3. Alpine influences on the Tertiary geology of Britain

Introduction (slide 1)

In this lecture I am going to focus on the evolution of the landscape in England & Wales during the Tertiary. An important factor which controlled the landscape was the formation of the Alps, a major tectonic event which profoundly affected the geology of Europe, including Southern England. We will also examine the gradual cooling of the climate during the Tertiary and the dramatic response of flora and fauna. In recent years the main river systems which were established in late Tertiary times in Central England have been mapped but of course these rivers were profoundly modified by later Anglian and Devensian ice sheets. Finally, we will have a glimpse of our early ape ancestors.

Lecture outline (slide 2)

- Mountains: some early ideas about their formation
- The evolution of the Alps and their influence on the geology of Southern England
- Climate and vegetation changes during the Tertiary
- The rivers of Britain during the Tertiary
- Ape and human evolution in the Tertiary.

Principal ideas about mountain formation in the 19th century (slide 3)

For European geologists working in the 19th century the construction of a theory for the origin of mountains was of overwhelming importance. Two contrasting theories with their own prestigious advocates and disciples dominated the debate.

- Horizontal compressional forces relating to a shrinking earth

This idea has its roots in the teaching of Werner, who is chiefly remembered for his ‘neptunian’ ideas about the aqueous origin for rocks of the crust. However, Werner had also placed great emphasis on the trend of geological structures such as faults and fold axes. Werner’s structural ideas were developed by later generations of geologists who attempted to interpret the results of their fieldwork in the context of mathematics and in particular geometry.

- Vertical uplift of strata by subterranean reservoirs of lava

Geologists who carried out fieldwork in the mountains of Europe were struck by what they saw as upthrust crystalline masses with disturbed strata on either side. Leopold van Buch was the principal advocate of the “craters of elevation” theory but it had many adherents.

Although today we understand orogenesis in terms of plate tectonics we can still see some of these early ideas reflected in our current understanding of geological processes.

Elie de Beaumont: the geometry of mountains (slide 4)

Jean-Baptiste Elie de Beaumont was a towering presence in European geology during the early and mid 19th century and his life's mission was to explain the formation of mountains.

Elie de B was both student and professor at the Ecole des Mines in Paris. He held various positions in the government department of mines, becoming inspector-general in 1847. He played a major role in constructing the first geological map of France.

His thinking about the mechanisms of mountain building was much influenced by the ideas ofWerner and Hauy and in particular the application of mathematics and geometry to geological problems. However, E de B. was not just a theorist and as Director of the 'Carte Geologique" he devoted much of his time to fieldwork in mountainous terrain. E. de B. based his theories of mountain building on Humboldt's theory of a shrinking earth from molten origins. According to this theory the earth's crust underwent periodic adjustments as the earth cooled, collapsing along great circles. This shrinkage resolved stresses which had built up over a long time but were suddenly released with great violence, causing tidal waves and mass extinction. This was geology as catastrophe.

E de B's main thesis was that mountain chains of the same age had the same or similar strike. (The image shows the strike of folds in the Anti-Atlas mountains in Morocco) On this basis E de B recognized 6 systems, but this soon became 12 and then 20! From this point he developed a complex "resau pentagonal" criss-crossing the globe. One has the impression of a man consumed by an idea which as taken him over to a point where he had few followers.

In spite of his weird geometrical obsession E de B made a number of very valuable contributions to the study of mountains. His concept of periodic episodes of mountain building was developed by later geologists and his suggestion that fold mountains are the result of compression has become part of the corpus of geological knowledge.

Leopold von Buch: craters of elevation (slide 5)

Leopold von Buch was one of the most influential geologists of his generation. A student of Werner, he travelled widely to enhance his understanding of geology.

His studies of mountains led to the idea of there being a central zone of plutonic rocks which had thrust upwards, deforming the adjacent strata and creating depressed areas called craters. He became convinced that reservoirs of molten lava had played a major role in causing mountain uplift. He used the pillars of rock in the High Dolomites as evidence of vertical upthrust but these are now seen as the products of erosion – a process which he rejected.

Whilst von Buch's theory seems very dated I recently noted a paper by van Wyke de Vries (2014) which cites examples in France and Tenerife of igneous activity causing 'bulges' associated with uplift. This is estimated to be 150 m in the Puys de Dome area France.

We will see shortly that vertical forces have proved to be a key component of Alpine folding.

The English perspective (slide 6)

The geological aristocracy in England had other fish to fry than thinking about mountains and were principally concerned with establishing a stratigraphic succession for the British Isles. This was certainly true of the big hitters Murchison and Sedgwick.

Charles Lyell was probably the most influential theorist of his times, partly through his widely acclaimed "Principles of Geology". Lyell's mantra was that all geological phenomena could be explained by the actions of processes still operating today, "the present is the key to the past". He insisted that mountains could form as the result of repeated earthquake activity. However, none of the geologists working on mountainous terrain in Europe or North America accepted this theory could explain their observations.

Henry de la Beche who became the first director of the British Geological Survey supported many of E de B's ideas stemming from the idea of a cooling earth.

He was influenced by James Hall's experiments with a squeeze box in which layers of sand and clay were compressed into folds under lab. conditions. He also accepted that the folding in the Alps required a directed thrust rather than repeated episodes of uplift.

In summary the most distinguished British geologists of the early mid 19th century made little contribution to the construction of a theory of mountain building. This would have to wait for a younger generation.

Solving the mystery of the Alps in the 19th century (slide 7)

After 17 traverses of the Alps between 1775 – 1796 the distinguished Alpine geologist De Saussure abandoned them "as a hopeless jumble". At the end of the 18th century the prevailing idea was that some sort of rigid mass had been thrust upwards along the axis of the range, forcing the strata apart. It would take several generations of Swiss and Austrian field geologists to arrive at an understanding of this highly complex mountain chain. The unravelling of the structure of the Alps is beyond the remit of this lecture. However, I want to focus on the concept of thrusting and nappe formation which were crucial to the interpretation of the geology.

Bernhard Studer, Arnold Escher and Edouard Suess were key players in developing the concept of a northerly directed thrusting as being of key importance in the evolution of the Alps. A key observation by Escher was that in the Glarus region of the Calcareous Alps older Permo-Triassic rocks were resting on the top of younger (white) Jurassic limestones. Escher interpreted the structure as a double fold but refused to publish on the grounds that" he would be declared insane and locked up"

The Glarus structure. (Slide 8)

Excellent photos showing the contact between Pwrmo-Trassic and Jurassic limestones

Interpreting the Glarus structure (slide 9)

The slide shows two interpretations of the Glarus structure. The upper section shows Escher's interpretation as a double fold. The bottom section shows the interpretation by Marcel Bertrand where the structure is a nappe. The implications of the two interpretations is huge. In Escher's case the rocks are essentially local in origin whereas Bertand advocates a substantial movement away from their source. The detailed work needed to support this theory rested partly on the study of the sedimentary facies of the differing units.

Note: a nappe is defined as large sheet of rock which has been transported a distance of 2kms or more from its original position by folding or faulting,

Nappes of the High Calcareous Alps (slide 10)

The slides shows the configuration of nappes in the High Calcereous Alps. It can be seen that there is a succession of nappe structures which have been thrust over each other in a north-westerly direction. Note that the nappes appear to drape over the older crystalline massifs.

Originally the nappes were interpreted as having formed in response to major compressional earth forces coming from the south. However, in 1893 Schardt suggested that they had formed by gravity gliding. His views were greeted with derision, but gravity is now seen as the main force controlling nappe formation.

Understanding the Alps in the 20th century (slide 11)

During the 19th century the crystalline massifs were seen as having played a passive role in the evolution of the Alps. The French geologist Emile Argand recognized that the foundation rocks, which consisted of steeply dipping bands of Carboniferous sediments plus older schists and gneisses had, influenced the structure of the younger sediments. Argand recognized that the older basement rocks had moved upwards as steeply dipping slices whilst the cover rocks moved tangentially. He attributed this movement to the collision of Africa and Europe with the Alps being squeezed as if in the jaws of a vice. However, we now know that the faults along which the basement moved dated from Hercynian times.

Thus, the Alpine movement caused re-activation of older faults with upward movement of the basement causing gravity sliding and nappe formation

Western European context (slide 12)

The main slide shows that the Alpine orogeny was the consequence of the vice-like convergence of the Africa and European plates. Note also that the boundary between the plates is a major thrust in northern Africa but passes laterally into the divergent plate margin of the North Atlantic. The Matterhorn nappe comprises gneisses which were originally part of the African plate.

The Alps: regional picture (slide 13)

We tend to think of the Alps in the context of France and Switzerland. The slide shows the much wider geological context of the orogeny, which includes the Atlas Mountains in North Africa, the Pyrenees and Sierra Nevada in Spain, the Dinaric Alps in the Balkans and further east the Carpathians. Note that the Rhone/Rhine graben structures are also an integral part of the Alpine orogeny.

The impact of the Alpine orogeny on Southern Britain (slide 14)

The slide shows the correlation between major tectonic events in the Alps and tectonic activity in Southern Britain. Note the episodic nature of the main tectonic events with the Laramide, Pyrenean and Jura events being of prime importance. We see these major phases in Alpine activity reflected in folding, faulting and uplift in Southern Britain.

Laramide orogeny: uplift and erosion of Chalk between 68 – 60 Ma due to stresses resulting from convergence between Africa and Europe. Note that north of the Thames estuary/Mendips line the younger sediments are broadly flexed and domed as a consequence of this deformation (Dunning 1992). For example, the gentle folding of the Jurassic in the Cotswolds, is evident in the dip slope of Bredon Hill.

The relationship between later Alpine events and tectonism in Britain will be dealt with in subsequent slides.

Pre-Tertiary foundation of central/southern England (slide 15)

The slide shows the main tectonic elements which constrained the extent of Tertiary sedimentation. The principal unit is the Midlands microcraton which we have already seen remained stable through Upper Palaeozoic times. SW England is underlain by Variscan granite and highly deformed Devonian sedimentary rocks. Eastern England is underlain by the Fenland terrane - sediments deformed during the Acadian orogeny. The boundaries of Tertiary sedimentary basins were limited by these stable blocks.

The Wessex Basin – a fault-controlled sedimentary basin (slide 16)

We will use the Wessex Basin as an example of how a subsiding, fault controlled basins can be transformed by compression into a positive region of uplift. The upper slide shows the regional extent of the basin with its fault- controlled margins. The thickness of sediments within the basin varies up to 3kms in places.. The sediment thickness is greatest near to the faults which may be viewed as growth faults. The sediments are predominantly Jurassic and Cretaceous in age.

Compressing the Wessex Basin (slide 17)

During Tertiary times the effects of the Alpine orogeny were expressed as compressive forces which caused regional uplift (inversion) of more than 1250m. The structural inversion occurred on two scales: a regional upwarp several tens of kilometres wide and localised faults. The latter originated as normal faults which had controlled the basin margins but were transformed into localized inversion structures. An example will be discussed next in the context of the Isle of Wight.

Alpine structures of the Isle of Wight (slide 18)

The Isle of Wight provides a good example of a localized inversion structure. Most of the island is underlain by gently dipping beds of Cretaceous and Tertiary age. However, the geology of the central zone is characterized by an E-W trending fold with a near vertical limb. Alum Bay is a classic locality where beds of Chalk and younger sediments of Eocene age have a localized vertical orientation (see photo).

What was the timing and correlation with Alpine movements? Chadwick (1993) suggests that uplift may have started in late Cretaceous times (Laramide) continuing through to the Pyrenean phase of Alpine deformation. He suggests that the main phase of uplift took place in Miocene times, which would correspond with the Jura phase of compression. It is clear that deformation on the Isle of Wight is post-Eocene.

Tertiary sediments in Devon (slide 19)

In Devon Tertiary sediments are restricted to three small basins which have a NW orientation and are intimately associated with the Sticklepath fault which can be traced across Devon and continues beneath the Bristol Channel. The NW trend suggests a Hercynian origin and Holloway & Chadwick (1986) have proposed a Variscan strike slip dextral displacement of up to 10kms. This fault was re-activated in early Tertiary times when 6kms of sinistral movement created a series of pull-apart basins.

The Bovey Basin is of principal importance and has been mined for both ball clay and lignite. The total thickness of sediments is about 1,100m (Durrance & Laming 1982) including mainly sands, clays and lignites. Dating of the plants suggests that most sediments are of Oligocene age but they may range from Eocene to Miocene. The sedimentary environment is considered to have been a river flood plain with short-lived lakes. Most of the lignite was derived from *Sequioa* forest growing on upland to the north and west of the basin. The sedimentary clays were derived from deeply weathered granite and slates adjacent to the basin.

Paleogeography of SW England (slide 20)

The slide shows the geography of the region during Late Eocene to mid-Oligocene times. Note that a low –lying landmass occupies a much larger area than today. Note major rivers draining from the spine of the Cornwall peninsula and from South Wales. The river which followed the line of the Sticklepath fault brought clay-rich sediment and abundant organic matter into the zone of subsidence.

Late Neogene uplift (slide 21)

Blundell (2002) describes the landscape of Britain through Neogene times as being of low elevation and subdued topography until about 2.6 Ma when a broad scale uplift occurred. He cites the estimates of other workers who have suggested regional uplift in Wales, the Pennines, Lake District and Southern Uplands of 300 – 400m and 500 –

600m across the Scottish Highlands. This is explained partly by isostatic uplift but there is uncertainty about the other factors which are involved.

The map shows the broad outline of Britain in Late Neogene times. The rest of the lecture will attempt to fill in details of the drainage pattern, flora and fauna.

I wish to paint a picture of our country before it was profoundly modified by several major glaciations in Pleistocene times.

Climate change in Tertiary times (slide 22)

The slide shows the global temperature curve during the Tertiary based on oxygen isotopes studies on formaminifera. A gradual cooling can be seen from early Eocene times with the Antarctic ice sheet starting to format the Eocene/Oligocene transition - about 34Ma years ago -due to a change in the pattern of ocean currents. The diagram suggests that Arctic ice formed at a much later stage. However, an article by Wikipedia suggests the Greenland ice sheet formed in mid-Miocene ca 15 million years ago. Recent research (reported in Beerling 2008 p167) based on pebbles and sand found in Arctic Ocean sediments indicate that icebergs were present some 45million years ago!

The period from Early Paleocene to Middle Eocene was one of the warmest periods in Earth history with deep ocean temperatures 9 – 12c higher than today (Willis & McElwain 2010).

An important consequence of tropical and warm temperate climates was the widespread chemical weathering which affected the land surface across Britain.The weathering results in a breakdown of most rock forming silicates to a range of clay minerals. In Scotland it has been estimated that weathering extended in places to a depth of 50m (Hall 2001). In SW England the chemical weathering formed a thick layer of kaolinised rock which became the source for the ball clay deposits of Devon and Dorset.

What were the factors controlling this long-term decline in temperature?

Causes of the Palaeocene-Eocene thermal maximum (PETM). (Slide 23)

The PETM occurred at 55.5 Ma and was the largest and most dramatic climatic perturbation in the Cenozoic. The evidence comes from oxygen isotope variation in forams. (temperature) and carbon isotope variation in marine algae (CO_2 content of ocean waters). The event took place rapidly (<10,000 years) with a 5c rise in temperature. The carbon and oxygen isotope disturbances lasted between 100,000 - 200,000 years. The event can only be explained by a massive addition of isotopically light carbon to the atmosphere (fout times current levels). The most likely source of carbon was gas hydrates (clathrates) trapped in sediment on the continental shelves. These formed from methane generated by methanogenic bacteria.

What triggered this event? A number of theories have been advanced. One is based on the presence of several large crater-like structures on the floor of the North Atlantic which have narrow sills of volcanic rock at their base. It has been suggested that the heat of the magma ignited shallow reserves of gas in the overlying sediment (Flannery 2018).

The diagram (based on Beerling 2007) shows the initial phase of warming would have been enhanced by other greenhouse gases such as methane, nitrous oxide, ozone and water vapour which would have provided feedback mechanisms.

Plate tectonics as the driver of climate change (slide 24)

It is generally accepted that plate tectonics are at the root of climate change. But what exactly does this mean? The answer is multi-faceted and the slide shows the principal processes which stem from plate movement. Many of these factors have already been covered in the lecture.

Note that the creation of the Alpine chain would have several impacts on climate.

Less obvious perhaps is that weathering of rock forming silicates liberates abundant calcium which combines with CO_2 to form carbonates and thus reduces the amount available in the atmosphere. It is estimated that in Late Cretaceous times CO_2 content of the atmosphere was x4 present day levels but this had diminished by Miocene times to levels comparable to today (Willis & McElwain 2010).

Influence of global currents. (Slide 25)

The movement of tectonic plates can dramatically alter the global oceanic currents, which can in turn have a major consequence for climate change. An example is provided by the separation of Antarctica from South America about 35 MA years ago. According to Flannery (2018) Drake Passage was initially shallow but water flow was sufficient to establish an ocean current around Antarctica. This allowed cold water to build up and an ice cap to form which led to a fundamental reorganisation of ocean currents and winds, bringing colder global conditions. In Britain isotopic evidence from snail shells indicate that summer temperatures dropped by 10C at this time

This dramatic change was first recognised by palaeontologist Hans Stehlin in 1910.

Map of Antarctic currents shows the principal current - Antarctic Circumpolar Current (ACC) as red arrows. This is the largest ocean current and is the primary means by which water, heat and other properties are exchanged between ocean basins.

Paratropical forests of the early Tertiary (slide 26)

The vegetation covering much of the Northern Hemisphere between 50 – 60 Ma

was unique in terms of composition and poleward extent. The term ‘paratropical forest‘ is used to describe an unusual mixture of tropical and temperate species. Mangrove swamps fringed the coastal zones where Nypa palms were common (see image). This type of forest extended about 50 degrees in both hemispheres and certainly covered southern Britain.

Paratropical forest exists today in slightly seasonal humid climates of southern China and adjacent highlands of S.E. Asia.

Note that forests and woodlands of angiosperm trees, shrubs, conifers and ferns extended to both poles in the early Tertiary.

Forests of the Oligocene (slide 27)

The transition from Eocene to Oligocene was marked by a significant decline in global temperature with increased aridity and major changes in ocean circulation. Ice sheets started to establish themselves in the Arctic. As a result the poleward extent of tropical vegetation became much more restricted.

In Northern Europe broadleaved evergreen and deciduous woodland replaced the tropical vegetation. The dominant species became cold temperate hardwoods such as *Alnus, Betula,* and *Quercus* together with warm temperate trees such as *Carya* and *Sequoia.*

Forests of the Oligocene part 2 (slide 28)

The rise of grass (slide 29)

We tend to take grass for granted because it so widespread, covering more than 30% of the Earth's land surface. However, grass is a relative newcomer to Britain.

Evidence from fossil pollen and macrofossils indicates that grass evolved in the late Cretaceous According to Willis & McElwain (201) the earliest unequivocal fossil evidence is from the early Eocene of southern England and North America. However, Bruce Cornet has published a record of mid-Upper Cretaceous plants from a site in New Jersey, USA which includes species which have a grass-like appearance. Perhaps an early ancestor?

By the early Oligocene there is widespread evidence from a range of settings to indicate that grass had become significant component of global vegetation but

it was not until the early to middle Miocene times that that there were abundant grass-dominated ecosystems.

The long narrative of grass (slide 30)

A number of suggestions have been made to account for the rise of grass,

- Increasing aridity coupled with decreasing temperature promoted the expansion of the grasses. Many of the features of grass that enabled it to withstand drought also favoured resistance to fire and grazing. Late Miocene pollen sequences from Africa often show evidence of fire and the ability of grass to survive would have been an evolutionary advantage
- A change in the balance of global faunas may also have been significant. An overall decline in reptiles and a major radiation of mammals during the early Tertiary may have favoured grasses.
- The first mammals were generalized omnivores but gradually diets became more specialized. By the middle Eocene there is evidence of hooved animals adapted to running at speed. These animals were clearly adapted to a life in open grassland and a high cellulose diet.

- The fact that grasses continue to grow when eaten (or mowed) as it grows from the base would have been an important factor.

Declining temperatures in the Miocene (slide 31)

Following a brief period of climatic warming from 18 – 15 Ma there was a steady decline in temperature during the Miocene. Terrestial ice sheets were starting to develop in the polar regions. As a consequence, there was increasing aridity and a lowering of sea level. By the late Miocene Antarctica had become deforested, replaced by a tundra vegetation.

In Northern Europe the vegetation in the Miocene was a mosaic of deciduous forest and open grassland. The forests were dominated by angiosperm trees such as Alnus, Acer,Ulnus, and Betula.

Rivers! (slide 32)

Rivers are such powerful features of the landscape that it's easy to assume that they have always been there. In fact many of our major river systems are relatively young and many were substantially altered by ice sheets during the Pleistocene. In this section of the lecture I want to see if we can build up a picture of Britain's river system just before the ice sheets played havoc with them. I begin with an overview of Britain's drainage pattern in the Palaeocene and Pliocene, then focus on particular regions.

Palaeocene drainage pattern. (Slide 33)

i) Domal uplift in area of Irish Sea created early surface on which drainage could be established.

ii) The Palaeocene drainage would originally have been established on a Cretaceous/Jurassic surface. What do we know about extent/pace of removal of these sedimentary rocks? Jurassic sediments vary in thickness depending on location. In the Glos/Oxon area total thickness of Jurassic strata is about 1750m. Chalk thickness in our area more difficult to establish but 140m in East Midlands plus 500m estimated for Northern Province. So, following Late Cretaceous uplift there would have been about 1750m of sedimentary rocks in our area which has subsequently been removed by erosion,

iii) Uplifted fault- bounded blocks control drainage attend in Scotland, Wales and Cornwall.

Wales - river draining from area of Lleyn based on Howells (2007 fig64). Does this conflict with Cope's dome?

Hall (1991) states that the maximum period of uplift in the Scottish highlands was in Late Palaeocene-early Eocene times. This estimate is based on 412m of Palaeocene sediment identified in the Forties Field. Note that Janet Watson estimated that 25 - 30kms of cover rocks were removed by erosion during the period 500 - 410Ma!!

iv)Magmatism, uplift and erosion took place between 55 - 61 Ma.

SE England continued to subside with deposition of 30m of glauconitic marine sands and clays.

Pliocene drainage pattern. (Slide 34)

SE England mainly land.

SW England no longer a zone of uplift.

Bytham River has become more complex.

Radial drainage pattern continues in Wales. Note NE trend of River Severn.

Lugg and Mathon are main rivers in our area (Richards 2005).

Scotland: Late Tertiary drainage patterns (slide 35)

I have already mentioned the importance of chemical weathering during the Tertiary. Hall (2001) makes a number of important points in this context:

Firstly, the survival of pre-glacial deep weathering in Scotland shows that glacial erosion was limited to removing the weathering mantle, so no more than 50m of weathered rock has been eroded by ice.

Also, the pre-glacial landforms frequently reflect variable rock resistance to weathering so the pre-Quaternary relief is the end product of a long process of Tertiary differential erosion. In other words, the hard crystalline areas resist erosion better than softer sedimentary rocks.

Hall considers that the Tertiary drainage mirrors the pattern established in earlier geological periods. “Tertiary uplift largely involved the re-emphasis of pre-existing topographic contrasts between a buoyant massif and subsiding marginal basins.”

In view of the very long history of rivers such as the Spey and Dee (see images) it is perhaps surprising that their valleys are not more deeply etched in the bedrock.

Finally, Hall estimates that in many areas of the Scottish Highlands the amount of lowering by Tertiary erosion is less than 1km, so the landscape shows continuity over a period of some 400Ma.

Landscape evolution of Wales (slide 36)

Ideas about the geomorphology of Wales have changed a good deal since the 1960’s. At that time geographers were concerned to explain the discordance between the drainage pattern and the Caledonian trend of the underlying geology. The consensus was that the drainage had been established on a Cretaceous surface and then superimposed on the underlying Paleozoic rocks.

Eric Brown was a dominant influence in the 1960’s and he interpreted the Welsh landscape in terms of three main plateau surfaces (peneplains) which reflected pulses of uplift through the Tertiary. Recent research has cast doubt on both these interpretations of the Welsh landscape, A key problem lies in correlating the erosional surfaces over long distance.

Wales: evidence from Tertiary sediments (Slide 37)

There are very few Tertiary sediments preserved on the landmass of Wales which makes interpretation difficult. However, extensive thicknesses of Palaeocene sediment have been preserved in fault bounded basins in the North Sea. The Mochras borehole has revealed 524m of Middle Oligocene and Lower Miocene sediments deposited in a half graben. The basal sequence comprises mainly thick conglomerate with interbedded sands and clays. These are interpreted as alluvial debris flows from a fault scarp and indicate uplift of the Welsh Massif in ten phases.

In the South Celtic Sea Basin over 500m of Eocene - Oligocene sediments have been recorded.

On land Paleogene sediments are restricted to the fill in cavities in limestones,

Thus, the sedimentary record suggests the main phases of uplift taking place in Eocene - Lower Miocene times,

Evidence for an ancient landscape (slide 38)

Yvonne Battau Queney (1984) has carried out extensive studies on landscape evolution in Wales. She argues in support of an ancient land surface which may have originated in Devonian times as an emergent landmass known as St George's Land. "The relief of St George's Land was smooth and sea levelled; a post Caledonian surface was achieved over a major part of central Wales in late Carboniferous (304 – 313Ma) times". YBQ goes on to argue that the Hercynian orogeny would have played only a minor role "nowhere in Wales did high mountains appear during or immediately after the Hercynian orogeny".

YBQ argues that the Welsh massif emerged before the Cenomanian (pre 99Ma) and subsequently underwent deep tropical weathering.

There is no evidence for chalk having been deposited over Wales which would have been emergent at that time.

Ancient structural influences (slide 39)

YBQ argues that the main phase of uplift took place in Neogene times along re-activated faults. (see map of Caledonian faults). The most dramatic example is provided by the contrast between Anglesey and the Snowdonia massif. Brown had interpreted Anglesey as a lowland plateau, product of two phases of marine erosion, whilst Snowdonia is cited as his upland plateau. YBQ regards both surfaces as being the product of prolonged chemical weathering with the Snowdonian massif uplifted in Late Neogene times. This interpretation is supported by Tertiary dykes which have the same texture and petrography in both regions in spite of a difference of elevation of some 780m (McCarroll 2005).

Neogene uplift around the Atlantic coast. (Slide 40)

Support for YBQ's thesis is provided by looking at the wider picture. Jepson et al suggest that the main phases of uplift in Europe took place in the Early Palaeocene and late Neogene. They describe a range of approaches which include studies of maximum burial, fission track analysis, geomorphology and structural relations.

Stoker (2002) argues for a late Pliocene age for the onset of uplift in NW Scotland,

The river systems of Wales (slide 41)

I have already commented that the rivers of Wales show hardly any Caledonian influence in their orientation.

The concept of the drainage having developed on a Cretaecous is no longer accepted. The slide shows a pattern of radiating drainage from three or more centres which can be explained in terms of separate crustal blocks forming their own characteristic topography. The blocks include Snowdonia, the Plynlimon area and the Brecon Beacons.

Late Tertiary rivers draining eastern England. (Slide 42)

Ideas concerning the drainage network in eastern England have evolved in recent years. Original interpretations were based on a series of gaps cut in the Jurassic escarpment, An example is the Ancaster Gap which is characterised by a steeply sided narrow valley. The map shows conjectural river courses based on the geomorphology.

The Bytham River. (Slide 43)

The Bytham was first recognised by James Rose of Royal Holloway University following a study of aggregates in a quarry at Withen, near Castle Bytham in the late 1980's. The sediments are a quartz-rich sand with very little clay and had previously been interpreted as glacial sediment. Rose correlated these sands and gravels with localities to the west and east and interpreted the sediments as being of fluvial origin. His interpretation is not accepted by all Quaternary scientists but is widely cited in the literature.

The River Bytham: an alternative (slide 44)

Gibbard et al (2013) have questioned the basis on which Rose defined the course of the Bytham River. Their main criticism is that glacial and immediately pre-glacial sediments have been incorrectly correlated.

Map A shows their preferred route for the pre-Anglian river.

Map B shows a later river discharging into the Wash.

They think the term Bytham River should be abandoned dismissing it as a useful discussion point.

30 million years of ape evolution. (Slide 45)

In the final section of this lecture I turn my attention to the 30 million years of ape evolution, from Rukwapitheus to Homo sapiens. My rationale is that humans have made a massive impact on the global landscape and part of the theme of this course is to chart the increasing impact of our species on our precious planet.

Evolutionary history of apes and human. (Slide 46)

The cladogram shows the differing evolutionary pathways of apes and human over the last 30 million years with a focus on the Last Common Ancestor at various points. Firstly, note that Old World Monkeys (Africa and Assia) branch off before the last common ape ancestor. Begun (2016) estimates this divergence took place between 31 - 38 Ma ago (Early Oligocene) although other specialists offer different dates (see diagram).

For further points of divergence I quote Begin "… a broad if not quite complete consensus is emerging that humans and chimps diverged between 7 - 8 Million years ago, gorillas around 9 and orangs between 14 - 16 million years ago." You could say that we have a Miocene pedigree

Four legs good: two legs better (slide 47)

We now turn our attention to early human evolution in Africa. During the late Miocene (10 - 11 million years ago) the climate in Africa became drier. As a consequence, the mode of transport for some ape species became modified for walking along the ground across clearings in the forest. Initially this would have entailed knuckle walking but gradually bipedalism developed in australopithecines. Clear evidence for this change of moving comes from Laetoli in Tanzania where an adult and child walked across a newly fallen deposit of ash leaving footprints which have been dated at 3.7Ma.

The diagram shows possible links between australopithicenes and humans, although some experts question this route to early humans.

Pliocene hominids: the Taung child (slide 48)

The Taung child was discovered by Raymond Dart in South Africa in 1925. This was the first discovery of an australopithecine and proved to be a child, about three years of age. Subsequently adult australopithecines have been discovered in South Africa, Tanazania and Ethiopia which have provided a much better picture of this human ancestor. The Taung child is now classified as A. africanus.

According to Richard Dawkins (2009) the Taung child was eaten by an eagle! The evidence is that damage marks to the eye sockets of the fossil are identical to marks made by modern eagles on monkeys as they rip out their eyes. Dawkins laments "poor Taung mother, weeping in the Pliocene".

Australopihtecus africanus 3.3 - 2.1Ma. (slide 49)

Evidence of A. africanus is limited to four sites in Southern Africa. The skulls and skeletons suggest a transition between ape-like characteristics and traits of human anatomy.

The human trait of upright walking is suggested by the structure of the pelvis. Also, the structure of the lumbar spine suggests an adaptation in females in order to more efficiently bear a load during pregnancy - an adaptation not needed in an arboreal environment. The structure of the hands shows a human trait with forceful opposition of thumb and fingers typically adopted during tool use.

However, the small brain size and arms which are slightly longer than legs indicate an ape like anato.

Lucy: australopithecine afarensis. (Slide 50)

The first species of A. Afarenis was discovered in the Hadar region of Ethiopia in 1974. The partial skeleton was named Lucy because the Beatles "Lucy in the Sky with Diamonds" was being played in the camp when the discovery was first reported. Since that discovery a further 200 skeletons on A. Afarensis have been found in the same area.

As with A. africanus there are traits of both ape and human anatomy.

The event to which A. afarensis was completely bipedal is uncertain. The pelvis suggests bipedalism but the anatomy of hands and feet indicate that the life style remained partly arboreal.

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