would complement a proximal turbidite origin for the overlying sandstones and shales. These shales and sandstones are frequently heavily deformed and sheared (Fig 8), with the degree of deformation increasing southwards, culminating in a thick subvertical mylonite zone. Mylonite is formed by recrystallisation as a result of deformation, at temperatures of 250°-350°C, typically during dynamic metamorphism, the foliation lies roughly parallel to the fault or shear zone.

Figure 7: Boudinaged pebbles at Cesson.

Figure 8: Severely sheared sequence, Cesson.

At Cap Frehel, on the eastern edge of Baie de St Brieuc, a sub-horizontal sequence of red beds (Fig 9), some cross bedded (Fig 10), others rippled, occur, indicating deposition under shallow water and the iron rich character suggesting an arid continental origin;

Figure 9: Note the flat-lying undisturbed nature of these red beds, which contrasts with the subvertical sheared nature of the turbidites seen at Cesson.

Figure 10: Close up of the red beds showing their cross bedded nature

At Erquy on the northern edge of Erquy bay, coarsely-bedded sandstones similar to those seen at Cap Frehel are present with locally well developed overgrowths forming good quartz crystals. Along the southern edge of the bay, a sequence of sediments and volcanics outcrop, which are now subvertical. The volcanic sequence exposed along the southern side of Erquy Bay comprises a sequence of relatively homogeneous bedded basalts, but other interesting features are:

- Ultrabasic serpentinitic rocks are also present (Fig 11), here apparently bedded and fractured; these probably represent oceanic crustal sediments or possibly subvertical dykes now appearing horizontal,
- Sometimes repeated volcanic activity has broken up earlier solidified lava to create clasts (Fig 12),
- Elsewhere pillow lavas are present; limonitic weathering is common, here outlining the pillows.

Figure 11: Ultrabasic serpentinitic rocks at Erquy

Figure 12: Volcanic clastsin lava at Erquy

Jersey Brioverian Sequences

I compared the Brittany Brioverian rocks with those in Jersey where the geology is also dominated by rocks of Brioverian age. The Jersey Shale Formation (~2500 m thick) is a sequence of fine-grained turbidite sandstones of a medial to distal fan setting (flow is dominantly to the north, away from Brittany), with lesser amounts of siltstone and shale, and occasional mud-rich conglomerates (Fig 13). Overlying these is the Jersey Volcanic Group (~2250 m), a sequence of volcanic rocks (dominantly andesites and rhyolites of an island arc setting) and a ploygenetic conglomerate (the Rozel Conglomerate – Fig 14) of a shallow water or continental origin (the clasts support themselves with no appreciable mud). The Jersey Shale shows multiple phases of deformation, but only low-grade metamorphism (to low greenschist facies) as in Brittany. The many granites of Jersey represent rocks from the magma chambers, below the volcanoes.

Figure 13: Jersey Shale - turbidite sequence

Figure 14: Rozel Conglomerate - continental deposit

There are multiple phases of igneous intrusion, dominantly granites and granitic rocks, with minor, older, diorites and gabbros, whereas in Brittany, the intrusions seen of equivalent age were dioritic (St Quay). Both groups of intrusive rocks are dated between 675–480 Ma and in Jersey are interpreted to have been emplaced post-deformation and -metamorphism. Both sets of igneous intrusions have produced localised thermal metamorphism with chlorite spots in the surrounding Brioverian sediments. The major faults also strike WNW-ESE in Jersey. Thus the same structural and depositional history has affected Jersey as Brittany.

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Ploumanach Granite on the Cote du Granite Rose - whilst in Brittany we visited this sequence. This granite pluton is late Variscan (290 Ma) and thus much younger than the Brioverian sequences, consequently I have kept its discussion completely separate from the other rocks.

It is interpreted as a series of intrusive fine to coarse-grained granitic bodies, formed during cauldron subsidence, with localised basic rocks in intimate association.

At Ile Tourony (Fig 15), micaceous laminae (once interpreted as ‘sedimentary’ structures) appeared to reflect downward dipping cone structures; I tentatively interpret these as ‘fracture linings’, where late-stage mica-rich fluids (possibly of a more basic lamprophyre magma) have passed up incipient fractures in the main granite.

At St Anne’s beach, the acid and basic magmas co-existed at the same time as immiscible liquids (Fig 16) it appeared that the dark basic rocks formed discreet globules with an acidic feldspar-rich crystal mush and an intermediate mica-lamprophyre crystal mush ‘filling the ‘pore spaces’ between the basic rock globules’. Whilst it is unusual for basic and acid rocks to occur together it is not unknown and they frequently appear to have come from immiscible liquids. Similar mixed basic and acidic rocks are present on Jersey and again they appear to have come from immiscible magmas. Similar Variscan-aged granite plutons occur in Devon and Cornwall.

The Kerleo quarry outcrop showed three different granites. Fig 17 shows a coarse grained granite on the left cross-cut by the finer granite on the right of the picture.

Figure 15: Micaceous laminae follow a structural junction and steeply dipping, curving cone-like features

Figure 16: At St Anne - Basic and acidic magmas

Fig 17: Kerleo Quarry -The Ploumanach granite

Figure 18: The group at St. Jacut

Thanks go to Graham Williams for organising a superb trip and also to Denis Bates for giving us the benefit of his vast knowledge and experience of this area. On behalf of the group (Fig 18), I must praise the patience and skill of the minivan drivers (Graham, Peter, Susan and Judith) and lastly Susan and Ann for their patience with us geo-enthusiasts during all weathers (mostly cold, windy but fine).

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1) The Brioverian (Upper Proterozoic) and the Cadomian orogeny in the Armorican massif, Rabu et.al.;
2) Cadomian tectonics in northern Brittany, Brun & Balé;
3) Brioverian volcanism and Cadomian tectonics, Baie de St Brieuc, Brittany: stages in the evolution of a late Precambrian ensialic basin, Roach et al.
4) Cadomian Magmatism in the North Armorican Massif, Brown et. al.

Liz Aston

The archaeology of Brittany and Normandy - FGS field trip, October 2008

As we went around on our excellent geological field trip led by Graham Williams and Denis Bates, we also visited some significant archaeological and historical sites. In the Neolithic, the domestication of plants and animals spread through Europe in two ways, some people adopting the new ideas, others bringing them as they migrated from the eastern Mediterranean. The two cultures came together in Brittany (We may talk about this on a later field trip).

We had seen the un-impressive menhir ‘Gargantua’s Finger’ at Fort du Latte, so Joan Prosser suggested a detour near Dol-de-Bretagne to look at a far better one, the 9.5m *Pierre du Champ Dolent* (Fig 1). Joan did not believe the legend that the stone fell from the sky to end a battle, instead she told us that these menhirs were put up in the Neolithic maybe 4000-2500 BC, to mark important or sacred places, springs, burials, perhaps for solar and lunar prediction, or territorial boundaries.

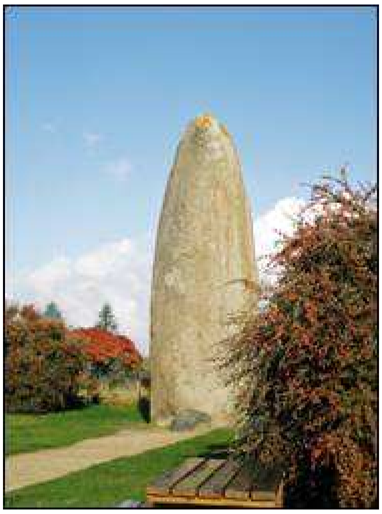

Fig 1: The Menhir Pierre Du Champ Dolent

Fig 2: Mont St Michel from the Causeway

At least once, everyone should visit the Romanesque and Gothic ecclesiastical fortress of Mont-St-Michel (Fig 2) on its granite island, so we did. It is well worth it. Founded in 708 by the Bishop of Arromanche, it became a place of pilgrimage in 10thC after a vision of St Michel appeared. As the fortress of the French king, it resisted many sieges by the forces of Henry VI. It is now the most visited of France's *Monuments Historiques*, a bit touristy but if you look carefully the Grand Rue still has its 15-16thC houses and the architectural engineering at the summit is extraordinary, in a simple style unusual for this period, the edifice capped with a remarkable spire 500ft above the sea. 'Pilgrims', after 1000 years, are still climbing up from *Porte du Roi* and buying their 'tokens'.

Frankish lords built private fortifications with garrisons of cavalry as protection. Facing repeated attacks from the Danish Vikings, as in Saxon England, in 911 Charles the Simple of France granted land to Rollo the Danish leader in a treaty, in exchange for protection against other Norse raiders. This became 'northmans' land', the Dukedom of Normandy, the greatest of the principalities to owe allegiance to Charles. But the Danes were in a foreign land and for protection against attack, and to control the populace, they copied the Frankish castles, breeding war-horse (destriers) for their heavily armed knights, later to be decisive in the battle for England at Hastings.

In Bricquebec we stayed at l'Hostellerie du Chateau within the medieval motte and bailey castle, complete with its polygonal keep (Fig 3). Like our English 'Conquest' castles, it dominated the church, market, village and access over the river. Barry Eade described the multiphase history of its architectural features, explaining that the 10thC castle on the 17m high motte would have been of timber, the oldest stonework, the residential 'camera' and hall with its Gothic arches, dating from 1190. It was captured by the forces of Henry V in 1418, then retaken by Charles VII, when much of the castle was destroyed by fire. It was probably quickly re-built, the date of much of the standing architecture, although two bailey towers are 13thC . Bricquebec was liberated on 20th June 1944, a PLUTO (pipeline under the ocean) routed just west of the village, now a pleasant little town.

Fig 3: The Polygonal Keep of Bricquebec Chateau

Fig 4: The 13-14thC Fort la Latte re-designed by Vauban in 17thC

En route to Cap Frehel, we called in on Fort la Latte (Fig 4), built in 13-14thC as a strongpoint and watchtower to protect the Duke of Brittany's land against his neighbours and the English. The Dukedom joined with France in 15thC but then an ally of Henry IV took over the fort, its re-capture by the French damaged virtually everything except the keep. In the 17thC, afraid that the English would attack Brest, Louis XIV entrusted the fortification of Brittany to Sebastien de la Prestre Vauban, one of the great post-artillery military engineers. Vauban re-designed the fort adding overlapping tiers of gun platforms and outreaching bastions, characteristic of the many other fortresses and defensive cities he constructed like Ypres and Verdun. The fort was in the film 'The Vikings' as a Saxon Castle, much too early though!!

Vauban re-designed the bayonet so that it could be firmly attached to a musket, while still allowing it to be fired; from then on the pike was redundant. A sort of justice here, a French invention carried by all the Allied soldiers on D-Day, helping to liberate France. Its use made clear, thanks to Peter Norgate; another curio found here and at Cap Erquy was a curious large 18thC oven for heating cannon balls to 'cherry-red' for use as incendiaries.

Ville de Granville was fortified by the English in 1439 to confront the fortress of Mont-St-Michel, but in 1442, it was lost to the French. The *Haute Ville* still has a complete circuit of ramparts despite being bombarded by English ships in 1695 and 1803. In contrast, we saw for ourselves the destruction of the batteries and strongpoints of the Atlantic Wall on *Pointe du Roc* (Fig 5) when Granville was again attacked, this time by the Allies prior to the town's liberation by the US 3rd Army on 30/31st July 1944.

Fig 5: The Atlantic Wall at Granville

Fig 6: This picture from the Lapworth Museum shows the potential problems of driving over bombed sand.

As we drove into Normandy we were very aware that this was the place of the historic invasion of German-held Europe, Operation Overlord. A few minutes after midnight on 6th June 1944, 20,000 Allied airborne soldiers parachuted and glided into Normandy. Six hours later, a fleet of 6,000 ships put nearly 250,000 more soldiers onto sixty miles of coast, from the River Orne to the Cotentin peninsular, in the biggest seaborne invasion in history. Overlord was the start of the liberation of occupied Europe, which, in one year of hard fighting, ended in victory.

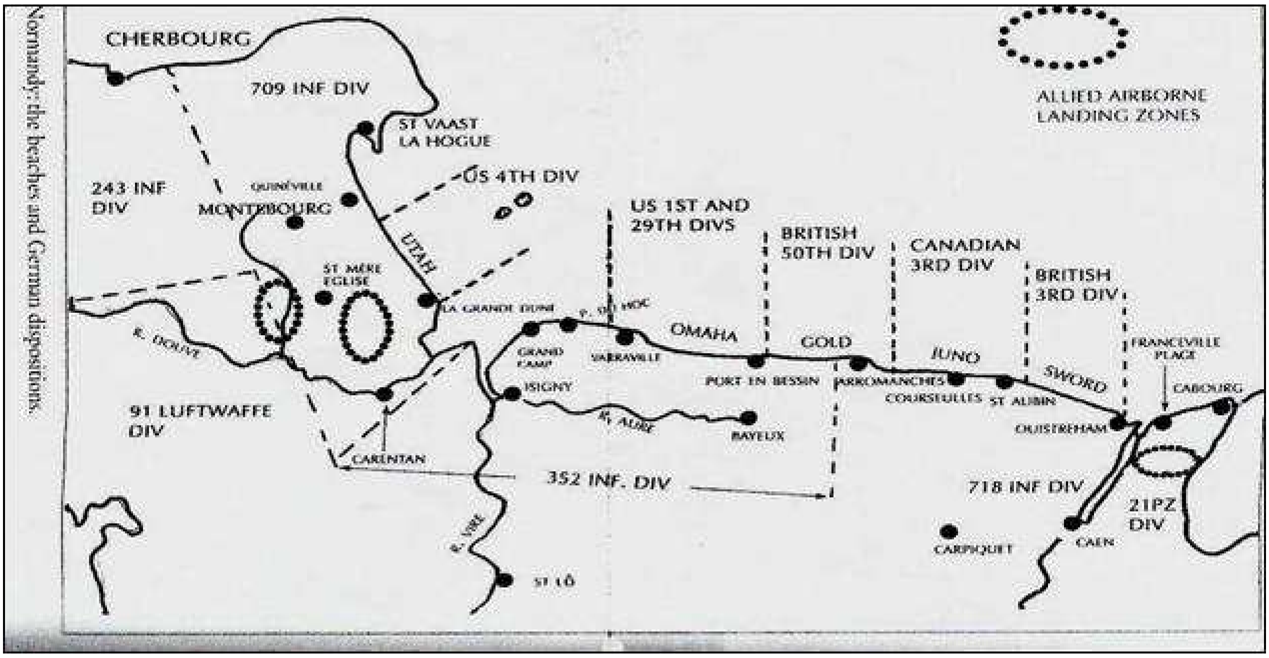

Fig 7: The Normandy invasion beaches

Whilst there were more historical than geological sites to see, the geology continued to be an important aspect of the trip, particularly as geology played a very important part in the Normandy landings on D-Day. Professor Fred Shotton and his team were key to the geological input; he was a Quaternary specialist and examined sands from various beaches and determined that the beach at Brancaster in Norfolk was the most similar to that of the Normandy beaches. This beach was then bombed to establish whether vehicles could pass over them without problems (Fig 6). Professor Shotton's work remained top secret and he had a continual input during the planning stages of the invasion to assist with the location of airfields, landing beaches (Fig 7) and sources of water for troops and pointed out potential geological hazards associated with dunes, cliffs, rivers etc.

Mike Rubra

GA Exhibit November 2008

Members manning the Society's stand at the GA Annual reunion which was held at University College, London, in November of this year.

FGS field trip programme for 2009

April 3rd- 6th weekend - The St.Austel Granite - led by **Dr Alan Bromley**

Alan is a very experienced expert on igneous and metamorphic rocks, particularly on associated mineralisation; he provides consultancy services to mining firms. He is the local expert, having spent more than 35 years in the area; he was based at the world famous Cambourne School of Mines.

The St. Austell granite is the most complex pluton in SW England, with a greater variety of rock types than any other; it is said to be the most intensely kaolinised granite in the world; there can be few areas where water - rock interaction is displayed on such a massive scale. It is a multistage intrusion into Devonian and Carboniferous sediments; this produced biotite granite, lithium-mica granite, tourmaline granite, topaz granite etc. Hydrothermal activity caused extensive metalliferous mineralisation. Surrounding Devonian country rock was metamorphosed, and high temperature minerals such as garnet, cordierite, and rarely kyanite and sillimanite were formed. Mineral veins contain copper, magnetite, tourmaline, pyrite, arsenopyrite etc; there is extraordinary tourmalinisation at Roche Rock; kaolinisation of the granite led to a major china clay industry. The area is famous for the abundance and variety minerals.

May 10th - 16th - Isle of Man - led by **Dr Bill Fitches**

Bill recently retired from university; he has undertaken research in the Isle of Man, and has led many student and adult (!!) geological field trips. We will study:-

- the sedimentation, deformation and metamorphism of Ordovician and Silurian rocks ("Manx Slates"), deformed in the Caledonian orogeny;
- Devonian (Peel Sandstone) terrestrial sediments, and Carboniferous Limestone with abundant fossils;
- Igneous intrusions - granites with their extensive mineral deposits, and Tertiary dykes intruded with the opening of the North Atlantic;
- Pleistocene (ice age) sediments and geomorphology - the north coast provides 30km of nearly continuous exposures unrivalled elsewhere in Britain.
- Mining and archaeology.

June 7th, Sunday – Avebury to Swindon - led by **Mike Rubra and Graham Williams**

Mike will lead us through the enigmatic stories behind the East Kennet, Silbury Hill and Avebury Circle Neolithic structures. The huge Avebury Circle stones are Sarsens - we will examine the complex processes that led to their formation. Old quarries and railway cuttings near Swindon expose another famous building stone - Portland Limestone. The sequence includes late Jurassic sandstone and limestone beds, rich in fossils.

June 19th, **Friday – Shere: mid-Summer's eve walk -** led by **Dr Graham Williams**

The evening walk will circle Shere to see how the Lower Greensand - Gault - Upper Greensand - Chalk sequence affects the landscape; there is even a rare Bargate Stone outcrop. We will visit some of Shere's ancient buildings from the 15th to 18th centuries, terminating in the White Horse two bay timber framed open hall house, built around 1450, to examine some important ales !!

July 5th, Sunday – Farringdon & Abingdon - led by **Dr Graham Williams**

See the world-famous Farringdon Sponge gravels of the Lower Greensand (age equivalent to our Bargate Beds). The rocks were deposited in a valley in the sea floor during a storm and contain superbly preserved fossils including the famous sponges, ammonites, echinoids, brachiopods and bryozoa. Some dinosaur and plesiosaur remains have been found, derived from Jurassic sediments probably also as a result of the storms. Many of the fossils found at Coxwell Pit are rare and are named after the quarry and the local town.

Then to Dry Sandford nature reserve near Abingdon where an old quarry exposes richly fossiliferous Corallian Beds (M Oxfordian 140my ago). The sediments were deposited in shallow coastal waters close to coral reefs. The succession includes the Lower Calcareous Grit, Trigonia Beds, and the Urchin Marl and Coral Rag of the Osmington Oolite Fm, with brachiopods, ammonites and corals.

August 30th to Sept 5th – Aberdeen and the Grampians led by **Donald Milne**

Don is an old colleague of mine and can be best described as a true Scottish gentleman. Don has worked all his life in the oil industry, primarily with BP, and is now a respected consultant and a very good friend. We will see some internationally famous sections; we plan:

- Highland Boundary Fault and Highland Boundary Series at Stonehaven; Devonian Old Red Sandstone conglomerates and volcanics south of Stonehaven.
- Metamorphics (Barrovian zones) and granites along the Stonehaven to Aberdeen coast section.
- Granite and Gabbro localities around Aberdeen;
- Devonian Rhynie Chert;
- Permo-Trias of Morayshire;
- Aberdeen‘s oil industry, ideally a visit to BP or other company to view a data cave in action. Also to see offshore supply vessels, drilling equipment etc.
- Archaeological and historic sites around Aberdeen.

October 4th, Sunday – Watership Down - led by **Mike Rubra and Graham Williams**

This walk follows some of the adventures described in Richard Adams' book of the same name. The sequence is Cretaceous, and there is also an extremely fossiliferous London Clay exposure nearby. We will see the effect of the rocks on the landscape, and how various Roman structures also were influenced by the landscape.

I hope this programme will provide something of interest for everybody - interesting places, beautiful countryside and seascapes, wild life and plants, ancient and modern rocks, building stones and archaeology. Please contact me if you wish to join any of the trips.

Graham Williams

The geology of paintings

Summary of September's lecture by Dr Ruth Siddall, Earth Sciences, University College, London

We use paints and cosmetics so routinely today that we rarely stop to think what gives them their beautiful colours, shades and textures, but these materials are often familiar compounds and materials especially to those of us with a background in mineralogy or geology.

Paint consists of two main components, the solid, finely powdered pigment which provides the colour and a medium which both binds the pigment together and makes the paint fluid. The medium, of course, also 'glues' the paint to the surface being painted. The medium is usually an organic material such as gum arabic which is used to bind the pigment in watercolours or oil (usually linseed oil) for oil paintings. Inorganic binders include lime wash which is generally used with the fresco technique of wall painting.

Pigments may be broadly divided into organic, mineral and synthetic materials. Organic pigments include the compounds that are familiar to use as textile dyes, such as cochineal (carmine) derived from scale insects or blue indigo and red madder both derived from plants. Mineral pigments are of course geological materials and many synthetic inorganic pigments have structures and compositions which are analogous to natural mineral species.

For mineral and inorganic synthetic compounds, the techniques routinely used by petrographers are an ideal way to classify and identify pigments. Any mineral which gives a strong colour in a streak test is likely to be useful as a pigment. The polarising light microscope is a very powerful tool for pigment identification, both for identifying mineral phases and for describing the optical properties of synthetic crystalline compounds. Microscopy also shows the breadth of material incorporated in pigments including mixtures of two different coloured pigments to obtain a third shade and the presence of materials used to bulk out paints and make the pigments go further. Rocks and minerals like pulverised chalk and clays are often used in these contexts. Obviously this technique requires that samples must be removed from the painting being studied, but such tiny amounts are needed that no discernible damage to the picture can be discerned. Further analytical techniques such as scanning electron microscopy, Raman spectrometry and electron probe microanalysis are also used to confirm the composition and structure of compounds.

Mineral pigments were some of the earliest materials mined by humans. This is testified by the famous Palaeolithic cave paintings of sites like Lascaux in France and Altamira in Spain. These stone age artists used ochres for their pigments, primarily red, yellow and brown ochres derived iron-rich sources and also manganese oxide-rich black ochres or ‘wad’, rich in minerals such as pyrolusite and hausmannite. Ochres, and particularly hematite-rich red ochres also clearly had a ritual significance in these societies too; burials from these periods frequently reveal the skeletons to be covered with red ochre as in the example of the Red ‘Lady’ of Pavilland Cave on the Gower Peninsula. Ochres are today the main pigments of choice used by many traditional societies including the Australian Aborigines, Native Americans and the Kalahari Bushmen. These materials are also used as cosmetics as well as for the decoration of surfaces and objects.

By the Roman period we have evidence for a broad range of materials being used as pigments. This information derives from archaeological sources such as the splendid wall paintings preserved at excavations like Pompeii and Herculaneum, but also from written records by contemporary authors Pliny the Elder and the architect Vitruvius. Both mention a whole range of pigments from standard ochres to other ‘earth’ pigments such as white from chalk or kaolinite, and green earth, which is coloured by the clay minerals glauconite or celadonite. The Roman authors also describe the use of expensive and exotic minerals being used as pigments such as cinnabar from the mercury mines in Spain, malachite and azurite, orpiment and realgar.

Blue colours have always been expensive and difficult to obtain. However in place of expensive azurite, The Romans used a synthetic calcium copper silicate compound, the recipe for which they obtained from Egypt, where this compound had been manufactured as a blue pigment for nearly four millennia. The blue pigment was therefore generally referred to as Egyptian Blue. It has a composition analogous to the rare mineral cuprorivaite. This became the most important blue pigment until the Renaissance when it was superseded by the rare and expensive mineral lazurite, derived from Afghan lapis lazuli deposits. This is the famous pigment called ultramarine. The Egyptians also synthesised greens and very occasionally purple-coloured compounds. On the other side of the world in 3rd Century BC China very similar blue and purple compounds based on barium copper silicates were being manufactured. These colours were used to decorate many artefacts including the Terracotta Warriors.

Many synthetic pigment compounds were first produced as by-products of metal extraction or glass making industries or discovered by alchemists during their experiments. Compounds such as verdigris for various shades of greens, red lead (lead[II,IV] oxide) and white lead (lead carbonate hydroxide) and synthetic varieties of cinnabar (vermillion), malachite and azurite (called green and blue verditer respectively) were commonly used by many different societies.

By the nineteenth century, advances in the science of chemistry had allowed synthesis of a wide range of compounds including a synthetic ultramarine and wide range of compounds based on the element chrome. For example, Chrome yellow, a synthetic form of the lead chromate mineral crocoite.

New colours like shades of purple, which had previously only been routinely available by mixing other pigments were now synthesised. For example, the cobalt violets were very popular with impressionist painters like Claude Monet. Many of these new pigment compounds we now know to be highly poisonous, particularly those based on arsenic - these included the green copper arsenites which were popular for printing rich emerald green wall papers as well as an arsenic-bearing form of cobalt violet. It is only with the advances in organic chemistry from the late nineteenth and twentieth centuries that we are now able to produce safe, strongly coloured and cheap pigments via large-scale industrial processes.

Ruth Siddall