Hastings & District Geological Society Journal

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Hastings and District Geological Society
affiliated to the Geologists' Association

President
Professor G. David Price, UCL

HDGS field trip to Eastbourne led by Professor Rory Mortimore - 31st July 2011

Volume 17 December 2011

Cover picture: HDGS field trip to Eastbourne led by Professor Rory Mortimore - 31st July 2011 - photo: Peter Austen

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2011 Officials and Committee

Professor G. David Price - President

Ken Brooks - Chairman......Tel: 01424 426459......E-mail: Iggyken@aol.com

Norman Farmer - Treasurer......Tel: 01342 410102

Diana Williams - Secretary......Tel: 01424 426459......E-mail: Iggyken@aol.com

Peter Austen - Journal Editor......Tel: 01323 899237......E-mail: p.austen26@btinternet.com

Joyce Austen - Assistant Editor

Trevor Devon - Website Manager......Tel: 01424 870402......E-mail: trevordevon@madasafish.com

Gordon & Siân Elder - Librarians

Gordon Elder - Education Officer......Tel: 01424 812216

Other Members of Committee

Colin Parsons John Boryer Pat Dowling

Hastings & District Geological Society Website - http://hastingsgeology.btck.co.uk/

Geologists' Association Website - http://www.geologistsassociation.org.uk/

Contributions for next year's Journal would be appreciated and should be submitted by the October 2012 meeting.
Please contact Peter Austen on: tel: 01323 899237 or e-mail: p.austen26@btinternet.com

This Journal is issued free to members of the Hastings & District Geological Society (HDGS) and is also freely available on the HDGS website.

HASTINGS & DISTRICT GEOLOGICAL SOCIETY

Minutes of the A.G.M. - 12th December 2010

The Meeting was declared open at 2.35 p.m. by the Chairman, Ken Brooks. There were twenty-nine members present.

1) Apologies: Were received from:
Trevor Devon, Tony Standen, Pat Littleboy, Pauline Mackay-Danton, Christine Wagner and Nancy Wagner.

2) Minutes of the last A.G.M.: These were printed in the *H.D.G.S. Journal* which had been handed out to members. Their acceptance was proposed by John Fowler and seconded by Pat Dowling, and a show of hands indicated that they were unanimously accepted.

3) Chairman's report:

a) 2010 Programme: Ken summarised the year's activities:

Lectures by visiting speakers:

'The Building Stones of Canterbury' by Geoff Downer
'The Wealden Iron Industry' by Jeremy Hodgkinson
'Scientists through Coelacanth Eyes' by *Dr.* Peter Forey
'The Giant Gastropod Mystery' by *Dr*. Paul Taylor
'Fossil Plants of the Jurassic' by *Prof.* Paul Kenrick
'Geomagnetic Reversal' by *Prof.* David Price

Members' Day talks:

'The Nautilus & the Ammonite' by Ken Brooks
Practical "Hands-on" Event

Field Trips:

Field trip to Sheppey: Leader Ken Brooks
Visit to Canterbury: Leader Geoff Downer

b) Ken said that the attendances had been up again on last year's figures, the average being 35 per meeting. He said that he was delighted with the wide range of subjects that had been covered in the programme. However, he said that he was disappointed that the number of members going on field trips was still very low, with only 8 people going on the Sheppey trip, and wondered whether future field trips should be designated as optional extras.

c) Ken commented on the purchase of the digital projector earlier in the year which had been bought with a donation from the Isabel Blackman Foundation after our application to *Awards For All* had been turned down (*see* last year's AGM Minutes). He said that having this, together with a laptop presented to the Society by John Boryer, meant that we didn't have to ask Gordon Elder to bring his equipment along to every meeting.

4) Treasurer's report:

Diana had typed up Norman Farmer's *Statement of Income & Expenditure for the Year Ending 31st December 2010* which was handed out to members. Norman briefly discussed the items, saying that little had changed since last year, except that we had gained one more member. He said that the higher surplus of income over expenditure had maintained the balance. The acceptance of the report was proposed by Gordon Elder and seconded by Stuart Barnes.

5) Election of the Committee:

Ken asked if anyone would be willing to take over from any of the existing committee members, but as no offers were forthcoming, it was suggested that the Committee be re-elected again *en bloc.* This motion was proposed by Geoff Bennett, seconded by Chris Woodcock and unanimously carried.

The Committee was said to be as follows:

2010	**2011**
Chairman	
Ken Brooks	Ken Brooks
Treasurer	
Norman Farmer	Norman Farmer
Secretary	
Diana Williams	Diana Williams
Journal editors	
Peter & Joyce Austen	Peter & Joyce Austen
Librarian & Education Officer	
Gordon Elder	Gordon Elder
Website manager:	
Trevor Devon	Trevor Devon
Other Officers	
1. Colin Parsons	Colin Parsons
2. John Boryer	John Boryer
3. Pat Dowling	Pat Dowling

6) 2011 Programme: Copies were handed out to all members present. Those unable to attend would be receiving their copies with the next letter to members. Ken thanked Diana for her work in preparing the Programme and gave a brief résumé of next year's lectures:

- ***'Darwin as a Geologist'*** by Chris Duffin
- ***'New Techniques in Conservation'*** by Chris Collins
- ***'The Polacanthus Story'*** by *Dr.* William Blows
- ***'Jurassic Fish'*** by *Dr.* Peter Forey
- ***'Seismic Surveying'*** by David Howe
- ***Presidential Lecture*** by *Prof.* David Price

He said that there would be two Members' Day talks this year:

• ***'Pierre Teilhard de Chardin'*** by Ken Brooks
• ***'Recent Discoveries in the Weald'*** by Peter Austen

The 'outings' for 2011 would be:

• New Year's Day walk at Fairlight
• Field trip to Bracklesham Bay
• Barbecue Party with Trevor Devon
• Field trip to Beachy Head with *Prof.* Rory Mortimore
• Peter Austen said that there would be field trips to Smokejacks in April & September and that there would probably be trips arranged at short notice to Warnham Clay Pit near Horsham.
• John Fowler suggested that we might organise a field trip to the Ibstock brickworks in Bexhill and that he might be able to help as he knew the Managing Director. Pat Dowling said that the brick works was going to become a landfill site, and Peter Austen said that although this was not imminent and that all was going well at the moment, most quarries were under threat or would be in the future.

7) Any Other Business

• Ken thanked Peter & Joyce Austen for all the time and effort they had put into producing another excellent *H.D.G.S. Journal* and Peter said that there had been a lot of good articles supplied.
• Ken thanked everyone for helping at meetings in putting out tables and chairs, making tea, washing up, etc.
• He also said that the sale of raffle tickets (especially for the 'agates' raffle) had been very impressive and had generated £61 for the Society, and that we would try and have more raffles in the future.
• Ken reminded everyone about the New Year's Day Walk which would begin with an optional lunch at the Smuggler Pub at Pett at 12 o'clock. The walk itself would start at 2 p.m. from the pub and he said that this year the tides would again be ideal for a walk along the beach. He asked members to let us know if they would like to have lunch first as tables had to be booked in advance.
• Ken also reminded members that their annual subscriptions were now due.

Ken declared the Meeting closed at 3.00 p.m.

HASTINGS & DISTRICT GEOLOGICAL SOCIETY

Statement of Income & Expenditure for the Year Ending 31st December 2010

INCOME	£	EXPENDITURE	£
Subscriptions		G.A. Affiliation fees	33.00
Single 39 @ £15.00	585.00	Hire of hall	141.75
2 (part year)	15.00	Society *Journal* production	181.90
Family 14 @ £20.00	280.00	Insurance premium	138.00
1 (part year)	10.00	Stationery, copying, postage	86.33
		Donations & gifts	39.23
	890.00	Lecture fees and expenses	235.51
		Purchase of digital projector	506.49
		Refreshments	25.00
		Provision for summer barbecue	110.00
		Raffle tickets	2.99
		Purchase of books	18.00
Donations	551.00		
Summer barbecue receipts	115.00		
Raffle receipts	61.00		
Sale of books and magazines	14.20		
	1,631.20		1,518.20
		Surplus being excess of income over expenditure	113.00
	1,631.20		1,631.20

Bank Account and Monies in Hand

Balances as at 31st December 2009	£	Balances as at 31st December 2010	£
NatWest Bank	417.73	NatWest Bank	481.26
Monies in hand	19.52	Monies in hand	68.99
	437.25		550.25
Increase in Balances	113.00		
	550.25		550.25

December 2010

OBITUARY

Dr. Terry Henman

5th September 1940 - 7th May 2011

Terry Henman, who was an active member of the Society, passed away in May of this year, aged seventy, after a long battle with cancer. His funeral was held on 27th May at Eastbourne Crematorium, attended by H.D.G.S. members and many representatives from other aspects of his full and interesting life.

Terry came from a humble background in Eastbourne, but he was a bright boy and was fortunate to win a scholarship to Cambridge in 1959. He read Natural Sciences and majored in Chemistry. This led to him staying on in Cambridge to do a doctorate in Organic Chemistry. He then worked for ICI as a Research Chemist for over 15 years before setting up his own specialist consultancy business. He lived near Cambridge for much of his life but decided to return to his roots in Eastbourne in 1998.

Although he became a specialist in the world of plastics and rubber (!) he always retained a love of geology. He first encountered the subject in his first year at Cambridge and often said that, in hindsight, he wished he had read geology instead. As a result he retained a keen interest as an amateur geologist and he took every opportunity to indulge his interest and get out into the field to collect samples.

Both of his sons remember vividly geology field trips from childhood - seemingly very long days outdoors but enlivened by the prospect of finding a nice fossil! As well as collecting samples from across the UK, this extended to more far flung locations from Tenerife to New Zealand. His last major trip was to California and Hawaii at the end of 2010 and he still managed to bring some samples back from the latter in his suitcase.

Over time, Terry amassed a huge collection of rocks, fossils and minerals. This extended to a large rock cabinet in his home as well as various garages and sheds squirrelled away in the Eastbourne area!

Terry was active in many geological clubs - not only the H.D.G.S., but also the U3A in Haywards Heath and Brighton and clubs further afield, e.g. Penrith. This followed his purchase of a holiday flat in Keswick, fulfilling a dream to spend more time in the Lake District. He loved the area, which he described as his “spiritual home”.

He was also active in many other fields and clubs and societies, many of whom were represented and gave tribute at his funeral. These included tennis, vintage buses, wine society, croquet club, hill-walking, cinema and many others. He liked to keep busy and always retained his unquenchable thirst for knowledge.

He is survived by two sons, Nick and Tom, and three grandchildren, Ben, Lucy and Katie.

Dinosaur quarries of Hastings

by Ken Brooks

For over two hundred years dinosaur bones and other fossils have been found along the beach to the east of Hastings, between Rock-a-Nore and Pett, but by far the most spectacular specimens were collected from local quarries in the 19th century. At this time Hastings was expanding rapidly as a popular seaside resort. As a result, huge quantities of sand, clay (for chimney pots and bricks) and stone were required for new buildings and roads. This is reflected in the large number of local quarries which are marked on the 1899 Ordnance Survey (OS) map of Hastings. Many brickworks were located near outcrops of Wadhurst Clay. As well as clay, this Formation also contains beds of sandstone and Tilgate Stone, a hard calcareous grit that was quarried for road stone (White 1928, p. 24, 25, 27). It was also known locally as 'Bluestone' or 'Hastings Granite' (Abbott 1907, p. 170). While the natural erosion of cliffs on the coast revealed occasional fossils, inland quarrying provided a more rapid and continual exposure of specimens. These included dinosaur bones from the geological section known today as the Hastings Group (Ashdown Sands and Wadhurst Clay - sedimentary beds which date from 141 to 137 million years ago and belong to the Valanginian Stage within the Lower Cretaceous.)

For many years I have been curious about the exact locations of these long-abandoned quarries, but my research was really inspired by a 'behind the scenes' visit to The Natural History Museum (NHM). Here in the storeroom were huge dinosaur bones, some with their original labels, that were identified as coming from the old quarries of Hastings (Figs 2, 4, 6). Unfortunately, the quarries were not named on maps and very few locations were recorded in sufficient detail in early scientific papers. For example, a quarry that was established on agricultural land was often named after the farm or nearby house belonging to the land owner. However, confusion arises when separate quarries were located within the boundaries of a single farm.

Gideon Algernon Mantell (1790 - 1852), a doctor based in Lewes, was a very keen amateur fossil collector. During the 1820s he described and named the *Iguanodon* on the basis of some teeth and dinosaur bones he found (or bought) at various quarries in the Tilgate Forest area of Sussex. In his personal journal (1822) Mantell complained about other collectors "poaching fossils" from quarries in his local area (Curwen 1940, p. 46). This may be one reason why some fossil hunters were not prepared to record precise details of their locations. Although Mantell visited Hastings on several occasions, I could find no evidence that he personally collected fossil specimens here.

The two most important local fossil hunters in the latter half of the 19th and early 20th centuries were Samuel Beckles and Charles Dawson.

Samuel Husband Beckles (1814 - 1890)
Beckles was born in Barbados and qualified as a barrister at the age of twenty-four, but when his health began to deteriorate he retired to St. Leonards in 1845. He became interested in the geology of the Weald, and made many important discoveries in the Hastings area, Dorset and the Isle of Wight. Among the many fossils he found were some well-preserved *Iguanodon* bones, including the first partially articulated hindfoot (Owen 1854 in 1853–1879). As a result of his discoveries Beckles was able to publish a number of scientific papers on local fossils and his importance as a geologist was recognised by his election as a Fellow of the Royal Society in 1859.

After Beckles' death a part of his large collection of Wealden fossils was bought by the Hastings Museum. Specimens included dinosaur vertebrae, limb bone and jaw fragments and a ripple-marked footprint of *Iguanodon*. Unfortunately, today very few of his specimens can be individually identified. The remainder of Beckles' collection was purchased by the British Museum (Natural History), later renamed The Natural History Museum.

Charles Dawson (1864 - 1916)
While Dawson lived in St. Leonards he became friends with Beckles, from whom he learned

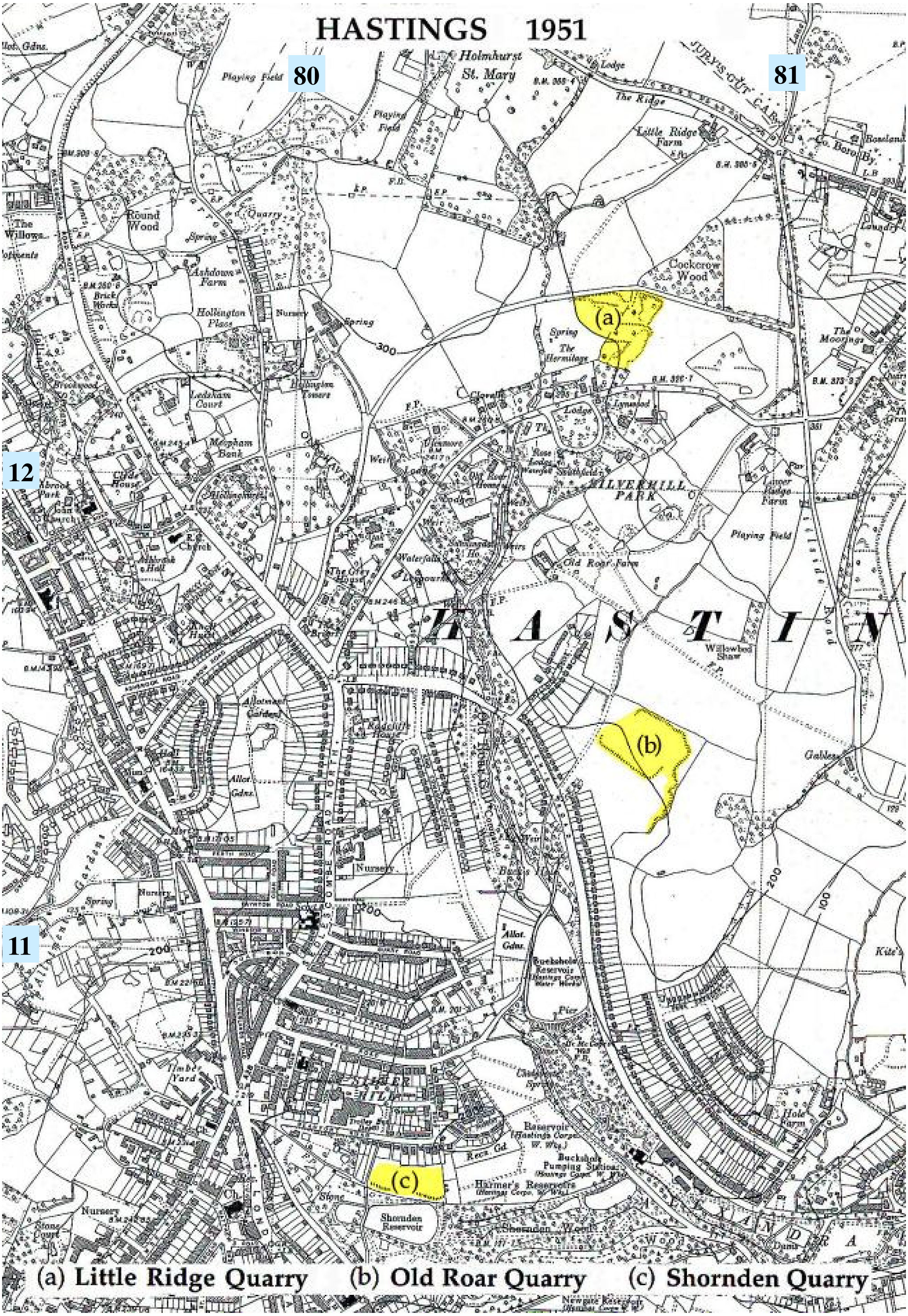

Fig. 1. Map of Hastings with three of the main quarries marked. (Grid references shaded blue)

considerable skills as a fossil hunter. Their visits to local quarries were so successful that, by 1884, Dawson had built an impressive collection of Wealden fossils. He also spent time investigating the coastal cliffs to the east of Hastings, from Rock-a-Nore to Pett. By the early age of twenty-one his work in geology brought him a Fellowship of the Geological Society of London. Later, on the recommendation of Richard Lydekker, he was appointed as an honorary collections advisor to the British Museum (Natural History) for over thirty years. Dawson found specimens that were used to establish three new species of *Iguanodon* (Lydekker 1888, 1889). One of them, originally named *Iguanodon dawsoni* in his honour, was based on a partial skeleton collected from a site that he referred to as 'Shornden' (Norman 2010, 2011*a*, *b*). Today these are recognised as belonging to two species: *Barilium dawsoni* and *Hypselospinus fittoni* (Norman 2010, in press). The 'Dawson Collection' in The Natural History Museum contains some of the very best dinosaur fossils ever found in Sussex. Today, however, Dawson is primarily remembered for his involvement in the Piltdown forgery and other deceptions (Weiner 1955, p. 83).

My quarry research involved the study of Ordnance Survey maps, geological maps and local street maps of the area. Other clues have been obtained from 19th century field trip accounts, articles in geological journals, contemporary newspapers and more recent descriptions of the fossils found in these quarries. Archives at the East Sussex Records Office, Hastings Museum, Hastings Reference Library and on the internet have also been informative. Once a potential quarry site had been identified the location was visited, mapped and photographed. From the material gathered I have selected three local quarries (see map fig. 1):

Little Ridge Quarry (TQ 8065 1240)

The 1873 OS map shows a quarry just south of the Little Ridge farmhouse. Today this overgrown site may be found on the south side of Little Ridge Avenue, a short distance from the Conquest Hospital. It has been suggested that Little Ridge Quarry was located at TQ 799126, west of Little Ridge farmhouse (Brooks in Batten and Austen 2011, p. 30), but further research has revealed that this site was not marked as a quarry on the 1873 OS map, and that the area was identified on the later 1899 and 1909 OS maps as Beauport Brickworks. There are also a number of smaller quarries shown on the 1873 OS map, such as 'Quarry Wood' to the east of Hillside Road.

Fig. 2. Iguanodon *bones from Little Ridge Quarry.*

Fossils in The Natural History Museum storeroom include a number of *Iguanodon* vertebrae, metatarsals and phalanges from *Iguanodon* (= *Hypselospinus*) *hollingtoniensis* (Fig. 2). These specimens are labelled as coming from 'Little Ridge Quarry' and represent part of the 'Charles Dawson Collection'. The species '*hollingtoniensis*' suggests an origin in or near Hollington, north of Hastings, and the original specimens (the holotypes) of this species included a variety of post-cranial bones collected by Dawson from a quarry referred to as 'Hollington' (Lydekker 1889). The dinosaur bones from Little Ridge Quarry were recognised as being very similar to those of the 'Hollington' specimens.

Old Roar Quarry (TQ 808115)

This quarry was named after a forty foot high waterfall (TQ 804120) that was a popular attraction in Victorian times. An early Hastings guide book states that, ". . . *after long heavy rains a large body of water tumbles over with a tremendous roar, that is heard half a mile off.*" (Barry 1797, p. 86)

The 1873 OS map has no quarry marked at the TQ 808115 site, but by 1899 there are three quarries indicated, with two of them labelled as 'abandoned'. In 1909 the OS map shows that these quarries had been combined into one large quarry. According to the geological map for the Hastings-Rye area

(Institute of Geological Sciences 1977), it would have covered an area of Wadhurst Clay, with an outcrop of sandstone to the north. By 1929 the site was no longer identified as a quarry and today it is occupied by the William Parker School's running track (Fig. 3). In the 1928 Geological Survey Memoir for the area there is a reference which provides a useful clue to the location of Old Roar Quarry: "*In the grass-land east of St. Helens Road, and about one third of a mile S.-by-E. of Silverhill Park, there is a large and much-degraded quarry in Wadhurst Clay.*" (White 1928, p. 67)

Fig. 3. William Parker School running track (Old Roar Quarry site).

In Hopkinson (1874, p. 213) a contemporary account of a field trip made by Geologists' Association members to this quarry is described:

> "*On their arrival at [St Leonards] station they were met by Mr. Peyton, who had most kindly provided carriages for the day. The Old Roar quarry, an extensive excavation in the Wadhurst Clay, was first visited. Here, a bone-bed, almost entirely made up of the teeth and bones of the old Wealden reptiles and fishes, is exposed. It appears to have formed the bed of a river, and may at one time have been continuous with the similar bed exposed at the Black Horse quarry, near Battle. Overlying the bone-bed a leaf-bed containing impressions of ferns is seen; and below it the Wadhurst Clay encloses a bed of stone, a concretionary argillaceous limestone from three to four feet thick, for which the quarry is worked. Below this is a bed of blue clay, and then another bed of stone, the whole reposing on the Ashdown Sand. Two other quarries, one in the upper part of the Ashdown Sand, the other in the Wadhurst Clay, were then visited, and in each of them numerous fossils were found.*"

Between 1908 and 1911 Pierre Teilhard de Chardin was a student priest at Ore Place, a Jesuit Seminary in Hastings. During his free time he was an enthusiastic collector of fossils, and in May 1909 he wrote a letter to his parents in which he described a field trip to a local quarry:

> "*In the past two weeks, I've become acquainted with Charles Dawson, a geologist in the area. It happened under amusing circumstances. While visiting a quarry close by, we were surprised to see the 'manager' take on an understanding attitude when we discussed fossils with him. He had just discovered an enormous pelvis bone from an Iguanodon and was very anxious to talk about it. I knew then that it was almost a whole Iguanodon being found piece by piece, and the fragments (you could say crumbs, for I wonder how they can be recognized) are piling up one by one in a crate destined for the British Museum.*"
> (Teilhard de Chardin 1968, p. 48)

Fig. 4. Iguanodon *pelvis and vertebrae from Old Roar Quarry.*

Although Teilhard de Chardin does not name the quarry, his description of the *Iguanodon* pelvis corresponds to a large partial skeleton, labelled 'Old Roar Quarry', in The Natural History Museum Collection (NHMUK R3788; Norman 2011*a*, *b*). The label also states that it was purchased by the 'British Museum' from Charles Dawson in November 1909. This magnificent specimen, originally named *Iguanodon dawsoni* (Lydekker 1888), was identified from a pelvic girdle, consisting of the ilium, ischium and pubis together with thirteen articulated posterior dorsal and sacral vertebrae (Norman 2011*a*, *b*) (Fig. 4).

In his 1922 article on *Dinocochlea ingens,* then identified as a 'gigantic gastropod', B. B. Woodward states that the specimen was discovered during road works near Silverhill, not far from the Old Roar Waterfall, and close to the quarry dubbed by Mantell the 'Iguanodon Necropolis' (Woodward 1922). Could this have been the Old Roar Quarry?

Shornden Quarry (TQ 802105)

This site was originally part of a large brickworks, with two kilns, close to Shornden Reservoir (Fig. 5) in what is now Alexandra Park. The geological map for the Hastings-Rye area (Institute of Geological Sciences 1977) indicates that Wadhurst Clay and Tunbridge Wells Sand would have been extracted here. In the 1880s dinosaur bones were obtained from the Wadhurst Clay, lying two feet (60 cm) below a bed of sand. A three foot (1 m) bed of ferruginous sand was separated by a stone band of two feet (60 cm) in thickness from the underlying clay bed. The brickyard was already established here by 1861 and it continued to operate until around 1890. The 1909 OS map shows the site to be occupied by a nursery.

Fig. 5. Shornden Reservoir (Shornden Quarry site).

Shornden Quarry is one of the locations named in The Natural History Museum's collection of Hastings fossils. Specimens collected here by Dawson include various pelvic bones and vertebrae from *Iguanodon* (= *Hypselospinus*) *fittoni* (NHMUK R1635 a-d) and *I.* (= *Barilium*) *dawsoni*, which still have their original 'Dawson Collection' labels (Fig. 6). Other fossils from these dinosaurs include an almost complete ilium and incomplete sections of pelvis, leg and foot bones (Lydekker 1888, 1890; Woodward and Sherborn 1890; Norman 2010, 2011*a*, *b*).

Note: Shornden Reservoir was cut into a down-faulted area of Tunbridge Wells Sandstone in 1852-53. The nearby Buckshole Reservoir (TQ 806110) was also constructed during this time.

Other local dinosaur quarries and sites

Hollington Quarry, Buckshole Quarry, Hole Farm Quarry and West Marina Quarry were also identified by Dawson and Beckles as yielding dinosaur bones in the Hastings area. Unfortunately, there is practically no recorded information about these quarries, apart from contemporary reference labels found on the fossils, although it is likely that Buckshole Quarry was located adjacent to Buckshole Reservoir (TQ 805110).

However, dinosaur fossils were also found at other locations in the town. In October 1848 work was in progress to construct a new gasometer (TQ 819099) near Queens Road. According to a local newspaper: "*In the excavation for the tank, which was very extensive, there was* (sic) *discovered many skeleton*

Fig. 6. Iguanodon *vertebrae from Shornden Quarry.*

specimens of the antedeluvian (sic) *world, belonging, we understand, to the Iguanodon class.*" (Anon. 1848, p. 3)
The following year the *Hastings and St. Leonards News* reported: "*We hear that some fossil remains of the old-world iguanodon have been found by the excavators of the new railway line near St. Leonards. The bones are in the possession, we believe, of Mr. Thomas Vidler, Castle-road.*" (Anon. 1849, p. 3; Baines 1963, p. 318)
William Diplock described an event near Silverhill junction (TQ 7993 1078) in 1860: "*Remains of Saurians have been found in the neighbourhood of Hastings. The skeleton of a gigantic Iguanodon was discovered in digging the foundation for the new house at Tivoli, called Silverlands. The bones are in the possession of S. W. Beckles, Esq., who it is hoped will one day put them together and describe them.*" (Diplock 1864, p. 341; Baines 1963, p. 366)
In 1925, during excavations for the building of the White Rock Pavilion (TQ 8115 0918), fragmentary "*saurian bones*" were exposed in the Wadhurst Clay. They were later put on display at Hastings Museum (White 1928, p. 45).
Sadly, it appears that apart from the above details, records of these specimens were not kept or have been lost.

Today, although the old quarries are now landscaped or buried under housing developments, there is at least one site near Hastings where the discovery and excavation of dinosaur bones continues. In recent years Dave Brockhurst has made some remarkable finds in the Wadhurst Clay of a Bexhill brickworks (Austen *et al*. 2011) – but, following tradition, I will not reveal the location**!** The fossils include the remains of *Iguanodon, Polacanthus* and even a posterior cervical (neck) vertebra of what may have been the world's smallest adult non-avian dinosaur (Naish and Sweetman 2011; Sweetman 2011; see also page 39 of this issue). Until it is officially named, it has been nicknamed the 'Ashdown maniraptoran'.

Acknowledgements
My thanks to Diana Williams, David Padgham, Peter and Joyce Austen, the Natural History Museum, London, Hastings Reference Library, Hastings Museum and especially to Dale Smith for his field trip research in rediscovering overgrown quarry sites. I am also very grateful to David Norman for his valuable help and advice.

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Field trip to Fairlight

Saturday, 16th April 2011

Ken Brooks leading one of his many field trips along the Fairlight coastal section.

Photo: Peter Austen

Mountain of Fire – Timanfaya

by Geoff Bennett

Last year I visited the almost 20 square mile Timanfaya National Park, where a continuous series of volcanic eruptions during the 18th century destroyed almost a quarter of Lanzarote.

Timanfaya, also known as the Mountain of Fire, is really hot! The Islote de Hilario, an 'island' inside the park is the hottest place in Lanzarote. You can't touch the ground. Only five inches below the surface it is 160 degrees Celsius, and at a depth of 30 feet the temperature reaches 400 to 600 degrees! Apart from the coaches, roads are closed to the public.

Fig. 1. Lichen catches fire from the heat.

Almost all visitors go to the Mountain of Fire in Timanfaya. There are only three ways to explore the park, all rather limiting. Guided tours cover 5 km and last 2 hours with a maximum of 16 people (three week's notice must be given, and applicants must be under 70 – no one under 18 permitted). With over two hundred camels available in the park, many visitors cover the simple loop of just over half a mile by dromedary, which is not overly interesting and takes only twelve to fifteen minutes.

I took the coach route to Islote de Hilario, the hottest area of all. It is an 'island' amidst the lava where lichen is thrown into shallow depressions to start a fire (Fig. 1). Water poured into holes vaporizes and explodes into a geyser. But most interesting is the El Diablo Restaurant (The Devil's Diner) where the food is grilled over a hole in the ground using geothermal heat (Fig. 2).

The entire area is just black gravel and lava (Figs 3 and 4). Almost the whole of Lanzarote is dark, black and virtually unchanged by the weather as there is scarcely any rain (perhaps 4 or 5 days in the year). During the past 300 years only lichens have gained a foothold.

Lanzarote is the second oldest Canary Island. When the North African Plate collided with the Atlantic Plate 36 million years ago the up-thrust of the Atlantic Plate was the beginning of the Canaries. Fuerteventura came first around 20 million years ago, followed 4 million years later by Lanzarote. Two parts reached the surface of the sea 16 million years ago but remained separate until fairly recently. A number of volcanic eruptions between these two islands about 5000 years ago in the form of cleft volcanism, where craters develop along a fault line like beads on a string, caused this necklace of volcanoes to bridge the northern and southern islands into one island. But the most vital volcanic eruptions took place at Monte Corona, where four volcanoes poured liquid rock covering the entire north of the island, enlarging it considerably into the modern island of Lanzarote. This release of molten magma also produced the five islands at the northern end of Lanzarote. One of these, La Graciosa, being the only inhabited one with a tiny population of 650. There is no source of water or made-up roads in La Graciosa.

Fig. 2. The Devil's Diner Restaurant grills its food by geothermal heat.

After a few thousand years of peace, came the eruptions of 1730 and 1824. These last eruptions were so fierce that many craters were formed on both sides of the fault line, so that today Lanzarote has a huge area of solid lava covering the soil, making the island impossible to farm. In fact, prior to 1736 there were many thriving farming communities who provided wheat and other grains to Fuerteventura.

Fig. 3. Black lava hills.

I was fascinated by the records of a Priest, Don Andres Lorenza Curbelo, who observed the eruptions from 1st September 1730 until they ceased in 1736, and documented them in his diary.

> *"Today, on the first of September 1730, between 9 and 10 pm, the earth tore open near Timanfaya, two leagues from here.*
>
> *A huge mountain formed in the first night already and flames shot out from the summit, burning for 19 further days. A few days later a new crater emerged and the lava flowed across Timanfaya, Rodeo and parts of Mancha Blanca [local villages]. The lava flowed towards the North, at first like gushing water, later viscous like honey. But on Sept 7th a huge rock rose out of the earth with an ominous rumble, forcing the lava to flow west and north-westward. There it destroyed Maretas and Santa Catalina."*

The village of Timanfaya was totally covered by lava and during the next six years, twelve other villages with 420 houses just disappeared. Some of the volcanoes are named after the villages but no trace of any community remains. Lanzarote became larger as the lava streams formed new coastlines in the north of the Island. Don Curbelo explains how the ground moved like the sea and the land surface broke like waves as massive volcanoes rose hundreds of feet into the air. A further twenty or so small hamlets also disappeared. He records the events over the whole period.

Fig. 4. A break in the lava crust.

Later, in 1824 a further three volcanoes appeared in the same area, with eruptions lasting for three months. They were much less severe than the previous century's eruptions.

The Timanfaya National Park was founded in 1974 and is the best existing volcanic landscape in Europe, second perhaps only to Hawaii. Lanzarote was designated a Biosphere Reserve by UNESCO in 1993 because of its importance to vulcanology.

Sand waves: Observations on their present-day environments and their presence in the geological record

by James Simpson

Abstract

Sand waves are identified specifically as those subaqueous bedforms which are of a distinctively asymmetrical triangular cross-section. They are formed in mainly unidirectional flow and travel downstream. Examples of the environments and locations where they are found, e.g. shallow seas, straits and large rivers, are drawn from the literature. The usually accepted method by which they grow and advance, once formed, is described.

Reference is made to simple small scale model experiments conducted by the author to investigate the hydraulic conditions at the inception and early stages of development of sand waves.

Observations of sand transport by both water and air in the course of a dredging and reclamation project are brought into play as they contribute to the understanding of sand waves. By singular good fortune, a length of sandstone outcrop supporting a dredge pipe at the same site was trimmed revealing cross-bedding indicative of sand waves.

The opportunity to observe miniature sand waves in streams crossing sandy beaches is discussed and photographs of examples included. Distinction is drawn between the unstable antidune which only exists while the flow is present and the true sand wave, which survives in the geological record.

Evidence of sand waves in local quarried sandstone forming a garden wall in Hastings is presented.

1.0 Introduction

The sand waves considered here are the subaqueous bedforms comprising regularly-spaced accumulations of sand, each of a distinctly low profile triangular section, the steeper face indicating both the direction of flow of the water in which they are forming and the direction of advance of the sand wave. Some researchers and authors have applied the term dune to this bedform. Sand wave is the accepted term in the literature.

2.0 The formation of the sand wave

The transport of sand under the action of flowing water has three phases:

i) On a plane bed at speeds sufficient to move particles, or at higher speeds as sheet flow of sand following the washout of the antidune described in ii) below.

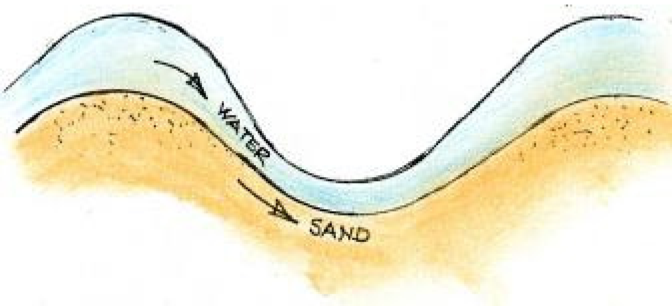
ii) Undulating flow of both water and sediment in unison as a standing wave with the special case of the antidune which breaks in the upstream direction (Fig. 1a, Photo no. 1). When the flow velocity falls such that it can no longer support the standing waves or ceases, this shape collapses leaving no trace of the shape, just a flat bed.

iii) The sand wave or dune which forms at a lower water speed than the standing waves and antidune and then only gradually as sand is moved up the gentle, stoss slope until it avalanches down the leading face leaving a permanent bedform (Fig. 1b, 2). If this is then covered by further sediment, it will remain in the geological record (Photo no. 2).

Photo no. 1. Antidunes breaking in flow of dredging run-off water - Abu Dhabi. Arrows indicate breaking antidunes.

FIG. 1. DISTINCTION BETWEEN SAND WAVE AND ANTIDUNE

DIRECTION OF FLOW →



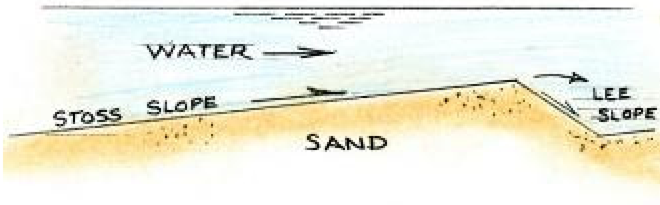


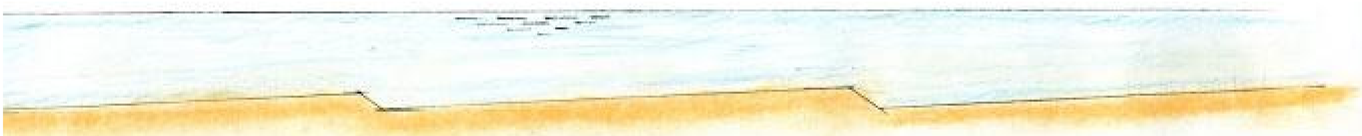
FIG. 1a. ***ANTIDUNE***

1. *BOTH SAND AND WATER FLOW*
2. *SINE WAVE SHAPE IS STATIONARY*
3. *WAVE SHAPE COLLAPSES WHEN FLOW SPEED DROPS OR FLOW CEASES*

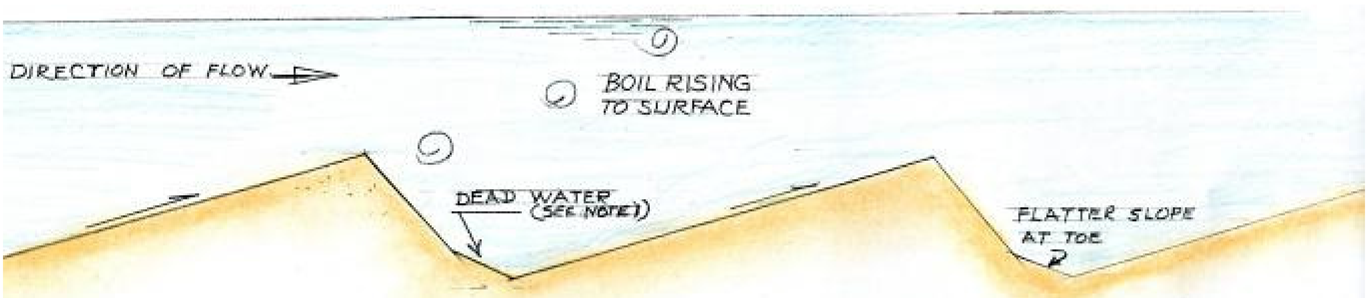
FIG. 1b. ***SAND WAVE***

1. *SAND TRAVELS UP STOSS SLOPE PROPORTIONS TO LEE SLOPE AND NEXT WAVE*
2. *BEDFORM REMAINS AFTER FLOW CEASES*
3. *→ INDICATES DIRECTION OF SURFACE SAND TRANSPORT*

FIG. 2. FORMATION of SAND WAVES and CREATION of CROSS-BEDDING INTERNALLY



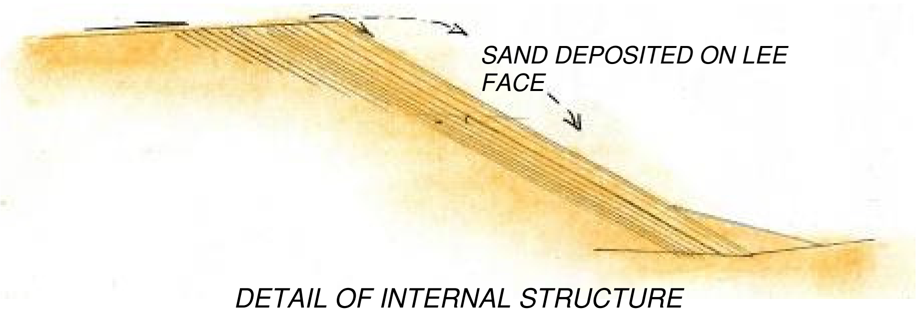
SAND WAVES TO NATURAL SCALE



SERIES OF SAND WAVES (EXAGGERATED VERTICAL SCALE)

NOTE 1. THE DEAD WATER AT TOE OF LEE SLOPE CONFIRMED BY USE OF POTASSIUM PERMANGANATE CRYSTALS IN SMALL CHANNEL EXPERIMENT

DIRECTION OF TRAVEL OF SAND WAVE →



DETAIL OF INTERNAL STRUCTURE

The regularly repeated avalanching of the sediment down the inclined leading face imparts the distinctive cross-bedding to the internal structure of the sand wave. Similar stratigraphy occurs in the leading edge of a delta or a point bar in a river.

Photo no. 2. Internal structure of sand waves in sandstone outcrop through sabkha - Abu Dhabi. (Coin equivalent in size to 50p)

3.0 The environments where large sand waves are found

Large sand waves are found in shallow seas usually where there is a large supply of sand and in large rivers, estuaries and tidal inlets. Where the supply of sand is limited the sand waves may form as discrete waves of the typical triangular shape, again as a series, but with a gap of hard bed between. A prerequisite of the locations is strong current flow at some time, in the region of one metre per second.

Some notable examples of locations, taken from the literature are:

The North Sea

a) Off the coast of Holland (J. Van Veen 1936). See Appendix A.

b) Off the east coast of the UK (Stride). Particularly noting the pattern of sand waves formed where the prevailing current flows onto and over sand bars. See also Appendix A (J. Van Veen, figs 29–30).

The Dover Strait (Admiralty 2010). See Appendix B.

The shelf-break of the English Channel at the Irish Sea end (Cartwright in discussion on paper by Pingree and Mardell in *Philosophical Transactions of the Royal Society, Series A*, 1981).

The Inland Sea of Japan (Ozasa 1974). Ozasa observed that sand waves occurred where currents impinge on banks or slopes.

The Golden Gate, San Francisco (Barnard among others).

River Mississippi (Various authors). Boils in the flow were noted at the water surface downstream of the sand wave. The boils are created at the sand wave face (see fig. 2).

Rio Parana, Argentina (Amsler and Garcia 1997).

USA, east coast tidal inlets, e.g. Chesapeake Bay (Ludwick).

Several UK estuaries where sand waves are exposed at low tide, e.g. Barmouth (Vaughan Cornish 1901).

Salcombe Estuary (Langhorne). This paper provides an historical record of the life of a sand wave in a tidal estuary over the spring and neap tides in the form of a series of longitudinal sections or profiles. Although the sand waves were ebb-dominated, i.e. maintaining the seaward facing shape, the crest was swept back and reduced in height on the flood.

Photo no. 3. Cross-bedding in stone in a garden wall in Hastings; likely evidence of a sand wave.

There is a long history of interest in this subject; Professor George Darwin, (the son of Charles), who, if not pursuing sand waves *per se* certainly conducted much illuminating work on the behaviour of sand in flowing water, and Professor Osborne Reynolds, discoverer of the law that identifies the change from tranquil to turbulent flow and regarded as the father of hydraulic modelling, found the location of sand waves in his scale model of the River Mersey (*circa* 1900).

4.0 Sand waves in the Geological Record

4.1 Distinction between sand waves and desert dunes

Sand waves identified in rock strata by their distinctive cross-bedding would have been formed under the same environment that we see today, i.e. in shallow seas or in rivers. Hydraulics of tidal flow would have been the same as today although the conditions would have differed.

Interestingly, in the case of Aeolian dunes it is possible that higher wind speeds than today would have been experienced in earlier epochs due to winds being confined to a narrower band of the earth by more extensive ice caps, resulting in larger dunes than could be raised in post-glacial times.

The record shown in photo no. 2 is of a sandstone outcrop through coastal sabkah where, to support a dredging discharge pipe, the rock was trimmed to a vertical face by machine, yielding a freshly exposed clear view of the internal structure. The author's immediate assumption was that these were fluvial sand waves of marine origin.

A section cut through a modern Aeolian dune for sand winning for beach replenishment, when compared with photo no. 2, showed major differences, firstly in the desert dune being considerably higher, secondly in having finer texture than water deposited structure. Finally, comparison with sections of sand waves in the literature lent confidence to the conclusion that these were fluvial, most probably marine sand waves.

4.2 Local Examples

The magnificent rock faces on West Hill, Hastings, included small areas where there may have been flow. However, the author failed to discover evidence of cross-bedding. This failure applies to many small outcrops seen in the country park and may be due to their being concealed by surface weathering.

Fortunately, cross-bedding was noticed in local stones used in a boundary wall (Photo no. 3). It is possible that these stones came from a nearby quarry, although this quarry has now been built over.

5.0 Some simple model experiments carried out by the author to observe the conditions for forming sand waves

The first experiment was in a small narrow flume in which the water was introduced by hose from the tap. Fine sand was scattered on the floor of the flume before the flow started. Once flow had commenced, a series of small sand waves formed on the floor of the flume and advanced slowly down-stream. Although it might be conjectured that the length of the flume between the two end walls influenced the wavelength of the sand waves, the effect of the width of the flume could not be dismissed.

The second series of experiments comprised a flume of rectangular cross-section. Water flowed in the flume between a header and a tail tank. Water was continuously pumped around the system, the header tank ensuring a reasonably placid commencement of flow in the channel (Photo no. 4), i.e. that no pulse was imparted to the flow in the channel.

Photo no. 4. Sand waves forming at upstream end of model flume. Red arrows point to accumulations of potassium per-manganate crystals, indicating dead water at toe of lee slope.

The use of potassium permanganate crystals was a useful adjunct in that it showed up the almost instantaneous formation of very low bars across the width of the channel (a similar use of potassium permanganate to identify areas of "trapped water" is arrowed in photo no. 4), which might otherwise have been missed.

Photo no. 5. Swinging flume experiment.

The third experiment was conducted by the author in a large flume at Southampton University. In order to avoid the labour of having large volumes of sand in the flume only a thin layer was scattered on the floor. This was rapidly formed by the flow into a series of zig-zag lines transverse to the flow. It was noticeable that when the pumps started the circulating flow there was a surge at the head of the flume. Hence it might be wrong to ascribe the formation of the transverse bars (i.e. sand waves) to the subsequent steady flow in the channel.

A fourth experiment was a swinging flume (Photo no. 5). A distinction has to be made here that the water is not flowing unidirectionally as in a stream or sea current but back and forth as part of a standing wave.

An adjunct to this experiment was to couple alongside the first flume and on the same centreline, a second flume of the same cross-section and water depth but differing from the first in being of half the length of the first flume. Thus both flumes experienced the same agitation or input of energy. The result was the same number and pattern of sand waves in each flume but within the half length in the smaller flume.

6.0 Field observations of sand wave related phenomena

Being engaged on dredging and reclamation projects in Abu Dhabi afforded the author the opportunity to observe sand waves (if in only two cases were these seen directly), together with several related sand transport phenomena, which might help to shed some light on the nature of sand waves themselves:

a) The leading or down-wind face of a deposit of sand (Photo no. 6a) has the same appearance as the lee face of both a dune and a sand wave. The avalanching of the sand on the lee face which stands at the angle of internal friction can be seen on photo no. 6b.

Photo no. 6a. Artificial dune forming at roadside, advancing over road - Abu Dhabi.

Photo no. 6b. Lee face of artificial dune at roadside showing avalanching of sand on advancing face - Abu Dhabi.

b) A channel for the return of dredging run-off water to the sea, when drained down on dredging ceasing, exposed a series of sand waves on the channel floor (Photo no. 7). When the channel was in full flow it had been noticed that boils appeared at the surface, leading to the expectation that sand waves existed on the bed (see fig. 2).

Photo no. 7. Sand waves formed by flow on bed of dredging water return channel (photographed after drawdown of the water) - Abu Dhabi. Flow was towards viewer.

Photo no. 8 shows a stream formed by dredging run-off water on a freshly-formed hydraulically placed reclamation in Abu Dhabi. The stream is about one to two metres wide. Already a variety of bedforms, including some of sand wave shape completely cover the bed of the stream. Although this provides a useful illustration of the beds of large present-day sandy rivers, it does not give an accurate representation of the mature river.

In clear shallow water over a sand bank offshore of Abu Dhabi, sand waves could be seen climbing the seaward face and over the crown of the sand bank. These exist on sand banks in the North Sea (Stride) but require the use of side-scan sonar to be seen.

Where there were small depressions (for tree planting) in a sandy reclamation surface, small dunes formed on the floor of the depression. This suggested that the wind blowing over the depression may have set up a resonance in the air within the depression, i.e. a standing wave. This in turn could explain the sand waves within the depression. It might be expected that the same effect could apply underwater.

On aerial progress photographs of port construction in Thailand a series of lines on the foreshore of an adjacent bay, which followed the curvature of the bay shoreline, suggested that these might be sand waves. On surveying these on a Spring low tide, they indeed proved to be sand waves, if of a very flat profile.

7.0 Miniature sand waves on any local beach

Whereas the opportunity to study the behaviour of sand waves *in situ* or in a laboratory is available to only a few, much can be learned at first hand about the behaviour of sand waves from observation of them in streams flowing seaward across sandy portions of beaches between high and low tides. They are also to be seen in the shallow channels in the beach that run parallel to the shoreline before turning seaward to discharge.

Photo no. 9 shows a series of undulations in a small stream flowing across a sandy foreshore at Fairlight, near Hastings. These appear to be antidunes, i.e. the sand is streaming through the wave form and the sinusoidal wave shape is moving slowly upstream (because sand transport is greater on the downstream face), hence the term antidune. When the water speed increases, the wave breaks, again facing upstream. The situation affords the opportunity to experiment by, for example, disturbing the series of waves and seeing if they reform, or to cut off or reduce the flow and observe the effect on the series of waves.

The two sand waves in Photo no. 10 were observed on a geological field trip to Beachy Head, near Eastbourne. Although there are only two waves, they are excellent examples being identical and filling the plan space available, which is constrained by the sharp bend to the left in the stream. It must be said that longer series of sand waves are the norm.

8.0 Speculation as to why sand waves occur in a repeating series

There are many examples in nature of periodic phenomena: cirrus clouds; water waves raised by wind; internal waves at the interface between two layers of differing density in a liquid moving relative to one

Photo no. 9. Standing waves (or antidunes) in small stream on beach - Cliff End, Hastings. Dog paw print for scale. Arrow indicates direction of flow.

Photo no. 10. Two sand waves in small stream on beach - near Beachy Head, Eastbourne. Arrow indicates direction of flow.

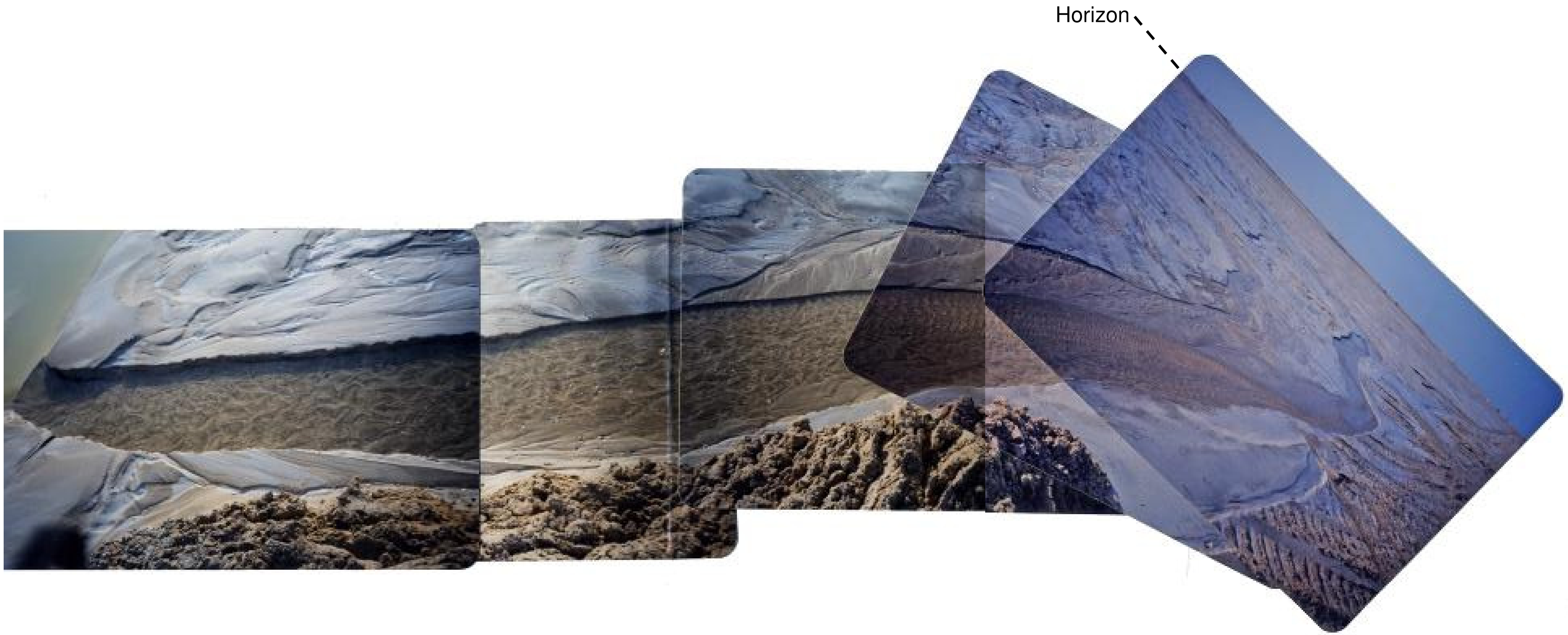


Photo no. 8. Stream of dredging run-off water on freshly formed reclamation - Abu Dhabi. Stream is around 1 to 2 metres wide in foreground. Flow was towards viewer.

another; roll waves in a sheet of water flowing down a steep paved street in a heavy downpour. Sand waves seem to be another periodic phenomenon.

One explanation for the formation of the sand wave, put forward in the literature, is that the saltation or leaping action of the sand particles of the mode, or most common size, land at much the same location and hence build a heap which gradually assumes the sand wave shape. This could only apply to the creation of the sand wave. However, a feature in the flow, such as a reef or rock, could start a sand wave as the particles ejected into the flow by the obstruction could repeat the process.

Another explanation is that some form of standing wave occurs in the flow. The original demonstration that the production of a musical note in a wind instrument is the result of a standing wave, was made by showing that fine powder spread in the sound tube rearranged itself in regularly-spaced heaps at the nodes of the sound waves. The similarity with the regularly-spaced deposits of sand on the floor of the large flume experiment described in section 5 above seems compelling evidence of a standing wave being a cause there also, but is not proof.

The simple experiments described in section 5 above point to this possibility. However, they share the detraction that they take place in a container which may control the dimension of the standing wave in the flow and thus cannot at first sight provide an explanation for the formation of sand waves in open water as in the North Sea.

The difficulty in explaining the wavelengths found in present-day sand wave fields in terms of the prevailing hydraulic conditions is the fact that they have developed over thousands of years and have been influenced by extreme events.

9.0 Concluding remarks

A knowledge of the formation and movement of sand waves is of practical importance in maritime civil engineering (a) in the location and burial of pipelines, and (b) in assessing and maintaining the navigability of shallow seas and of major rivers, e.g. the Rio Parana and the Mississippi.

Such knowledge may also prove useful to the space scientist in detecting former watercourses on planets, say Mars, or differentiating between Aeolian or wind-blown dunes and previously subaqueous sand waves.

To the geologist, the cross-bedding as provided by sand waves as an indicator of palaeo-currents has been an indispensible tool in mapping the geology of an area, particularly of the United States.

Appendix A

The following is taken from J. Van Veen's chapter on Coastal Engineering in Comrie (1961).

> *"In tidal streams, where silting and scouring change even during the tide, we should not lose ourselves in too much detail. The graph of sand content in a scouring river is markedly different from the graph of a silting one.*
> *A sand-laden stream will not pick up more sand than it can carry. This is the reason why bars will not scour. A stream not carrying sand* e.g. *a stream coming through a weir or barrage, is able to pick up its full load. Scour may therefore take place downstream of a patch of rocky bottom, thus originating a sand stream. Narrows (*e.g. *the Straits of Dover) show such a clean rocky bottom with no sand movement above it. Its huge stream is undercharged.*
> *Nevertheless in such regions there may be long and high sand banks lying on the hard bottom in the general direction of the ebb and flood currents. Because they offer little resistance to these currents they have remained in their places during the past centuries. They resemble the desert formation called Libyan dunes,* Figures 29, 30.

Figure 29. Cross section of 'Libyan dune'

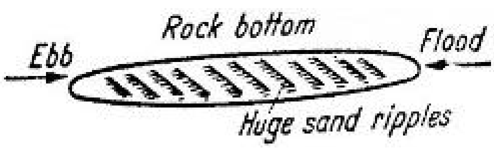


Figure 30. Top view of 'Libyan dune'

*When the sand grains are the right size and the currents have the right velocity a sand bottom will produce huge bed dunes, perpendicular to the general current direction. These submerged dunes may be 20, 30 or even 60 ft (6 m to 18 m) high in the southern North Sea and about 3 ft (1 m) in a river of say 15 ft (4.5 m) depth. Generally the height is about 20 per cent of the free depth. The form of these huge ripples depends on the supremacy of either the ebb or the flood. They give an indication in which direction the sand is moving (*Figure 31*). Regular bed dunes can only occur where much sand is available and do not occur when rock, or a clay bottom, is partly exposed to the currents.*

Where only a small quantity of sand is lying upon a rock or clay bottom this sand collects into 'barchan' dunes where the current is continuous in one direction, and into long sand banks, resembling Libyan sand dunes, where there are alternating currents."

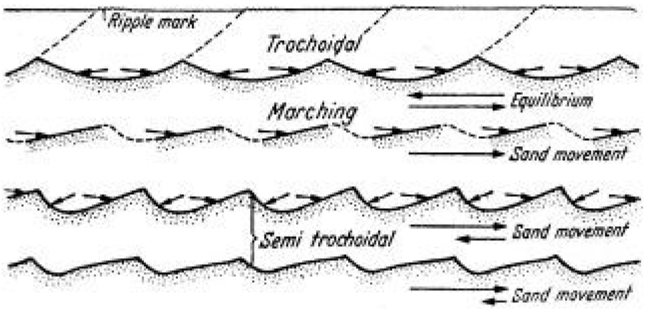


Figure 31. Types of bed dunes (ripples)

Reference

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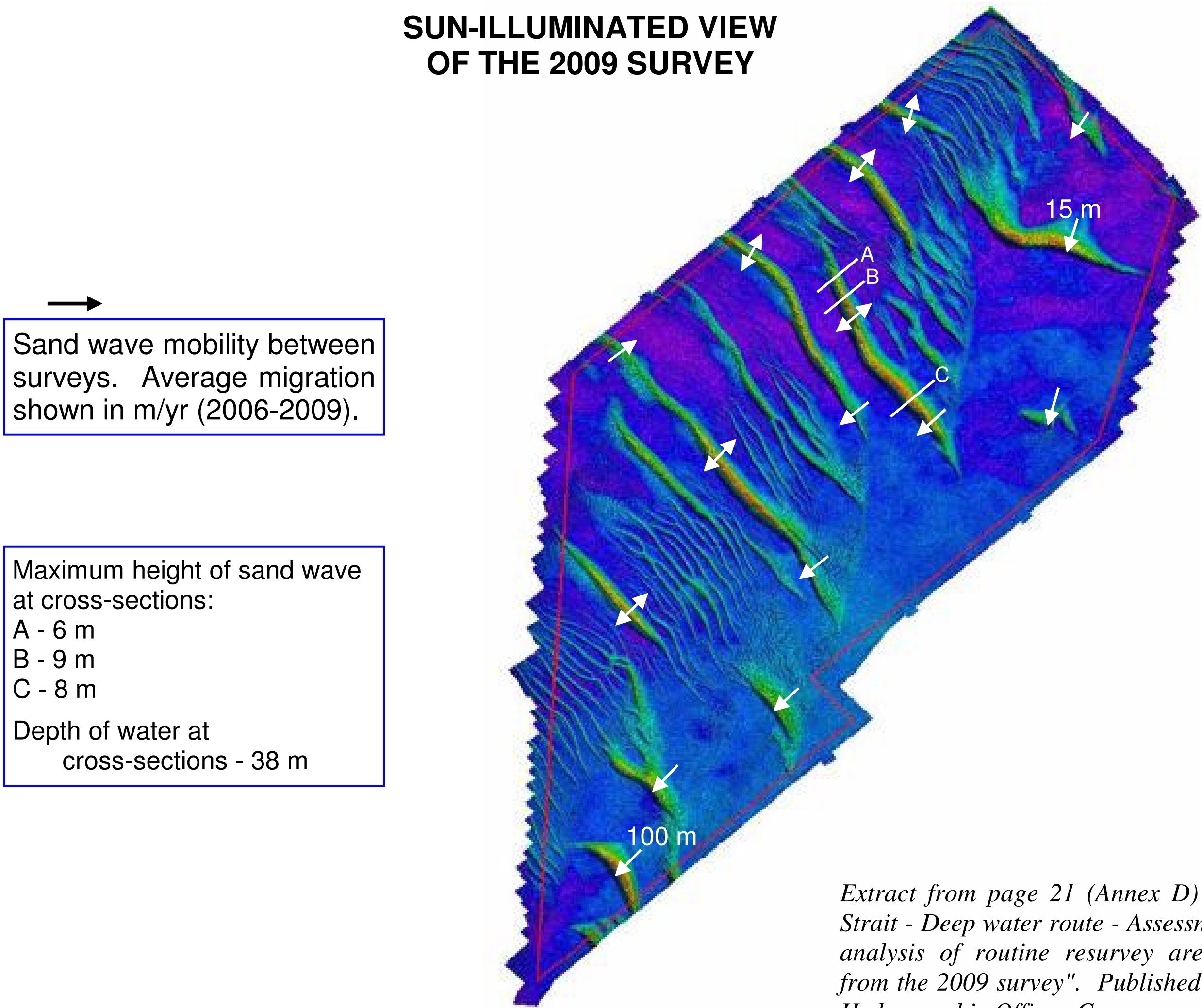
Appendix B

Extract from Admiralty report on navigation depths in Dover Strait. Available on the internet at:
http://www.ukho.gov.uk/AboutUs/Documents/2009/DWRT Deep Water Route.pdf

This shows a plan of an area of sand waves in Dover Strait, studied in the report.



Extract from page 21 (Annex D) of "Dover Strait - Deep water route - Assessment on the analysis of routine resurvey area DWR T from the 2009 survey". Published by the UK Hydrographic Office. Crown copyright.

On the first usage of 'Plate Tectonics'

by Anthony Brook

In the last issue of the HOGG (History of Geology Group) Newsletter (No.42, June 2011, p.18) I requested assistance in identifying the proponent(s) of the all-powerful paradigm of Plate Tectonics in the 1960s, and also who first used the two technical terms Plate and Tectonics, in association, as a shorthand description of this innovative idea. So far I have had more success with the latter than the former, and wish to report that its debut seems to have been belated, accidental and incidental. It was used for the first time quite some after the event, so to speak, when Earth Scientists were searching for a succinct phrase to encapsulate what had been so elegantly elaborated. The term Tectonics had been prefixed by 'raft', 'continental' and 'global' by various authors, but none captured the scientific and public imagination quite like Plate Tectonics.

In 2001 Naomi Oreskes edited a collection of essays entitled Plate Tectonics: An Insider's History of the Modern Theory of the Earth which is exactly what it says on the front cover: 17 original essays by the scientists who made Earth History. One of those essays was by Dan McKenzie, who was in the Department of Geodesy and Geophysics at Cambridge University at the time, and in this essay he wrote (p.184): "*Who invented the term Plate Tectonics itself is unclear. Several people tried to coin a term, partly (it must be said) with aim of being able to say that they discovered the theory. None of these proposals stuck. One of the earliest uses of the term that I know of was by Jason [Morgan] and myself in our paper on the evolution of triple junctions [in NATURE] in 1969. But I certainly would claim only to have written down a term by which the theory was, by then, widely known.*"

The paper by Dan McKenzie and Jason Morgan on 'The Evolution of Triple Junctions' in NATURE (11 October 1969) begins, on p.125, thus: '*A precise version of the hypothesis of seafloor spreading has recently been presented. This new formulation requires that all the aseismic areas of the Earth's surface move as rigid spherical caps, and, for this reason, it is often called "plate tectonics".*' Note the use of inverted commas, indicating first usage: a geological neologism.

But – and there is always a 'but' – the entry in the multivolume Oxford English Dictionary (2nd Ed. 1989, Vol. XI) for plate tectonics, which is buried in the small print on p.998, suggests otherwise. It reads: 1969 Scientific Journal Aug., 40/2 "*Plate tectonics….has shown its ability to predict, amongst other things, the direction of movement accompanying earthquakes.*" That is a couple of months prior to McKenzie and Morgan, and therefore takes precedence.

However, thanks to the tireless effort of Jane Dore, Information Librarian at Worthing Reference Library, it has proved possible to push the priority several months further back in time. In the article by James Schopf entitled 'Ellsworth Mountains: Position in West Antarctica due to Sea-Floor Spreading', published in Science on 4 April 1969 (Vol. 164, 63-66), there occurs the following sentence, on page 64/3: "*If one…considers continental drift in the light of plate tectonics, displacement of the Ellsworth Mountains can readily be explained.*" It would thus appear that James Schopf takes the publication honour, in April 1969.

So, first usage of the term Plate Tectonics seems to have taken place in early April 1969, which is surprisingly late, but it caught on like wildfire – unless, of course, you can improve upon the priority.

Update on '*Wealden News*'

by Peter Austen

It is hoped that the next issue of Wealden News (Issue No.9) should be available sometime during 2012. Back copies of *Wealden News* are available at http://www.kentrigs.org.uk/wealden.html.

Wealden fish

Based on a talk given by Peter Forey (Natural History Museum)

Edited by Peter and Joyce Austen

The following is based on a talk given by Peter Forey (NHM) to the Horsham Geological Field Club (14th July 2010) and the Brighton & Hove Geological Society (2nd February 2011). Additional information, photographs and references have been added where relevant. The species names used for the sharks are those familiar to most collectors, although a number of changes have been made to these over recent years (e.g. Rees and Underwood 2002), and work is still ongoing.

Introduction

The early Cretaceous was a time when the continents were separating from each other, and the Tethyan Ocean was forming. At the start of the Cretaceous, during the Wealden period (125–142 million years ago), England lay at the northern limit of the Tethyan Ocean, about 30 to 35 degrees north of the equator, and was thought to have a sub-tropical climate, considerably warmer than today.

The Weald today in southern England is bounded to the north and south by the chalk of the North and South Downs respectively, and is made up of clays, sandstones and ironstones of the Hastings Beds (comprising the Ashdown, Wadhurst and Tunbridge Wells formations) and the overlying Weald Clay (Fig. 1). The Wealden succession comprises 800 m of lacustrine and deltaic deposits, stretching from the top of the Berriasian through to the Barremian, bounded below and above by marine beds. Most of the rocks that make up the Wealden were formed by erosion of the upstanding land to the north of the Weald which was being eroded into the Weald Basin. There was another basin a little further to the west, the Wessex Basin, which was receiving deposits from the erosion of similar age rocks, primarily from the west and the south-west. Although the type Wealden is restricted to Sussex, Surrey and Kent, the Wessex Basin on the Isle of Wight is also regarded as Wealden, and is equivalent to the upper parts of the Weald Clay (Fig. 1), the fishes there being very similar to those found in the Weald Basin.

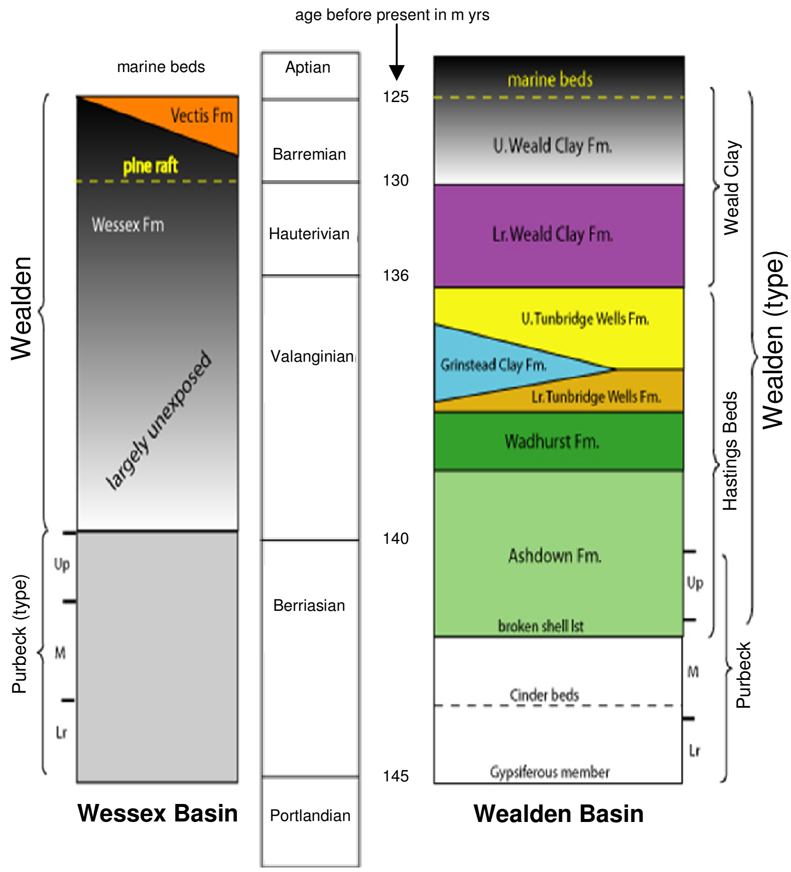


Fig. 1. Stratigraphical column showing the type Wealden (right), and comparable deposits in the Wessex Basin of the Isle of Wight (left).

Fossil material

Figure 2 shows the type of fish material (teeth and vertebrae) that can normally be found in the Weald, either from bone beds, or from certain Wealden sediments (e.g. plant debris beds). The material was obtained by drying, washing and sieving sediments, possibly from the Hastings Beds, to obtain the residue of fish teeth and vertebrae shown. It illustrates the difficulty in identifying this type of isolated material, particularly if there are no complete fossil fish with which to make comparisons. Complete fish are occasionally found in the Weald, but they are rare. This lack of complete specimens also causes problems when naming species, and the situation has arisen where several isolated parts of a single species have each been given their own species name. The aim of this article is to provide sufficient descriptive information to enable a general identification of most of the fossils in this photograph.

Fig. 2. A collection of teeth and vertebrae from Wealden fish. (Photo: David Ward)

Cartilaginous fish (sharks)

Hybodus

Hybodont sharks were typical Mesozoic sharks, slightly different to the sharks that are alive today. *Hybodus* was common throughout the Jurassic and Lower Cretaceous up to the start of the Chalk of the Upper Cretaceous. Although most of the fossil fish material found in the Wealden are teeth, vertebrae and fragments of bone, near-complete specimens of the shark *Hybodus* can be found. Historically, such specimens of *Hybodus basanus* were collected from Cooden Beach, Bexhill, and Pevensey, both in East Sussex, and they can still be found today. John Evans, an HDGS member who specializes in Wealden sharks, has collected around 100 specimens from Cooden (Evans 1999), most of which have been donated to the Natural History Museum, London. They are normally encased in ironstone nodules and can be up to 2 metres long, and being ironstone, it is extremely difficult to prepare the fossils out of these nodules.

It is, however, much more usual to find the isolated teeth, and fin and head (cephalic) spines of *Hybodus* (Fig. 3). A fin spine (Fig. 3A) supported the leading edge of each of the two dorsal fins (top two fins in figure 3B). These spines are not common in modern-day sharks; probably less than five of the 350 or so known species have them, but it is a characteristic feature of Mesozoic sharks. Apart from defence, the two fin spines may also have formed a cutwater to cleave through the water, making the shark more streamlined. Most of the fin spine is embedded within the trunk of the fish, with a smaller portion exposed (Fig. 3A). The males of *Hybodus* have two small head spines just above their eyes, and these can often be found isolated (Fig. 3C–D). The head spines are shaped like small anchors, and figure 3 shows views of the head spine from above (Fig. 3C) and from the side (Fig. 3D). These head spines are unique to male sharks, which are distinct from the females in having very long claspers (not illustrated) on the pelvic fin (lower second left fin in figure 3B) that are used as an intromittent organ to facilitate the fertilization of the females. Complete specimens have been found that reveal both the head spines and the pelvic claspers. Scales of *Hybodus* (Fig. 3E–F) can also be found, although they are very small, and realistically can only be recognized using a microscope; the photographs in figures 3E–F were taken using a scanning electron microscope. The scales are made of enamel and dentine, similar to teeth, with thousands covering the shark's

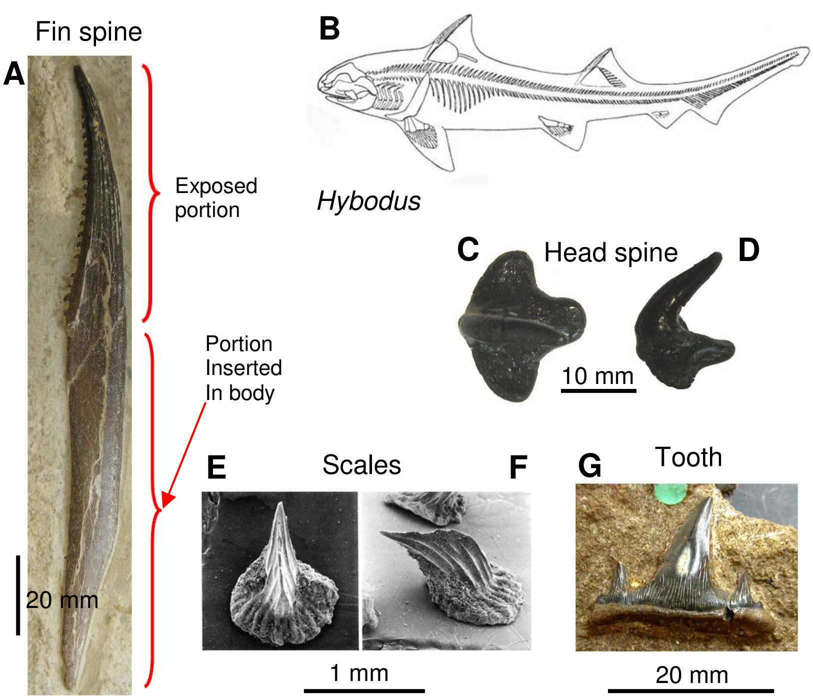


Fig. 3. A–G. Hybodus. *A, fin spine, showing both exposed and internal portions. B, skeletal reconstruction of* Hybodus. *C–D, head spine (cephalic spine). C, from above. D, side view. E–F, scales (from Maisey 1983, p.55, fig.23A–B). G, tooth.*

body. The scales are fluted, with the fluting varying in shape over the body of the shark; this fluting allows for the smooth flow of water over the shark's body, thus reducing turbulence as it moves through the water, similar to present-day sharks. The most commonly found shark fossils are teeth (Fig. 3G). Figure 3G shows an *Hybodus* tooth, which has a large central cusp with a smaller cusp on either side, together with the root at the base of the tooth. Shark skeletons are made of cartilage or gristle, rather than bone, so the actual skeletons only preserve under exceptional circumstances.

Shark dentition

Present-day shark jaw

Figure 4 shows the lower jaw of a present-day sand tiger shark, *Odontaspis taurus*. There is a single row of functional biting teeth on the outside of the jaw, but there are also teeth inside the jaw which are the young growing teeth; these new teeth move outwards to replace the outer biting teeth as they are lost, either being ripped out when struggling with prey or just falling out. As the teeth grow they move out towards the edge of the jaw and when they reach the edge, if not already lost, the old tooth falls out. This means that a shark will shed many hundreds of teeth in its lifetime, and because they're so hard they preserve very easily; it also means of course that finding a shark's tooth is not an indication of where the shark died. There are also tremendous variations in the shapes of the teeth in any one jaw. The complete sand tiger shark jaw in figure 4 illustrates the variation in tooth shape in just one species. The functional biting teeth vary from being tall and slender at the front of the jaw to being short and squat at the back, with varying degrees of difference along the length of the jaw. Also the younger growing teeth are a different shape to the older functional biting teeth. If these teeth were to be found isolated in the sediment, it is likely that they would be regarded as completely different species. This is one of the problems with fossil shark taxonomy; many species of shark are erected on different types of teeth, but the different sharks teeth could possibly come from different places in the jaw of a single species of shark, so it is likely there are less species of shark than there are species of sharks teeth. The ideal solution is to find an articulated fossil shark which has all its teeth in place so that the variation can be seen.

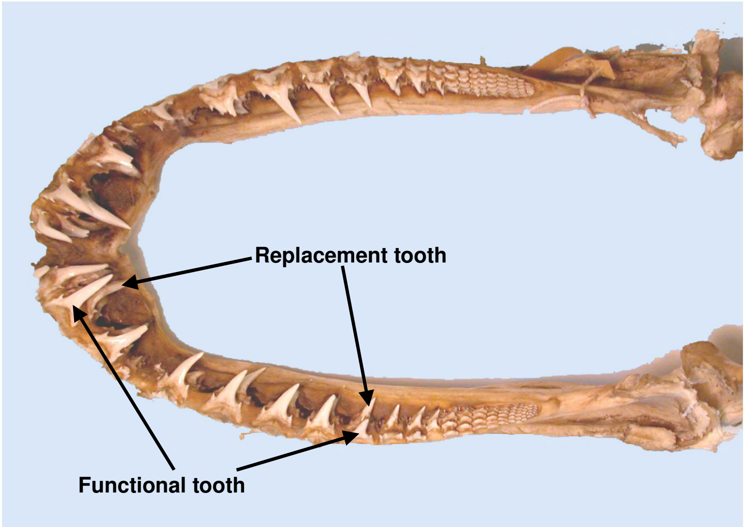


Fig. 4. Lower jaw of the present-day sand tiger shark, Odontaspis taurus*, showing the variation in teeth in any one jaw.*

Hybodus jaws and teeth

Hybodus basanus and *Hybodus brevicostatus* are the two species of Wealden shark where complete jaws and dentition have been found, most of which were collected from the Weald Clay in the former Henfield Brickworks, West Sussex, which closed in the 1960s (Young and Lake 1988, pp. 22–23).

Figure 5 is an example of complete dentition from *Hybodus basanus*, showing both an upper (Fig. 5A) and lower jaw (Fig. 5B and enlargement Fig. 5C). These photographs show the same situation as in the

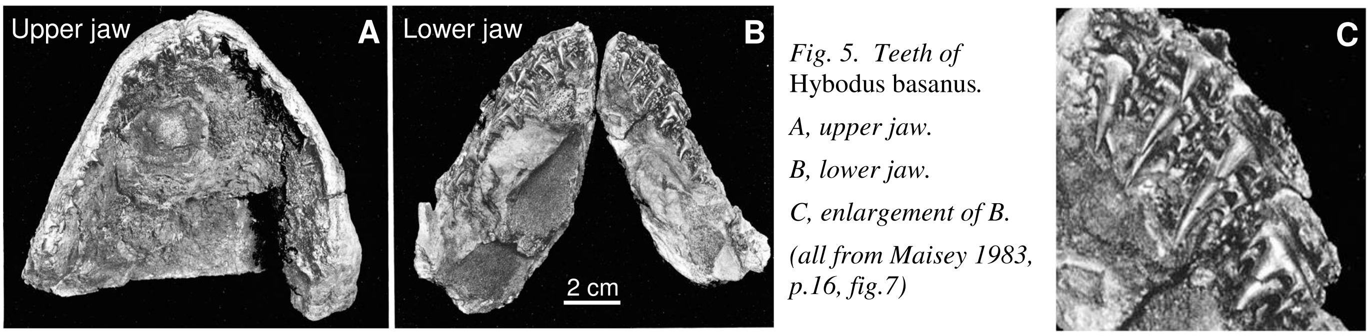


Fig. 5. Teeth of Hybodus basanus.

A, upper jaw.

B, lower jaw.

C, enlargement of B.

(all from Maisey 1983, p.16, fig.7)

sand tiger shark (Fig. 4), with rows of young growing teeth moving from the inside of the jaw out to the edge to form the functional biting teeth, thus allowing the association of several different types of teeth with one individual.

The reconstruction in figure 6A has been prepared from the rows of upper and lower functional biting teeth seen in the articulated specimen in figure 5, and can now be compared with known species (Fig. 6B–D). *Hybodus basanus* (Fig. 6B) comes from the front (symphysis) of the mouth; *Hybodus ensis* (Fig. 6C) is slightly further back and is squatter and longer, with striations running up from the base of the tooth; *Hybodus parvidens* (Fig. 6D) is towards the rear of the mouth and is much smaller and squatter. This shows that these three species of teeth actually belong to one species of shark.

Articulated *Hybodus basanus* dentition

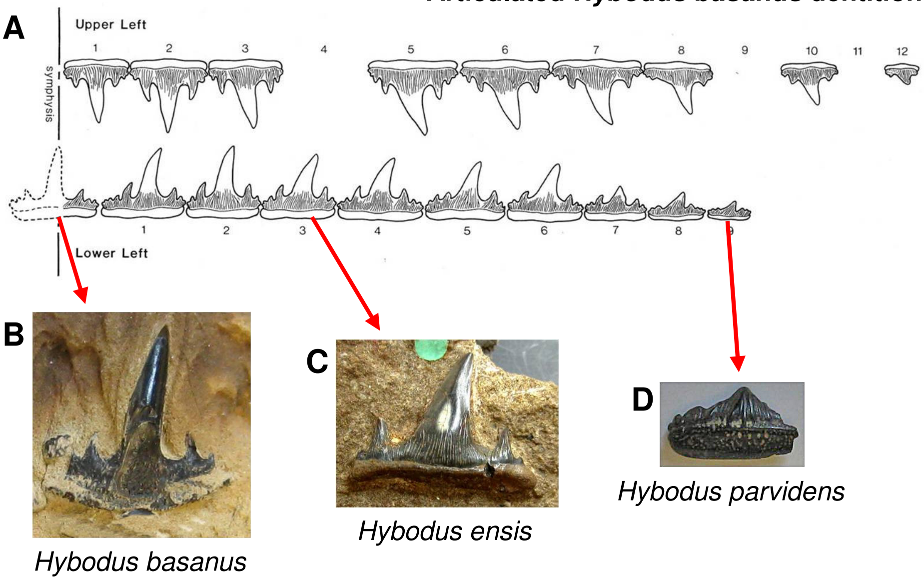


Fig. 6. A, reconstruction of articulated Hybodus basanus *dentition seen in the specimen in figure 5 (from Maisey 1983, p.49, fig.18).*

B–D, different species of teeth found in the jaw of Hybodus basanus.

B, Hybodus basanus.

C, Hybodus ensis.

The other shark for which we have complete dentition is *Hybodus brevicostatus* (Fig. 7). This shark's teeth differ from *Hybodus basanus* in having much lower crowns, with accessory cusps either side.

Articulated *Hybodus brevicostatus* dentition

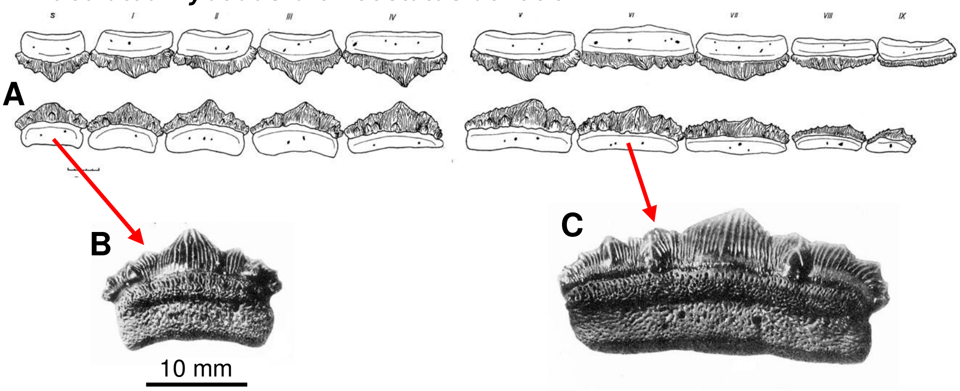


Fig. 7. A, reconstruction of Hybodus brevicostatus *dentition from specimens found in the Weald Clay of Henfield, West Sussex (from Patterson 1966, p.302–303, fig.10). B–C, two of the teeth of* Hybodus brevicostatus, *illustrating differences across the jaw.*

Lonchidion

Another type of shark found in the Weald is *Lonchidion* (Fig. 8). *Lonchidion* is thought to have been a small shark, no more than about a metre long, which had very small teeth with a protrusion on the outside of each tooth allowing them to fit together in a pavement-like way (Fig. 8D). Figure 8D gives an occlusal view (from above) of this pavement-like structure, and it is likely these would have been crushing rather than biting teeth. *Lonchidion* is known from two species, *Lonchidion breve* (Fig. 8A) and *Lonchidion striatum* (Fig. 8B); the latter having ridges over the surface of the tooth. A third species of tooth has been described, *Lonchidion rhizion* (Fig. 8C), but it is now thought that these may in fact be scales (Fig. 8C) as no specimens have been found with a root.

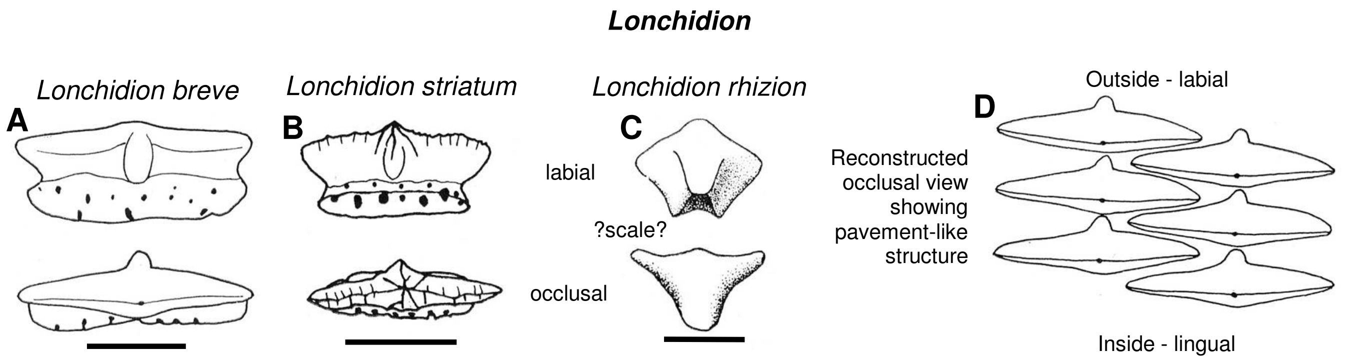


Fig. 8. Teeth of Lonchidion. *A,* Lonchidion breve. *B,* Lonchidion striatum. *C,* Lonchidion rhizion. *D, reconstructed occlusal view of* Lonchidion breve *showing pavement-like structure. (all from Patterson 1966; A, p.313, fig.14; B, p.321, fig.22; C, p.322, fig.23; D, p.319, fig.20) (scale bars 1 mm.)*

Other remains thought to be associated with *Lonchidion* are fin spines (Fig. 9A), which differ from *Hybodus* spines in that they are much smaller, not curved, and have different tooth-like protuberances at the back. There are also head (cephalic) spines (Fig. 9B), which are much smaller and more slender than *Hybodus* head spines.

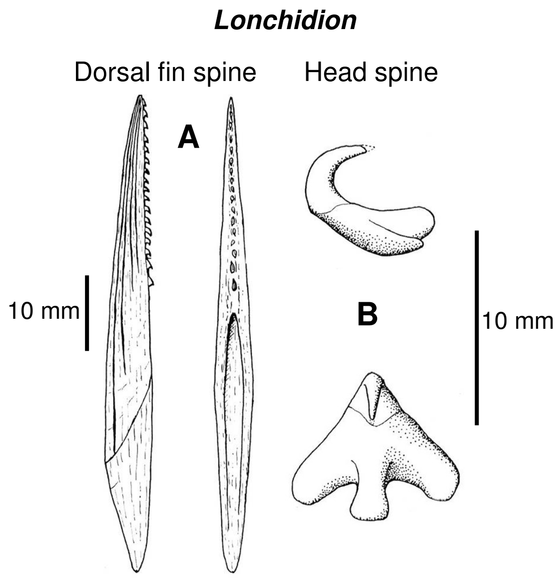


Fig. 9. Lonchidion. *A, dorsal fin spine. B, head spine (cephalic spine). (from Patterson 1966, p.328, fig.26)*

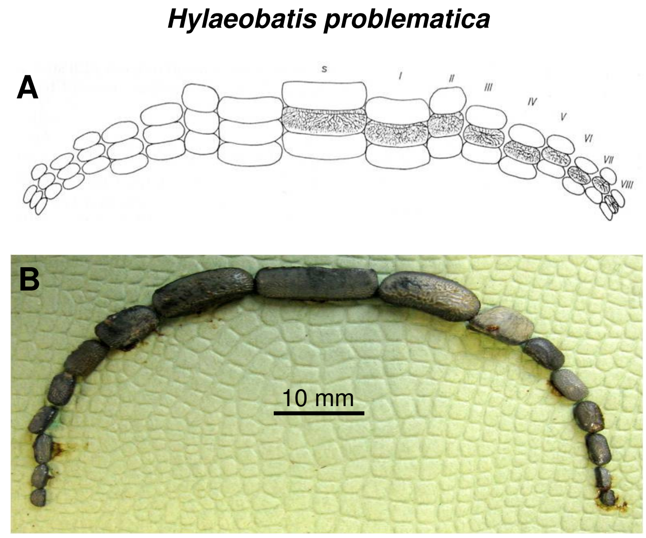


Fig. 10. A, reconstruction of Hylaeobatis problematica *dentition based on specimens from the Weald Clay of Henfield, West Sussex (from Patterson 1966, p.334, fig.28). B, actual specimens from the Weald Clay of Henfield, West Sussex (NHMUK P.47229).*

Hylaeobatis problematica

Another Wealden shark is *Hylaeobatis problematica*, which has flat teeth, rather like granite setts (Fig. 10). Figure 10B shows an associated dentition found in the Weald Clay, again at Henfield; figure 10A gives a possible reconstruction of the dentition. *Hylaeobatis* probably used its flat teeth for crushing molluscs and other invertebrates, equivalent to today's skates or rays. The teeth are quite distinctive, having a rounded and wrinkled surface.

Shark egg cases – "*Spirangium*"

Other remains that can be associated with sharks are shark egg cases, known as "*Spirangium*" (Fig. 11). These are quite rare in the Weald and figure 11A shows a specimen found at Smokejacks Brickworks, Surrey, in 1997; it displays a distinctive spiral structure (Fig. 11A). Originally, these were thought to be the seeds of plants, and early restorations showed them hanging as fruits from trees; the name "*Spirangium*" being derived from 'spiral', referring to its structure, and 'angium', a botanical term for a female fruit. Eventually, they were found in association with sharks and it was realized that they were the egg cases of freshwater sharks (Fig. 11A). Modern day equivalents are 'mermaid's purses' which

A

B

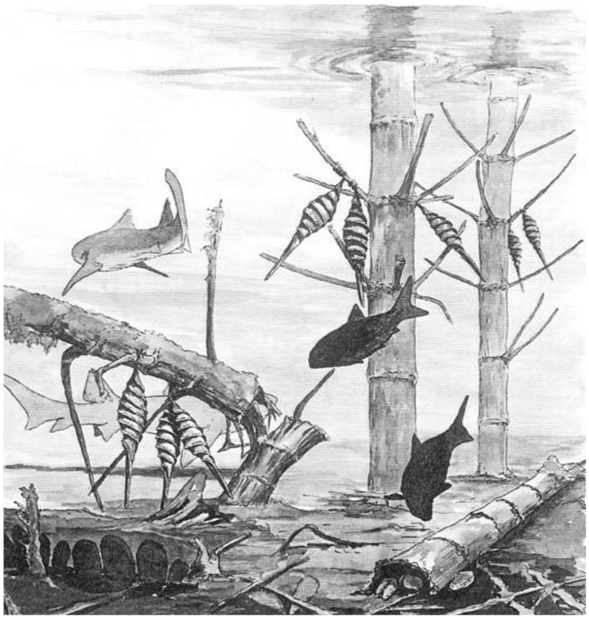


Fig. 11.

A, freshwater shark egg case "Spirangium"*, found in the Upper Weald Clay at Smokejacks Brickworks, Surrey, by Peter Austen in 1997 (NHM entry no. OE-PAL-2010-40 & 41) (scale in cm.) (photo: Peter Austen).*

B, reconstruction showing how the shark egg cases would have been attached to underwater vegetation (from Fischer and Kogan 2008)

are the egg cases of dogfish (a form of shark), and can sometimes be found loose on the beach/foreshore; these would have contained the dogfish embryo. The reconstruction in figure 11B is from a paper describing deposits in Russia where numerous fossil shark egg cases have been found. Early Cretaceous shark egg cases are rare, and there are very few deposits in the world where they occur.

Bony fish

Evolutionary history of the bony fish

Bony fish today are extremely diverse and numerous, and include species such as carp, herring, perch, pike, and almost any fish that we eat that is not a shark. There are three kinds of bony fish – the palaeoniscids, the Holostei and the Teleostei – and the Lower Cretaceous was a particularly interesting time in their evolution.

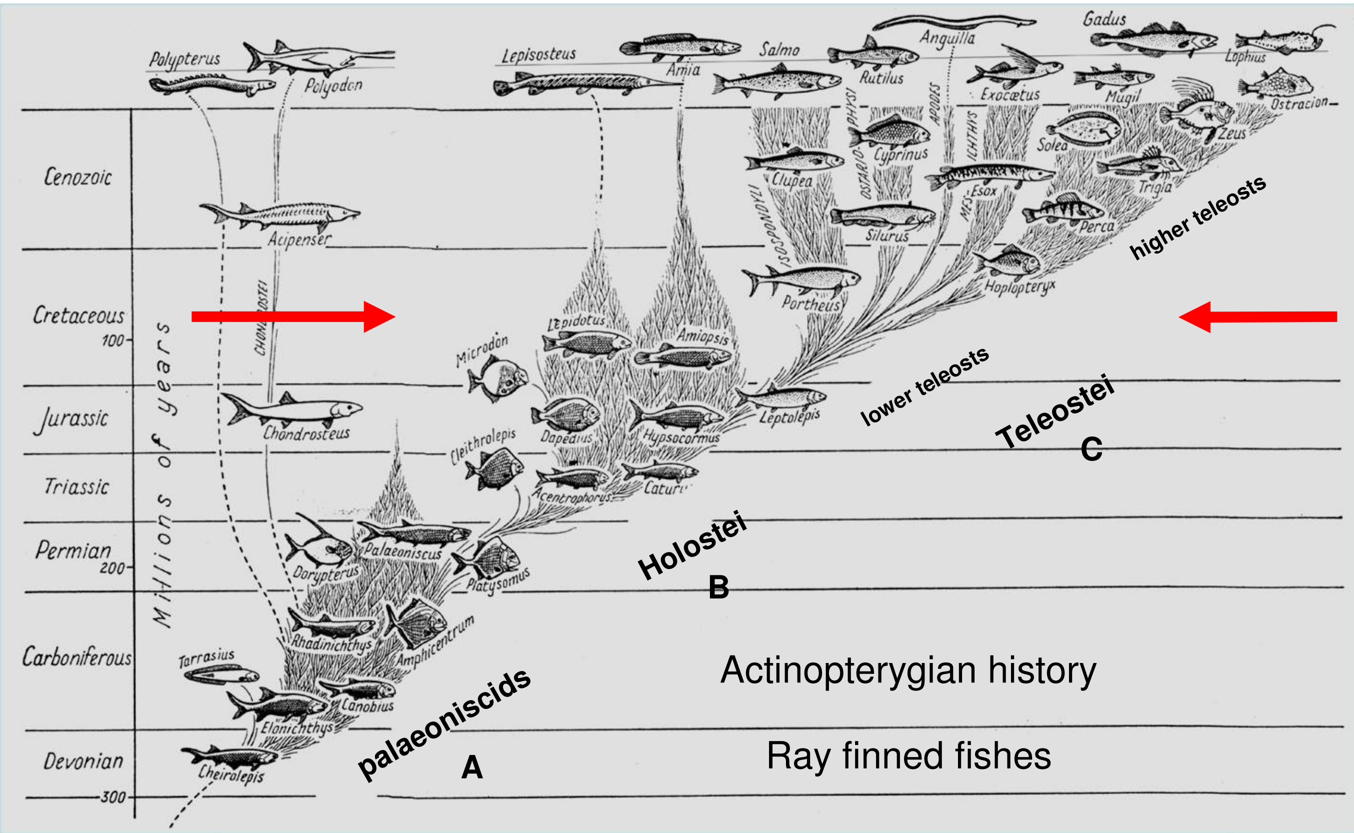


Fig. 12. Evolutionary history of the bony fish. A, palaeoniscids. B, Holostei. C, Teleostei.

The most primitive group is the palaeoniscids (meaning 'old scale') (Fig. 12A) which had their roots in the Palaeozoic. However, there are very few species remaining today, and they are mainly represented by the sturgeon.

The second group, the Holostei (meaning 'whole bone') (Fig. 12B), were the dominant fish in the Mesozoic, particularly in the Jurassic, although by the Cretaceous they had begun to decline, with only a limited number of species surviving through to today, including the gars and amia – freshwater fishes which live primarily on the eastern side of the United States.

The final group are the teleosts (Fig. 12C) which, with over 23,000 species, are the dominant group of fish today; almost all of today's bony fishes are teleosts, and they make up half of all vertebrate species in the world and provide a third of the world's protein. In the Lower Cretaceous they were in the early stages of their evolution. They had first appeared in the Upper Triassic, but it wasn't until the Chalk of the Upper Cretaceous that they really began to flourish.

To summarize, in the Wealden we have the last stragglers of the palaeoniscids (Fig. 12A), the last of the Mesozoic holosteans before their decline (Fig. 12B), and the beginnings of the teleosts (Fig. 12C) – a time of changeover for the bony fishes.

Palaeoniscids

There is only one species of palaeoniscid known from the Cretaceous, *Coccolepis* (Fig. 13), of which only fragments are found in the Weald, normally the jaws. *Coccolepis* is characterised by having long jaws and fused cheek bones, together with small teeth (Fig. 13B) and a characteristic ornamentation on the outside of the jaw (Fig. 13A, C). Figure 13A shows part of the upper jaw of a specimen from the Wadhurst Clay of Hastings, East Sussex, and figure 13C is part of a lower jaw found in Compton Bay, Isle of Wight, in 2010, indicating that similar material is present in the Wessex Basin.

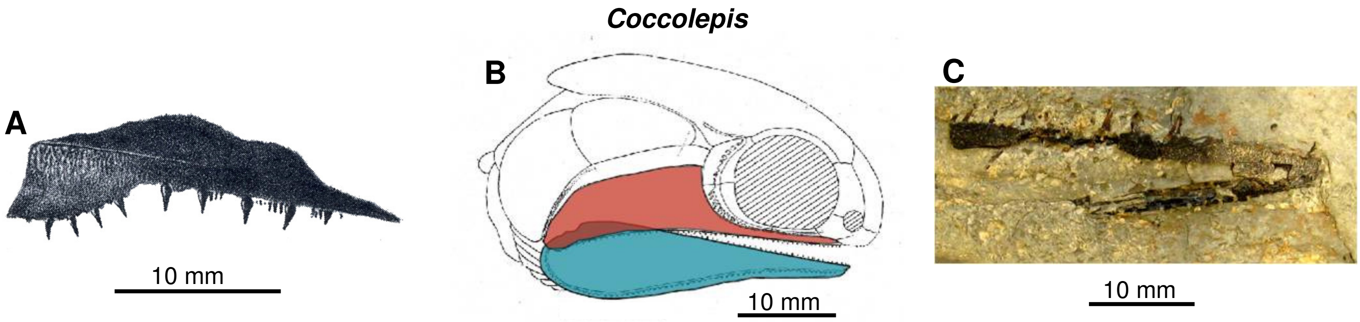


Fig. 13. Palaeoniscid, Coccolepis. *A, upper jaw from the Wadhurst Clay of Buckshole Quarry, Silverhill, Hastings, East Sussex (NHMUK P.11924) (from Woodward 1916, pl.4, fig.4). B, reconstruction of head, highlighting fused cheekbones. C, lower jaw, found in the Wessex Formation of Compton Bay, Isle of Wight, by Peter & Joyce Austen in 2010 (NHM entry no. OE-PAL-2010-40 & 41).*

Holosteans

Pycnodonts - *Coelodus*

There are a number of holosteans in the Weald, although very few complete specimens have been found. Articulated pycnodont fossils are found in the Lower Cretaceous marine deposits of Italy (Fig. 14B), and are comparable to modern-day parrot fish that live around reefs, with small incisor-like teeth at the front of the jaws and grinding teeth behind. Figure 14A shows a rare articulated specimen of a pycnodont, probably *Coelodus*, found at Smokejacks Brickworks, Surrey, in 2005 (Anon. 2007), the only articulated specimen known from the Weald. It was found in association with a mass mortality of other types of fish, mainly small leptolepids (Anon. 2007), which may have all become trapped in a small birth pool.

The most commonly found pycnodont fossils in the Weald are teeth and parts of the jaw (Fig. 15). Figure 15A shows a palate with teeth from the roof of the mouth (the dashed red line indicates the midline of the mouth), and figure 15B shows a palate with teeth from the lower jaw. The teeth are often bean-shaped (Fig. 15B) or rounded, and usually have depressions or pits in the top, making them easily

Coelodus

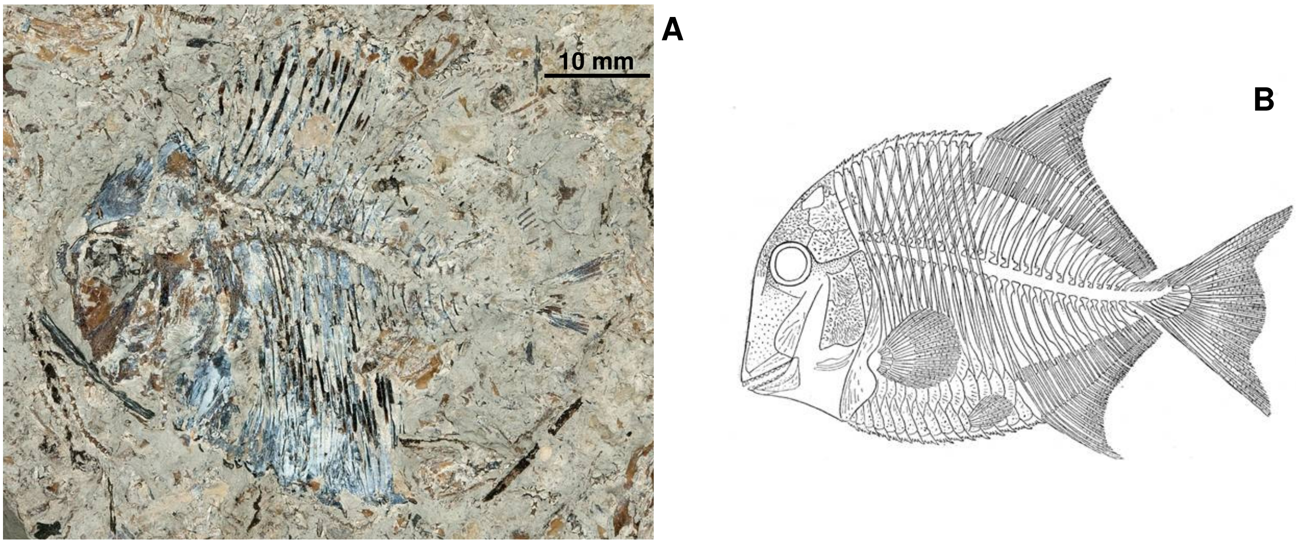


Fig. 14. A, pycnodont, probably Coelodus*, found in the Upper Weald Clay at Smokejacks Brickworks, Surrey, by Terry Keenan in 2005 (donated to the Natural History Museum, London) (photo: Natural History Museum, London). B, reconstruction of* Coelodus costae *from the Lower Cretaceous (Aptian) of Italy.*

recognizable when found isolated. It is likely that Wealden pycnodonts would have used their teeth for crushing molluscs and shells. Marine equivalents from other parts of the world were known to crush and eat corals.

Coelodus teeth

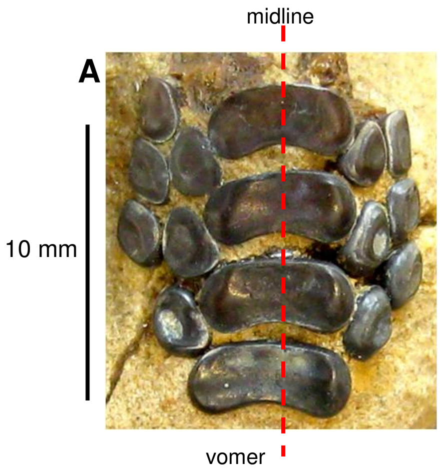
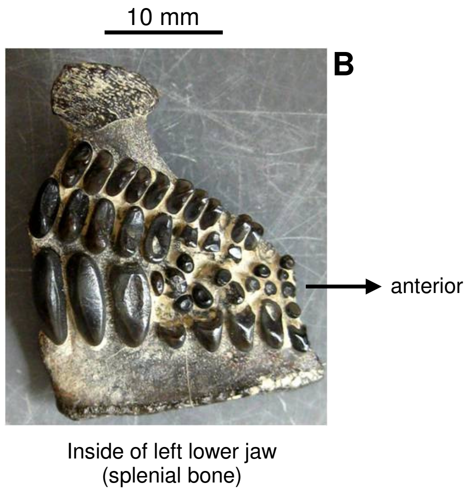


Fig. 15. Coelodus mantelli

A, palate with teeth from roof of mouth; Grinstead Clay, Tilgate Forest, West Sussex (NHMUK P.34051).

B, palate with teeth from lower jaw; Wessex Formation, Cowleaze Chine, Atherfield, Isle of Wight (NHMUK P.13282) (Forey and Sweetman 2011, p.227, text-fig.18.1B).



Lepidotes

Another type of Wealden holostean fish is *Lepidotes* (Fig. 16). *Lepidotes* is one of the rare examples in the Wealden where a number of complete individuals have been found (Fig. 16A), mainly from the Hastings area. *Lepidotes* grew to about a metre in length and was covered in thick, heavy interlocking scales which formed an armour over the fish. The scales of *Lepidotes* are different shapes according to their position on the body (Fig. 16B–D), and have pegs and sockets which lock the scales together (Fig. 16B–C). The external scale surface is shiny, whereas the surface hidden under the neighbouring scale is matt (Fig. 16B). Figure 16E is a *Lepidotes* palate with teeth, from one side of the roof of the mouth. *Lepidotes* had rounded pebble-like teeth, similar to some pycnodont teeth, but instead of a depression in the tooth, *Lepidotes* usually has a protuberance at the tip of the tooth. *Lepidotes* teeth also often have a little 'neck' so they stand up from the base of the bone, and they are never bean-shaped as in some pycnodont teeth. Other species of *Lepidotes* have been described from the Weald, but similar taxonomic problems are encountered as with the sharks; *Lepidotes* species have often been described according to different shaped scales (Fig. 16B–D), whereas in reality the scales probably all come from different parts of the same species.

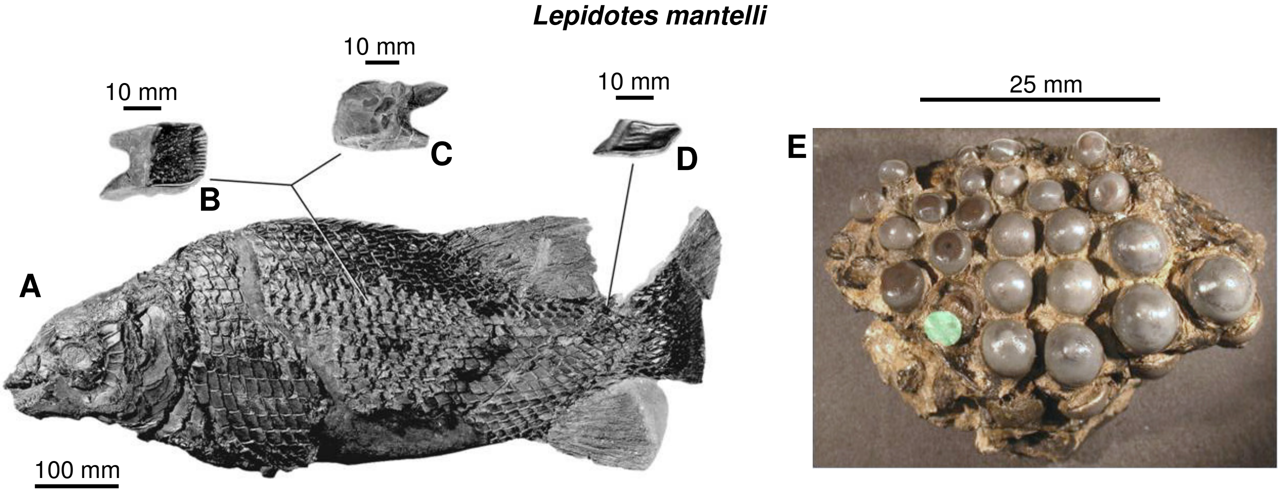
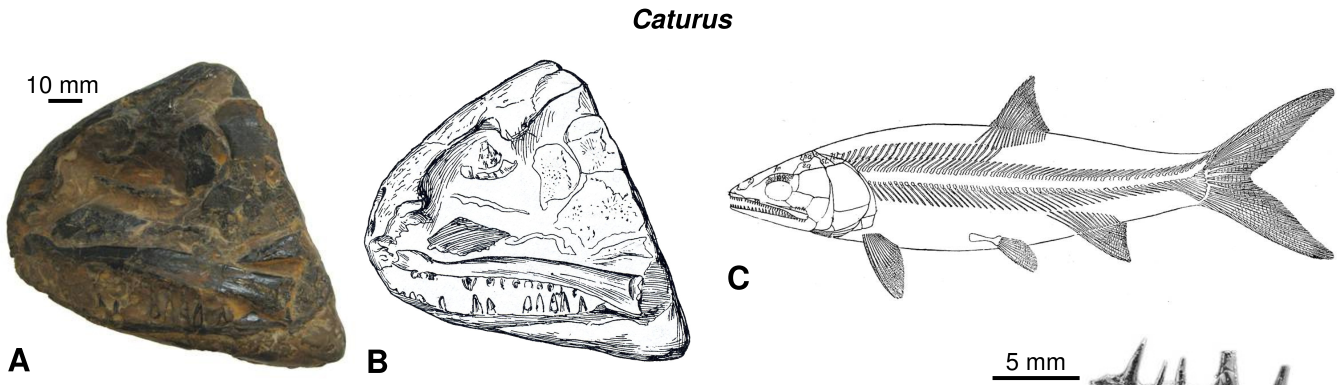


Fig. 16. Lepidotes mantelli. *A, almost complete specimen; Wadhurst Clay, Hastings, East Sussex (NHMUK P.11832). B–C, flank scale (NHMUK 3057). D, scale from near dorsal or ventral margin (NHMUK 3109). B–D, Wadhurst Clay, Tilgate Forest, West Sussex. A–D, Forey and Sweetman 2011, p.230, text-fig.18.3. E, palate; Tilgate Forest, West Sussex (NHMUK 2326) (Woodward 1918, pl.11, fig.5).*

Most of the complete specimens of *Lepidotes* were found in the 19th century when more quarries were being worked and much of the extraction was carried out by hand, giving more chance for specimens to be discovered. However, complete, or partially complete specimens can still be found. A head and part of the body of *Lepidotes* was found at Bulverhythe in 2008, and is now on display in the Shipwreck and Coastal Heritage Centre at Rock-a-Nore, Hastings. Photographs of this specimen can be seen in the *HDGS Journal* for 2008 (Brooks 2008), and *Wealden News* (Anon. 2010).

Caturus

The holostean *Caturus* (Fig. 17) is also found in the Weald. These were fast-swimming predatory fish with large teeth, and could grow up to one and a half metres, but it is very rare to find articulated specimens in the Weald. Figure 17A–B shows part of the head of a specimen from Hastings. The diagram in figure 17C is of a complete specimen from the Upper Jurassic of Bavaria. Isolated jaws (Fig. 17D) are sometimes found in the Weald, and can be identified by their long needle-like teeth with an obvious small clear glassy cap at the tip; although this glassy cap is a feature of all bony fish, it is more pronounced in the sharp teeth of *Caturus*.



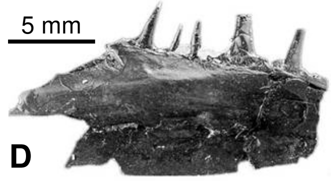


Fig. 17. A–B, part of head and line drawing of Caturus latidens*; Hastings, East Sussex (NHMUK P.6360) (Woodward 1918, p.84, fig.28). C,* Caturus furcatus *from the Upper Jurassic of Bavaria. D, part of jaw of* Caturus tenuidens*; Weald Clay, Henfield, West Sussex (NHMUK P.46837) (Forey and Sweetman 2011, p.232, text-fig.18.4A).*

Figure 18 shows a very small jaw, similar to *Caturus*, found at Langhurstwood Quarry, Warnham, West Sussex, in 2008 (Austen *et al*. 2010, p.35, fig.1). The jaw is only about 2 mm long and has very sharp teeth like those of *Caturus*, but whereas in *Caturus* the teeth are well separated from each other, the teeth in this jaw are conjoined at the base. This jaw (Fig. 18) has not been positively identified, although there is a possibility it could be an immature *Caturus*.

Fig. 18. Jaw of a small unidentified predatory fish; found in the Lower Weald Clay at Langhurstwood Quarry, Warnham, West Sussex, by Barbara Loney in 2008 (length of jaw section 2 mm.) (Austen et al. *2010, p.35, fig.1) (photo: Terry Keenan)*

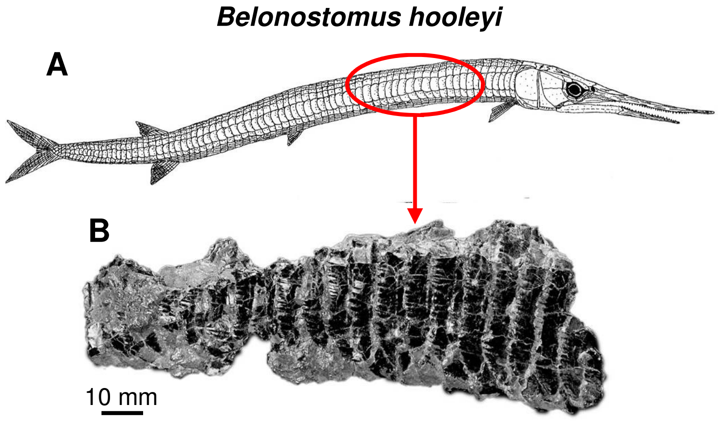


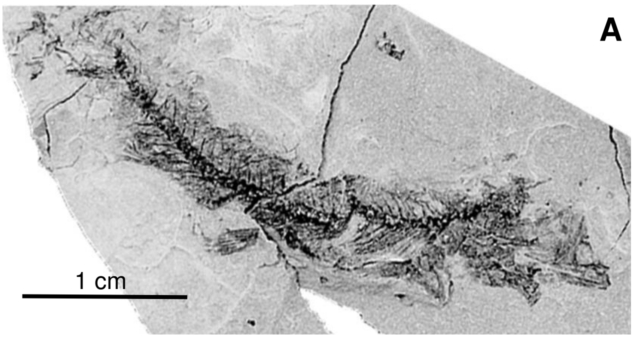
Fig. 19. A, reconstruction of Belonostomus hooleyi. *B, articulated flank scales of* Belonostomus hooleyi*; Vectis Formation, Atherfield Point, Isle of Wight (NHMUK P.47358) (Forey and Sweetman 2011, p.232, text-fig.18.4D).*

Belonostomus hooleyi

Another Wealden holostean is *Belonostomus hooleyi* (Fig. 19), comparable to the needle fish of today (Fig. 19A). It had thick, heavy overlapping scales like *Lepidotes* and although the specimen shown in figure 19B is from the Wessex Basin, Isle of Wight, scales are also found in the Weald. The jaws are long with tiny needle-like teeth.

Teleosts - *Leptolepis*

As mentioned previously, although teleosts are the dominant group of fish in the world today, there were very few in Wealden times, the majority of bony fish at that time being holosteans. The specimen illustrated in figure 20A is *Leptolepis brodiei*, found at Hamsey Brickworks, near Lewes, East Sussex, in



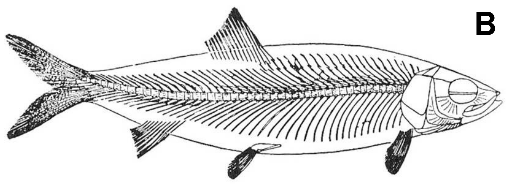


Fig. 20. A, primitive teleost, Leptolepis brodiei*; found in the Lower Weald Clay, Hamsey Brickworks, nr Lewes, East Sussex, by Derek & Pat Martin in the late 1980s (Forey and Sweetman 2011, p.234, text-fig.18.5A). B, reconstruction of* Leptolepis.

the late 1980s. In 2005 a mass mortality of juvenile leptolepids, consisting of at least 100 strings of vertebrae, was found at Smokejacks Brickworks, Surrey, in association with the pycnodont mentioned above (Anon. 2007). *Leptolepis* is a genus containing a large number of species; any fish resembling a small herring in rocks of this age is likely to be included in this genus. Figure 20B is a generalized reconstruction of *Leptolepis*.

Anaethalion

Another Wealden teleost which is extremely rare is *Anaethalion* (Fig. 21), known from only one specimen, about 40 cm long, found in the Weald Clay at Southwater Brickworks, south of Horsham, West Sussex. This site closed in 1981 and is now a country park (Batten and Austen 2011, p.50). *Anaethalion* is related and very similar to a modern-day tarpon.

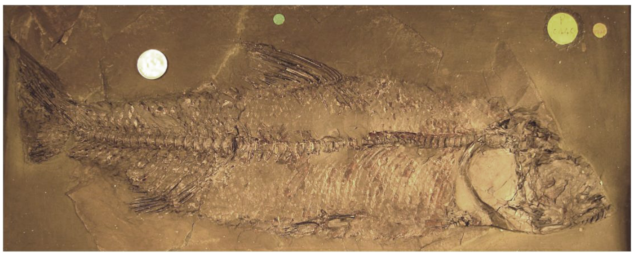


Fig. 21. Anaethalion valdensis*; Lower Weald Clay, Southwater Brickworks, West Sussex (NHMUK P.10440).*

Bony fish vertebrae

Figure 22 shows three different types of bony fish vertebrae commonly found in the Weald. Figure 22A shows a centrum of *Lepidotes* which, as can be seen, does not form a complete disc, only half a ring, just below the notochord. Figure 22B is the centrum of another type of holostean fish, *Neorhombolepis*, closely related to *Lepidotes*, which does have a complete disc, and the side view of the centrum shows that it has smooth sides. Figure 22C is a teleost centrum, once again a complete disc, but the side view of the centrum shows big pits or depressions. These differences make it possible to distinguish a teleost centrum from an holostean centrum, although it may not be possible to distinguish between species.

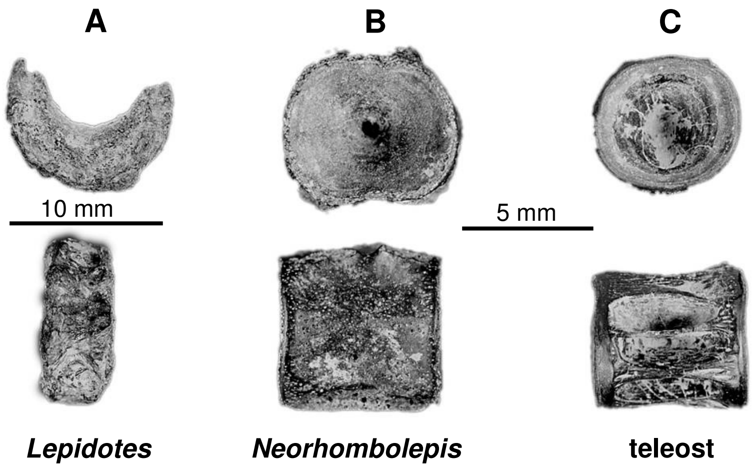


Fig. 22. A–C, Wealden vertebrae, illustrating different types found in the Weald.

A, Lepidotes *(NHMUK P.65648).*
B, Neorhombolepis *(NHMUK P.65649).*
C, Teleost (NHMUK P.65649).
A–C, Upper Weald Clay, Henfield, West Sussex (Forey and Sweetman 2011, p.234, text-fig.18.5D–I).

Identification

Returning to our original figure (Fig. 2), it is now possible to identify some of these remains (Fig. 23). Centre left is a tooth of *Hybodus brevicostatus*. Centre top and below are the teeth of the small shark *Lonchidion*, which has teeth which interlock to form a pavement-like structure. Top right are teeth of *Caturus*, the fast-swimming predatory holostean fish, both with a little clear glassy cap. Bottom right are *Lepidotes* teeth, which have a little 'neck' and, being a bony fish, also have a glassy cap. Centre bottom is a pycnodont tooth which is rounded with a little depression in the centre. Top right are two teleost vertebrae locked together, clearly showing the depressions in the side. What at first appeared to be a jumble of teeth and vertebrae can now be seen as a selection of fish and shark remains, most of which can now be identified to at least genus level.

Fig. 23. A collection of teeth and vertebrae from Wealden fish, including identifications. (Photo: David Ward)

Species numbers in the Weald

There are considerably fewer species of fish in the Wealden compared with numbers from the preceding Upper Jurassic Portlandian and the following later Cretaceous Albian and Cenomanian. However, this is only to be expected as the freshwater/estuarine environment of the Wealden was considerably more restrictive than the more open marine conditions of the Portlandian or the Albian, where there are likely to be greater numbers of species. The Wealden sees the last of the Hybodont sharks, and once into the Albian (Greensand and Gault) we begin to see sharks that belong to modern-day orders and families – the neo-selachians. In the bony fishes, holosteans are beginning to decline, and teleosts to increase; most of the fishes in the Albian will be teleost fish with many fewer holosteans, and by the time we reach the Cenomanian (the Chalk) nearly all fish are teleosts. Although the Wealden shows a reduction in fish species when compared with the deposits above and below the Weald, there is no reduction when compared with contemporaneous deposits around the world, particularly for the bony fish.

Wealden fish project

Although much is known about Wealden fish, it is still unclear where most lie within the stratigraphic sequence, and whether certain species are restricted to certain levels or environments within the Weald, which can vary from freshwater lake deposits to brackish estuarine deposits. The NHM collections, which are mostly 19th century, only have limited, if any, locality and stratigraphical information; in fact many of the 19th century quarries and pits no longer exist. The Wealden covers a period of 18 million years, so must have witnessed a turnover of types and species of fish; for example the prevalence of certain shark species changes throughout the sequence. Peter Forey asked for collectors to let him know where Wealden fish material was being found, both geographically and stratigraphically (i.e. what was being collected, at what level, and in what geographic area), and is currently photographing selected specimens in the NHM collections in order to produce an identification guide for Wealden fish. Collectors can then use this guide to identify their finds and send this information to a central collator. This identification guide, together with contact details, should be completed at some stage during 2011/2012 and loaded on to the internet or included in *Wealden News*. The eventual aim is to produce a geographic/stratigraphic succession of different types of fish throughout the Weald.

Acknowledgements. We are indebted to Peter Forey for allowing the use of photographs and reconstructions from his presentations. All photographs are by Peter Forey unless otherwise stated.

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Horner and Hutton: the French Connection

by Anthony Brook

Earlier this year I read a recently-published biography of a significant but underrated geologist of the first half of the 19th century, namely Leonard Horner (1785-1864), entitled Leonard Horner: Pioneer Reformer, by Professor Patrick O'Farrell, of Edinburgh University. It seemed to be far more concerned with Horner's educational innovations, e.g. Mechanics Institutes, and his decades of unremitting hard work as the leading Factory Inspector, than with any of his geological researches and activities, despite the fact that Leonard Horner twice served as President of the Geological Society (1845-1846, and 1860-1861). Over many years Horner presented papers to Meetings, published erudite research papers in the Transactions, and attended conscientiously to delegated business of the Council, all in his spare time, and all for the passionate pursuit of the rapidly developing science of Geology.

In the sole chapter devoted exclusively to Horner's lifelong geological interests, there occurred a most intriguing statement connecting Leonard Horner and James Hutton, both eminent sons of Enlightenment Edinburgh (p.327): "*During 1809 he [Horner] also wrote and published (in French) 'Notes on the Huttonian System of Geology'* " – which implies that Horner must have read and thoroughly digested Playfair's Illustrations of the Huttonian Theory of the Earth, published in 1802, which made James Hutton's innovative 'landscapes-cycles-in-endless-Time' framework for geological processes understandable. As I had never come across this conjunction before, in any text dealing with the geological ideas and personalities of the time, Wendy Cawthorne, of the Geological Society Library, contacted Professor O'Farrell, on my behalf, to ask for details of the source(s) for his assertion, which he, unfortunately, was unable to provide. As the authority on the history of geology of this period, Professor Martin Rudwick was then asked for his opinion, and replied that he "*can find no trace of it in my copious notes. Since I combed through the 1809 volumes of all the main francophone journals with geo material, years ago, and since you say it's not in the Royal Society Catalogue, I suspect it may never have been published. It's not in Dennis Dean's vol. on Hutton himself.*"

So, we have an unproven assertion of a publication, written in French – a language that Horner knew well, that would be historically invaluable, if only it could be located, even in manuscript form. Can anyone throw any light on this mystery of geological history?

Geology and Palaeontology in the News

A review of recent research and discoveries

Edited by Peter Austen

Introduction

The following is a summary of recent research and discoveries in or associated with geology and palaeontology. Where possible I have included enough detail (i.e. species name, author, etc.) to allow for a search of the internet for further information. In most cases more information is available, including an abstract of the paper and press releases, and quite often if you go to the author's own website or the museum/university website to which the author is affiliated you may be able to obtain a copy of the original paper. If you do not have a computer at home, all libraries in the UK are now equipped with computers with internet access for use by the general public.

World's smallest adult dinosaur found in Bexhill

The Ashdown Brickworks in Bexhill is renowned for its remarkable vertebrate fauna (*Wealden News*, Feb. 2010, No. 8, p.13–23), mainly due to the work of Dave Brockhurst, who works at the pit. It achieved yet another first in 2011 with the publication by Darren Naish and Steve Sweetman (University of Portsmouth, UK), of the world's smallest adult dinosaur (*Cretaceous Research*, 2011, Vol. 32, No. 4, p.464–471), dubbed the 'Ashdown maniraptoran'. It was identified from a single cervical vertebra (Fig. 1), found by Dave at the Brickworks. The neural arch of the vertebra was fused to the centrum, meaning that the dinosaur was fully grown at the time of death, and the authors estimate that it was less than 40 cm in length, making it one of the world's smallest adult dinosaurs (Fig. 2).

Fig. 1. Cervical vertebra of new Wealden theropod. Photo: Steve Sweetman

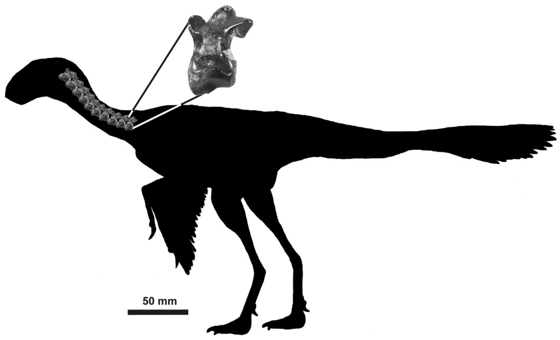

Fig. 2. Cervical vertebra shown in approximate life position in a generalised maniraptoran silhouette. (from Naish and Sweetman 2011)

We also learned in October that Dave had received the 'Mary Anning Award' from the Palaeontological Association for his 'outstanding contribution to the science of palaeontology'. Well done to Dave on both counts.

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NAISH, D. and SWEETMAN, S. C. 2011. A tiny maniraptoran dinosaur in the Lower Cretaceous Hastings Group: evidence from a new vertebrate-bearing locality in south-east England. *Cretaceous Research*, **32**, 464–471.

End-Palaeocene mass extinction

The mass extinction at the end of the Palaeocene 56 million years ago was thought to have been caused by a dramatic rise in global temperatures (known as the Palaeocene–Eocene thermal maximum) caused partly by a massive release of trapped methane. However, recent studies of oxygen isotopes in mammal teeth from the Bighorn Basin, Wyoming, USA, by Ross Secord at the University of Nebraska, Lincoln, Nebraska, USA, and colleagues, show a temperature increase of around 5 °C before the release of the methane, meaning that there were two separate warming events (*Nature*, 2010, Vol. 467, No. 7318, p.955–958). The source of the earlier warming event is unknown, but the authors think that it was unlikely to have been methane.

Plant diversity after end-Palaeocene mass extinction

It had been thought that as carbon dioxide levels increase and the Earth warms, plant species diversity in rainforests would start to fall. However, a study carried out by Carlos Jaramillo, a palaeobiologist at the Smithsonian Tropical Research Institute in Panama, and his colleagues, shows this not to be the case following the Palaeocene–Eocene thermal maximum (PETM) 56 million years ago (see previous article). Jaramillo and his colleagues studied fossilized pollen contained in rock cores taken from after the PETM from Colombia and Venezuela. They found that rather than plant diversity decreasing, it actually increased (*Science*, 2010, Vol. 330, No. 6006, p.957–961). However, this increase covered a period of 10,000–20,000 years, and Guy Harrington, a palaeobiologist at the University of Birmingham, UK, warns that any positive effects on plant diversity are likely to be wiped out if temperatures rise too quickly for the plants to adapt. Harrington's own work on the fossil deposits from the same period in North America, show that many native species died out there as temperatures rose, and that higher latitudes are more likely to suffer from extreme conditions and lack of water, implying that the only areas to benefit after the PETM were the tropics.

An early flowering plant from China

The flowering plants (angiosperms), with more than 250,000 species, are the most important group of plants on the planet. They are the dominant vegetation in most terrestrial ecosystems and provide most of the planet's food resources, either through the crops that are grown, or the livestock that feeds on them, but they only first appeared in the fossil record in the Early Cretaceous between 125 and 130 million years ago. There are five major lineages of angiosperms; the Chloranthaceae, the magnoliids, the monocots, *Ceratophyllum* and the eudicots, the eudicots forming the majority of the angiosperms in the world today. The last 10 years has seen a number of early angiosperms discovered in the now famous Jehol Biota from the Yixian Formation (Early Cretaceous) of northeast China. Ge Sun of the Shenyang Normal University, Shenyang, China, and Jilin University, Changchun, China, and his colleagues, report on a basal eudicot named *Leefructus mirus* (Fig. 3) from these deposits (*Nature*, 2011, Vol. 471, No. 7340, p.625–628). The morphological characters of the plant, including its trilobate leaves, suggest affinities with the Ranunculaceae (e.g. buttercups and water crowfoot), a basal eudicot family, and its age (122.6–125.8 million years) is in close agreement with the earliest fossil records of eudicot pollen (125–127 million years). The leaves also bear a close similarity to the early 'flowering plant' *Bevhalstia pebja* from the Weald Clay of Surrey and Sussex, which dates to around 128–130 million years ago (see *HDGS Journal*, Dec 2008, Vol. 14, p.18–21). *Bevhalstia* is also thought to have Ranunculid affinities.

Fig. 3. Reconstruction of Early Cretaceous flowering plant, Leefructus mirus*, from China. (height of specimen shown 14 cm)*

Reference

SUN GE, DILCHER, D. L., WANG HONGSHAN and CHEN ZHIDUAN 2011. A eudicot from the Early Cretaceous of China. *Nature*, **471**, 625–628. .

Evidence of life in 3.5-billion-year-old Apex Chert questioned

For the past 20 years the 3.5-billion-year-old Apex Chert rock formation in Western Australia has been thought to house some of the earliest evidence for life on Earth. The rocks contained filamentous structures thought to be fossils of oxygen-producing cyanobacteria, but this claim has always been controversial, with some arguing that what was thought to represent a shallow sea floor was actually a hydrothermal vent. Alison Olcott Marshall and her team at the University of Kansas in Lawrence, Kansas, USA, have carried out a study of the rocks and found that the supposed fossils were of inorganic origin, and what were previously thought to be the fossils was actually Haematite (*Nature Geoscience*, 2011, Vol. 4, p.240–243). However, although the researchers think that the filamentous structures are now of inorganic origin, the rocks contained carbonaceous material, which could possibly have been formed by living things. The case remains open.

New candidates for oldest fossils

What could be the world's oldest fossils have been discovered in 3.4-billion-year-old black sandstone rocks of the Strelley Pool Formation in Western Australia. Martin Brasier, a palaeobiologist at the University of Oxford, UK, and his colleagues, found microbial mats which were thought to have grown on an ancient beach (*Nature Geoscience*, 2011, Vol. 4, p.698–702). What were previously thought to be amongst the world's oldest fossils, fossilized cyanobacterial mats from the 3.5-billion-year-old Apex Chert Formation, 30 kilometres from Strelley Pool, have recently been shown to have an inorganic origin (see "*Evidence of life in 3.5-billion-year-old Apex Chert questioned*" on previous page). However these newly discovered fossils are characteristic of bacterial colonies. They are between 5 and 80 micrometres in diameter, and shaped like spheres, ellipsoids and rods, and their chemical signature is indicative of life.

Migrating sauropods

A study of the teeth of large sauropod dinosaurs from the Morrison Basin in Wyoming and Utah, USA (late Jurassic, 145–160 million years ago), has provided the first hard evidence that they did undertake seasonal migrations (Fig. 4), something that has always been suspected, but not proved beyond doubt. Henry Fricke, a geochemist at Colorado College in Colorado Springs, USA, and his colleagues, looked at 32 teeth from the sauropod *Camarasaurus*, and compared the oxygen isotope ratios of the tooth-enamel carbonate with those of the carbonate in the sedimentary rocks found in the area. The oxygen ratio in the teeth relates to the ratio in the water they were drinking when their teeth were growing, and the sedimentary rocks record those local ratios. Some parts of the teeth matched the Morrison Basin, but others did not, and their composition indicated that the dinosaurs had probably migrated to higher elevations during seasonally dry periods. It is thought that they migrated at least 300 kilometres between the basin and highlands to the west (*Nature*, in press, doi:10.1038/ nature10570).

Fig. 4. Sauropod dinosaur Camarasaurus.
Credit: Wikimedia

Earth's earliest non-marine multicellular life found in Scotland

Evidence for the earliest terrestrial (non-marine) life forms is extremely rare, with the most widely cited example being cyanobacteria from 1.2-billion-year-old palaeokarst deposits in Arizona, USA. Organic-walled microfossils have also been known from the non-marine Torridonian sequence of northwest Scotland (1.0–1.2 billion years ago), but few species have been recognized, and they are still thought of as nondescript 'leiospheres' (single-celled, smooth-walled, spherical algae). However, recent work on these Torridonian deposits by Paul Strother of Boston College, Weston, Massachusetts, USA, and colleagues, using acid maceration and thin section techniques, has recovered large populations of "*diverse organic-walled microfossils, as well as multicellular structures, complex-walled cysts, asymmetric organic structures, and dorsiventral, compressed organic thalli, some up to one millimetre in diameter*" (*Nature*, 2011, Vol. 473, No. 7348, p.505–509). Their work provides evidence that eukaryotes (multicellular organisms) were living in freshwater and terrestrial habitats during the Proterozoic era, implying that the evolution of eukaryotes on land may have started far earlier than previously thought.

Predatory dinosaurs hunted at night

It has long been thought that during the Mesozoic only mammals were active at night, but a recent study of the eye sockets of fossilized dinosaurs and other reptiles by Lars Schmitz and Ryosuke Motani of the University of California, Davis, USA, found this not to be the case (*Science*, 2011, Vol. 332, No. 6030, p.705–708). The researchers looked at the internal diameter of the 'scleral ring' of bone within the eye to see if it was large in relation to its external diameter. If it was, this implied that the animal was active at night. The team found that most of the theropod predators and some of the pterosaurs were active at night, whereas other pterosaurs and all of the birds were active during the day. Most of the large-bodied herbivorous dinosaurs had 'scleral ring' bone ratios part way between the two, implying that they were active during both day and night, similar to most of today's large herbivores.

The giant rabbits of Minorca

Fossil bones from a giant rabbit, *Nuralagus rex* (Fig. 5), have been discovered on the Mediterranean island of Minorca. The rabbit dates from the Neogene period, about 5 million years ago, and weighed in at around 12 kilograms, ten times larger than its closest living relative. The fossil was reported by Meike Köhler at the Catalan Institute for Research and Advanced Studies in Barcelona, Spain, and her colleagues (*Journal of Vertebrate Paleontology*, 2011, Vol. 31, No. 2, p.231–240). It had a relatively small skull and sensory organs, and the backbone was unsuitable for hopping. These features together with its size were thought to be due to it being on an island with no predators.

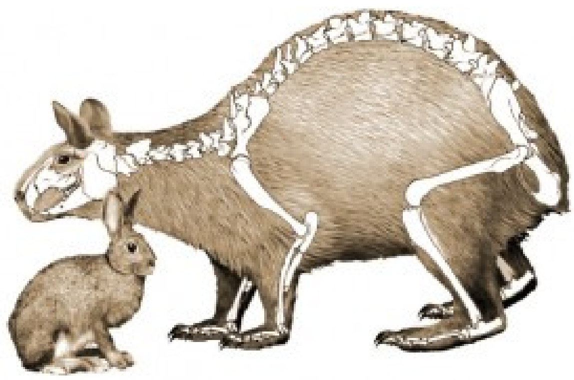

Fig. 5. Giant Minorcan rabbit, Nuralagus rex *(approx. 75 cm long), with present-day relative.*

Adapted from Quintana, Köhler and Moyà-Solà 2011.

Ancient marsupials lived in groups

Although modern mammals often live in groups, most marsupials are solitary animals. However, this does not appear to have been the case at the start of the Palaeocene 64 million years ago. Sandrine Ladevèze, a palaeontologist at the Royal Belgian Institute of Natural Sciences in Brussels, Belgium, and her colleagues, report a rare find of 35 well-preserved primitive opossums (called *Pucadelphys andinus*) of varying ages and sexes huddled together in two groups just 3 metres apart, from the Tiupampa locality of Bolivia (*Nature*, 2011, Vol. 474, No. 7349, p.83–86). Because of their near perfect preservation it is thought that they were not washed together by the action of a river, but were overcome in their burrow by some sort of natural disaster, such as a flash flood. Christian de Muizon, a co-author of the paper, points out that at this time marsupials were radiating across South America, and that this social behaviour may have made settlement in new regions easier. Once populations became established, social behaviour no longer proved useful and they became more solitary creatures.

Bacterial mats helped early animals to breathe

A study of bacterial colonies called microbial mats in the present day Los Roques lagoons of Venezuela has thrown light on how ancient life forms may have survived the harsh Precambrian conditions where oxygen was scarce. Murray Gingras, a palaeontologist at the University of Alberta in Edmonton, Canada, and colleagues, examined the chemistry of the water above and inside the microbial mats in the Los Roques lagoons (*Nature Geoscience*, 2011, Vol. 4, p.372–375). The microbial mats in Los Roques are in highly saline waters, and almost completely cover the lagoon floors, similar to the microbial mats that would have existed in the Ediacaran Period, 542 million years ago, when multicellular animals were just starting to evolve. Gingras and his colleagues found that although oxygen levels in the surface waters of the lagoon were very low, daytime levels in deeper waters near the mats were much higher as the photosynthesising bacteria released oxygen, and in the top millimetre layer of the mat itself the team discovered an environment of almost pure oxygen. The authors think that not only would the early Ediacaran animals have fed on the mats, but they would have also used them to provide the oxygen they needed to survive.

Increase in brain size in early mammals

Recent work by Timothy Rowe at the University of Texas in Austin, USA, and colleagues, has shown that mammals may owe their large brains to the development of more acute senses, such as smell and touch, in their extinct pre-mammalian ancestors (*Science*, 2011, Vol. 332, No. 6032, p.955–957). They made computed tomography scans of two skulls of mammalian ancestors found in 200-million-year-old Chinese deposits. The two skulls, from *Morganucodon oehleri* and *Hadrocodium wui*, showed a much larger brain relative to body size than their predecessors, with the areas involved in sensing and processing smell and touch showing the largest increase. The authors think that the increase in these areas laid down the neural framework for future improvements in brain function and the large brains we enjoy today.

Arthropod eyes in the Early Cambrian

Despite the fossil arthropods in Cambrian Burgess-Shale-type deposits showing exquisite preservation, apart from biomineralized trilobite eyes very little is known about the optical design of the eyes of these arthropods. Michael Lee of the South Australian Museum, Adelaide, and the University of Adelaide, South Australia, and colleagues, report exceptionally well-preserved fossil eyes from the Early Cambrian (around 515 million years ago) Emu Bay Shale of South Australia (*Nature*, 2011, Vol. 474, No. 7353, p.631–634). The fossils reveal that some of the earliest arthropods had highly advanced compound eyes, some of which were as advanced as those of many of today's living forms. This complexity had not previously been recorded in the fossil record until about 85 million years later.

Archaeopteryx knocked off its perch?!

The discovery of an *Archaeopteryx*-like theropod fossil that seems to fall between the birds and the dinosaurs has led to the claim that *Archaeopteryx*, long hailed as one of the earliest birds, may not be a bird at all. A feathered fossil named *Xiaotingia zhengi* (Fig. 6) from the Late Jurassic (145–161 million years) rocks of the Liaoning province of China was reported by Xing Xu, a palaeontologist at the Institute of Vertebrate Palaeontology and Palaeoanthropology in Beijing, China (*Nature*, 2011, Vol. 475, No. 7357, p.465–470). The discovery of numerous small feathered dinosaurs in China over recent years has blurred the line between birds and dinosaurs, and the latest discovery bears more resemblance to the dinosaurs *Velociraptor* and *Microraptor* than to early birds, and so belongs in the dinosaur group Deinonychosauria rather than in the bird group. However, an analysis of the shared characters of this newly discovered fossil and other related dinosaurs, together with *Archaeopteryx*, also places *Archaeopteryx* in this Deinonychosauria group, displacing it from its position as one of the earliest birds. Even so, it's a fine line between birds and dinosaurs, and when the analysis was repeated excluding the new discovery, *Archaeopteryx* fell back into the bird group. More fossil evidence is needed to settle the case either for or against.

Fig. 6. Artist's impression of Archaeopteryx*-like theropod,* Xiaotingia zhengi *(approx. 40 cm long), from the Late Jurassic of China.*

Spinosaur discovery in Australia extends global range

The discovery of the cervical vertebra of a spinosaurid theropod dinosaur in the Australian state of Victoria has significantly extended the geographical range of the spinosaurs. The discovery, reported by

Paul Barrett at the Natural History Museum in London, and his colleagues, is similar to spinosaurids from Pangaea's northern region, Laurasia, and together with other recent discoveries in the Southern Hemisphere suggests that dinosaurs, previously thought to have only lived in the north of the supercontinent, had a near-global distribution (*Biology Letters*, 2011, Vol. 7, p.933–936).

Ancient photosynthesis

The earliest yet most direct evidence for photosynthesis has been discovered in a matted carpet of microbes from the 3.3-billion-year-old Josefsdal Chert microbial mat, from the Barberton Greenstone Belt in South Africa. Frances Westall at the Centre for Molecular Biophysics, a laboratory of the French National Centre for Scientific Research (CNRS), in Orleans, France, and her colleagues, used electron microscopes and a synchrotron light source to look at the microbial mat. In the mat's surface layer they found tiny remnants of photosynthetic microbes, and beneath the surface they found small particles of aragonite, a calcium carbonate mineral, which could only have been produced if the surface was photosynthesising. The group's findings were presented by Westall at the Origins 2011 conference in Montpellier, France.

Early arthropod from China

The discovery of a Lobopodia (an extinct group of animals resembling worms with legs) called *Diania cactiformis* (Fig. 7) and nicknamed the 'walking cactus' has shed new light on the evolution of the arthropods. The discovery of the fossil from the 500-million-year-old Chengjiang fossil Lagerstätte (Cambrian Stage 3), Yunnan, southwestern China, was reported by Jianni Liu, a palaeontologist from the Early Life Institute at Northwest University in Xi'an, China, and colleagues (*Nature*, 2011, Vol. 470, No. 7335, p.526–530). The Lobopodia are thought to have given rise to Onychophora (velvet worms) and Tardigrada (water bears), as well as to arthropods in general. The fossil shows 'armoured' appendages and appears to be closer to the arthropods than any previously known lobopodian, effectively a 'missing link', and could imply that arthropods developed hardened limbs before hardened bodies.

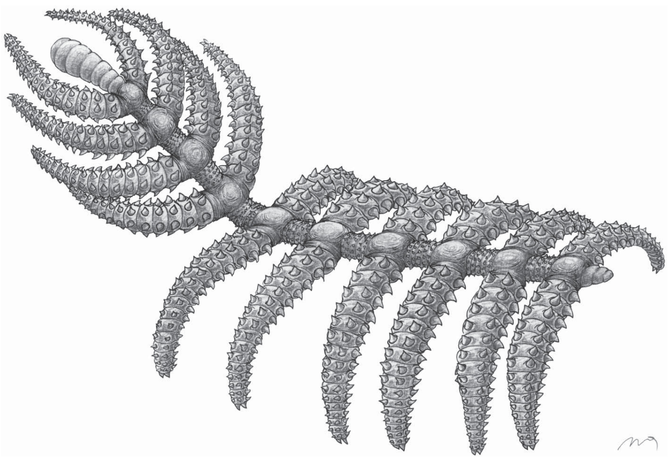

Fig. 7. Reconstruction of Early Cambrian arthropod, Diania cactiformis*, from China. (length approx. 6cm)*

Reference

LIU JIANNI, STEINER, M., DUNLOP, J. A., KEUPP, H., SHU DEGAN, OU QIANG, HAN JIAN, ZHANG ZHIFEI and ZHANG XINGLIANG. 2011. An armoured Cambrian lobopodian from China with arthropod-like appendages. *Nature*, **470**, 526–530.

Plesiosaurs gave birth to live young

The fossil of a plesiosaur, an extinct marine reptile, found in Kansas 24 years ago, has revealed that these animals gave birth to live young, and may have also cared for their offspring in a similar way to today's whales and dolphins. Robin O'Keefe at Marshall University in Huntington, West Virginia, USA, who analyzed the fossil with Luis Chiappe at the Natural History Museum of Los Angeles County in Los Angeles, California, USA, reported that the 78-million-year-old fossil called *Polycotylus latippinus*, which was 4.7 metres long, was carrying a single foetus which was 1.5 metres long (*Science*, 2011, Vol. 333, No. 6044, p.870–873). Other marine reptiles were known to have given birth to many small babies, but with *Polycotylus latippinus* giving birth to one large baby, it is likely it would have cared for its offspring until it was ready to fend for itself, as with today's whales and dolphins.

Feathers in Canadian amber

Palaeontologist Ryan McKellar and his colleagues at the University of Alberta in Edmonton, Canada, have conducted a painstaking search of more than 4,000 pieces of amber looking for fossil feathers. The amber, from a site called Grassy Lake in western Canada which was once a conifer forest, is between 70 and 85 million years old. Their search revealed just 11 fossil feathers, but because the amber-encased feathers are not associated with body fossils, they could not be sure what animals they came from (*Science*, 2011, Vol. 333, No. 6049, p.1619–1622). However, their structures indicated that they covered both birds and non-avian dinosaurs, including plumage that could have been used for flight and underwater diving. It is hoped that future work with amber inclusions will throw more light on the evolution of feathers.

Geological Websites

by Peter Austen

Over the past couple of years, while jointly researching and writing a contribution for the Palaeontological Association Field Guide on English Wealden fossils (Batten 2011), and assisting with cross-checking references for the whole volume, I found two websites to be invaluable – in fact without them it would not have been possible to achieve the detail and accuracy the Guide required. I've briefly mentioned both in previous issues of the Journal, but it's worth explaining their value in more detail.

Internet Archive

The first site is the 'Internet Archive' (http://www.archive.org/), a site from which historic books can be accessed and in most cases downloaded. One of the many aims of the Field Guide was to provide author references for all the species included, making the book a useful research tool for anybody wishing to investigate further. I was involved in the chapter on Wealden plants (Austen and Batten 2011) where a number of these author references date back to the 19th century when many fossil plant species were first erected, and it was often necessary for me to refer to some of these works. This was also necessary when checking the references for the remainder of the volume. Not so long ago this would have necessitated a visit to a University library, or in the case of rarer works, The Natural History Museum or even the British Library, which could be a costly and time-consuming affair. However, most of the 18th and 19th century works (and more than 90% of those that I required) are now available on the 'Internet Archive', and the numbers are increasing daily.

Amongst those included are some of the classic works on geology and palaeontology: Sowerby (all 7 volumes) and Orbigny on molluscs; Agassiz on fish (all 5 volumes of his classic work on fossil fish including plates for volumes 1 to 4); Brongniart, Sternberg, Lindley & Hutton, Seward and Stopes on plants; Owen and Mantell on dinosaurs and other vertebrates; Handlirsch on insects; Topley (Weald); Giebel (Weald); Dixon (Sussex); Phillips (Yorkshire); Plot (Oxfordshire, 1704). Also available are 19th century volumes of geological and palaeontological journals: Transactions of the Geological Society; Quarterly Journal of the Geological Society; Proceedings of the Geologists' Association; Monographs of the Palaeontographical Society; Geological Magazine; Palaeontographica; many of which include some of the early classic papers in geology and palaeontology. It's a truly remarkable resource and extremely useful, as in a lot of cases the online digital versions of the works are fully searchable. For works that are not searchable the 'Internet Archive' offers a 'djvu.txt' version which is a text listing only and allows you to search for whatever term you're after (e.g. the name of a quarry) – this option is accessible through the HTTP portal.

Where's the Path

The second site is 'Where's the Path' (http://wtp2.appspot.com/wheresthepath.htm). This site allows you to view the Ordnance Survey (OS) map of a particular area alongside an aerial photograph of the same location. Both maps cross reference to each other, and allow you to zoom in to look at detail, and by use of the cursor it is possible to identify the grid reference to within one metre, something not previously possible by just looking at an OS map. You can call up the relevant map and aerial view by putting in the post code, address, or the grid reference. This website was used extensively for the sites chapter in the Field Guide (Batten and Austen 2011), and proved invaluable in identifying the exact location of many of the sites, particularly the older now defunct ones.

Other sites

Royal Society journal archive (1665–1940)

http://royalsociety.org/news/Royal-Society-journal-archive-made-permanently-free-to-access/

In October the Royal Society announced that it was making its entire archive of 60,000 historical scientific papers from 1665–1940 freely available on the internet on a permanent basis. These include some of the key papers that marked the start of the scientific revolution, including papers by Isaac Newton, and later, papers by Charles Darwin.

If you do not have access to a computer at home, all libraries in the UK are now equipped with computers with internet access for use by the general public.

If you know of any particularly good websites then please let me know and I will include them in the next issue of our Society Journal.

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GEOLOGISTS' ASSOCIATION FIELD MEETINGS – 2012

The Hastings & District Geological Society is affiliated to the Geologists' Association (GA), and as such members are entitled to attend GA lectures, normally held at Burlington House, Piccadilly, London, W1, or attend any of the GA field trips. Below is the 2012 GA field programme, although some of these dates may change. Details of these trips and also GA lectures appear in the *Magazine of the Geologists' Association*, which is available at HDGS meetings. Details can also be found on the GA website http://www.geologistsassociation.org.uk/. All bookings must be made through the Geologists' Association office – details in the *Magazine of the Geologists' Association.*

FIELD MEETINGS IN 2012

Sat 17th March	Seaford, East Sussex	Geoff Toye
Sat 28th April	Dundry Hill, near Bristol	Simon Carpenter
April (date t.b.c.)	Sussex coast weekend	Rory Mortimore
Sat 12th May	Middlesex churches	John Potter
Sat 19th May	Ketton Quarry, near Stamford, Rutland	Andy Swift
Sat 2nd June	Cotswold coach trip	Mike Howgate
June (date t.b.c.)	Bytham (Lincolnshire)	Jim Rose
July (date t.b.c.)	Wealden excursion	Peter Austen
Sat 4th Aug. to Sun 5th Aug.	Mid Wales	Steve Howe
Sat 15th September	Harkstead, Suffolk	Graham Ward
Fri 28th Sep. to Sun 30th Sep.	Dorset	John Cope
October/November (date t.b.c.)	Fossil Fest VIII	Neville Hollingworth

HDGS field trip to Bracklesham Bay

Sunday, 12th June 2011

Summer at Bracklesham. Need I say more!

Photo: Jim Simpson

HDGS field trip to Eastbourne

Sunday, 31st July 2011

Professor Rory Mortimore explaining chalk structures in the cliffs along the Eastbourne coastal section.

Photo: Peter Austen

SUSSEX MINERAL SHOW

Saturday 10th November 2012

10.00 am to 4.30 pm

Clair Hall, Perrymount Road, Haywards Heath

(Close to Haywards Heath Station)

Minerals, gems, fossils, meteorites, flints, books and accessories on display and for sale

Illustrated Talks

Organised by the **Sussex Mineral & Lapidary Society**

Details and map available from Trevor Devon at HDGS meetings closer to the date of the Show