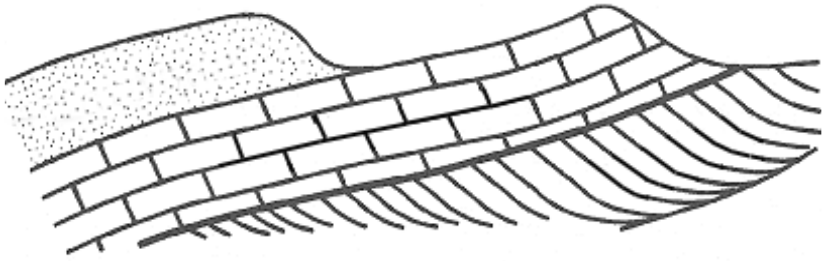
Farnham Geological Society

[www.farnhamgeosoc.org.uk]

Farnhamia farnhamensis



A local group within the GA

Vol. 11 No.2 **Newsletter** June 2008

INSIDE THIS ISSUE

As from September, the venue for the Society's Friday meetings will be the Barley Room at The Farnham Maltings – see page 3 for further details. From personal experience I can say that this is an excellent meeting place with its own car park. However, for most Society members the Friday meetings represent the *raison d'etre* of the Society; since many do not go on our excellent field trips a change of meeting place can be somewhat unsettling – like moving house.

This, of course, is not our first move. The Society was officially constituted at the Inaugural Meeting on 6th April 1970 held in council premises in South Street. Before this there had existed a group of people who had attended a WEA geology class for a number of years before deciding to break away and form Farnham Geological Society. During 1971 the newly constituted Society started to meet in the Adult Education Centre in West Street, where its 50 members could be accommodated and where a small room was available for the Society's collection of specimens.

The Society met in the Lawson Room in West Street for 22 years but in 1994 had to move to the Farnham Central Club premises in South Street and the specimen collection had to move first to the Godalming Adult Education Centre and subsequently to Peter Luckham's premises in Churt. Our agreement with the Farnham Central Club had unfortunately to be terminated and at this point we moved to our present location in Church House. These premises are to be closed for major modernisation, hence the need for our move to the Maltings.

Peter Cotton

COMMITTEE

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Remaining programme of lectures - 2008

Date	Title	Speaker
April 11th	**The geology and petroleum geology of the deep water areas around Borneo**	Tim Chapman, Consultant
May 9th	**Graptolites**	Dr Denis Bates, Aberystwyth University
June 13th	**Managing our wastes – the geological perspective**	Brian Marker
July 11th	**Members evening and presentations**	
Sept 12th	**Geology of paintings**	Dr. Ruth Siddall, University College, London
Oct 10th	**Geology of London**	Dianna Clements, Natural History Museum
Nov14th	**Diamonds through time**	Prof. Andrew Fleet, Natural History Museum
Dec 12th	**Charles Darwin – a glacial geologist**	Peter Worsely

Field excursions 2008 - see page 3 for detailed descriptions of June to October

Date	Field trip	Leader
April 4th – 7th	**The Lizard Peninsula**	Dr Alan Bromley
May 4th	**Guildford area**	Dr Graham Williams
June 1st	**Osmington to Overcombe, Dorset**	Dr Graham Williams
June 20th	**Bargates and the Devil's Jumps**	John Gahan
July 4th – 7th	**Cardigan Bay**	Dr Denis Bates
Aug 3rd	**Mupe Bay or Ringstead Bay**	Dr Graham Williams
Sept 7th	**Medway, Kent; Pleistocene and Palaeolithic**	Dr Martin Bates
Oct 3rd – 12th	**Brittany and East Normandy**	Drs Denis Bates and Graham Williams

Increased volcanic activity linked to global warming

Increased volcanic activity is linked to ice melted by the effects of global warming, a study has found. So much ice in Iceland has melted in the past century that the pressure on the land beneath has lessened, which allows more of the rock deep in the ground to turn to magma. Until the ice melted, the pressure was so intense that the rock remained solid. Carolina Pagli, of the University of Leeds, led research which calculated that over the past century the production of magma had increased by 10 per cent. The research team, reporting their findings in the journal *Geophysical Research Letters*, said an extra 1.4 cu km of magma has been created under the Vatnajökull ice-cap in the past 100 years. Since 1890 the ice-cap has lost 10 per cent of its mass, which has allowed the land to rise by up to 25m (82ft) a year. The volume lost between 1890 and 2003 is estimated at 435cukm. How long it will take before the extra magma erupts in Iceland and other regions of the North Atlantic Ridge remains uncertain. It is formed at depths of 15 to 112 km, and Dr Pagli estimated it will be a century or two before it is ejected by volcanoes.

Lewis Smith, The Times, Saturday 5 April, 2008

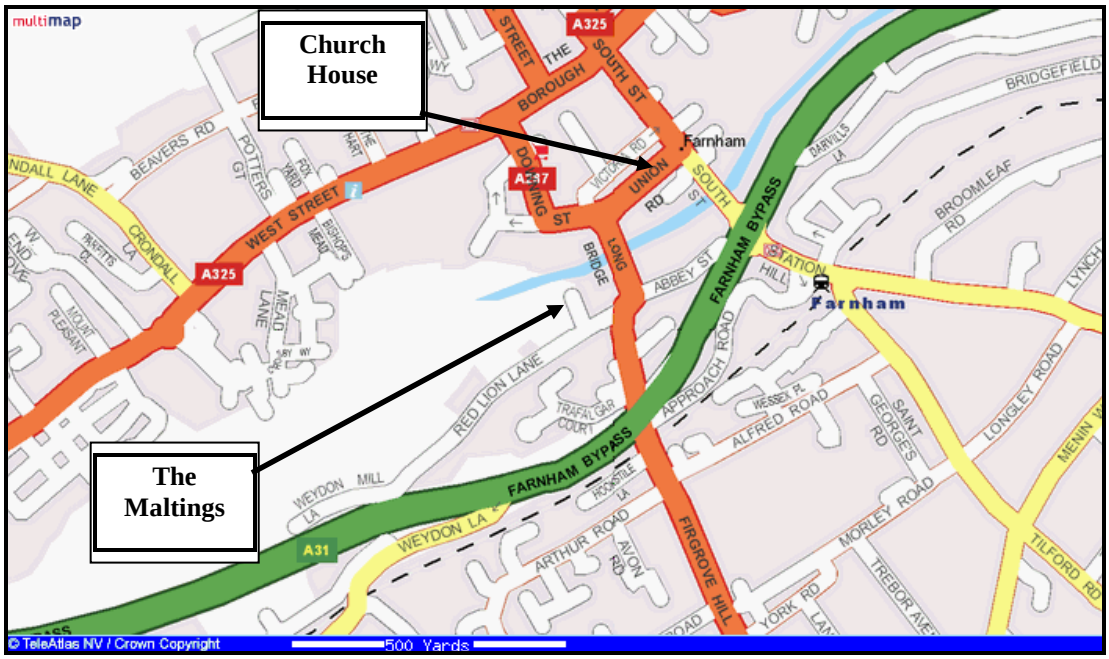
IMPORTANT - CHANGE OF MEETING PLACE

***Church House*, our current meeting place, is closing down for a major refurbishment this Summer. As a consequence, the Society is having to move its meetings to a new venue.**

Starting in September, meetings will be held in *The Barley Room, Farnham Maltings*. The timing of the meetings will remain unchanged at 7.30 for 8.00pm.

Many members will know where the *Farnham Maltings* complex is situated, but for those who are unsure, the building is very easy to find:

Enter Farnham's one-way system and continue along Union Road past *Church House*
Take the next left into Long Bridge (in front of the Police Station)
Then take the first right into Red Lion Lane just after *The William Cobbett* pub
***The Maltings* and its car park are on your right.**



GA annual re-union: a festival of geology

The GA, at its annual re-union this year, is celebrating its 150th anniversary with a Festival of Geology, to be held at University College, London on Sat 1st Nov. The Society will be represented by a display compiled by Janet Philips; all members are urged to attend what in past years has been a very interesting event.

2008 Field trip programme – Part 2: June to October

June 20th **Devils Jumps and Bargate Stone** led by **John Gahan**

This "*mid-Summers eve*" evening walk will explore some of our local rocks, the Lower Greensand and particularly the Bargate Stone. The Bargate Stone is sandstone which is well cemented with quartz cement and consequently is an important local building stone. It extends between Thursley and Chert, along the foot of Hindhead Hill, where there is a line of well preserved oak timber framed medieval hall houses with Bargate Stone foundations and walls (now farms and cottages). The evening will terminate at the adjacent Pride of the Valley hostelry.

July 4th - 7th **Cardigan Bay** led by **Dr Denis Bates**

Denis led our trip to Ireland in 2007. Now retired, he was a lecturer at University College of Wales, Aberystwyth, and has an extensive knowledge of mid-Wales geology, particularly Palaeozoic sediments and fossils. We will be based in Aberystwyth, staying on campus in ensuite rooms. We haven't finalised the itinerary,

but it will extend from Friday late pm through Monday am, and will include the Silurian Aberystwyth Grits, Ordovician and Cambrian sediments along the coast, and visits inland to see the old mines (lead etc), and Devil's Bridge and the Rheiddol Gorge.

August 3rd Mupe Bay or Ringstead Bay led by **Dr Graham Williams**

We plan to visit Mupe Bay in Dorset, but I have to check that the Army Ranges are safe for us. We will walk eastward from Lulworth Cove and visit the Fossil Forest, Bacon Hole and Mupe Bay. The sequence includes Lower Cretaceous Purbeck limestones deposited in shallow marine, coastal, and lagoonal settings; they include evaporates, and even soils with fossil tree preserved. These limestones are overlain by Wealden muds and sands (there could be dinosaur bones), Gault Clay, Upper Greensand and Chalk. The rocks are folded and faulted, and this, together with the varied rock types, results in a remarkably beautiful coastal landscape.

September 7th The Medway Pleistocene sequences led by **Dr Martin Bates**

Martin led our successful trip to Hampshire and Sussex in 2007. Martin is both geologist and archaeologist, particularly interested in sediments and archaeology of the Palaeolithic period (the last ½ million years or so); he leads the Medway Palaeolithic Project, and he will demonstrate his latest research.

The River Medway has existed over 2,000,000 years, draining N from the Weald. For most of this period the landscape of S England was substantially different to the present day, and the course of the Medway has varied considerably. Until 500,000 years ago, the Thames Estuary did not exist, and the Medway flowed N to enter the North Sea near Ipswich. Then, around 500,000 BP, Britain was affected by a major ice age. An ice sheet 100m thick covered East Anglia, advancing S towards London. It diverted the Thames, which at that point flowed East across Essex and Suffolk, further S. Through time, due to a combination of erosional downcutting and uplift of the earth's crust in SE England, the Medway has flowed at progressively lower levels. Sand and gravel deposits laid down by earlier courses of the Medway are preserved as "terraces" high above the banks of the present river channel. In some places a "staircase" of terrace deposits is preserved, with successively older deposits occurring higher up the valley sides. The river was often similar to rivers in Arctic Canada to-day, with numerous shallow (braided) channels crossing a gravel plain. These terrace deposits contain fossil animal bones and flint artefacts, caught up when they were formed, and thus provide a time capsule of evidence about the climate and environment in this ancient time, and about human activity in the area.

October 3rd - 12th Brittany and East Normandy led by **Drs Denis Bates and Graham Williams**

Denis has led many undergraduate trips to Brittany, and he will show us ancient metamorphic and igneous rocks, including metamorphosed and deformed sediments, mylonite, red beds, turbidites, the Ploumanach Granite and the Erquy pillow lavas. I will lead the trip to East Normandy to demonstrate the geology of the D-Day landings; we will see the Cotentin Peninsula and Paris Basin structure, the relation between geology and landscape and choice of invasion sites, German defences and Middle Jurassic limestone, how the Jurassic helped the invasion - landing sites, airfields, transport, water supply. We will visit Pegasus Bridge and see how the Jurassic and Pleistocene controlled the Parachute Regiment's capture and defence of the eastern flank, and final breakout. We will visit Ranville Cemetery for a final reflection - all those young lives…..

And finally, in October, we will have a local **"Chairman's" trip** led by **John Gahan**, before our annual **Society Lunch**. I hope this programme will provide something of interest for everybody - interesting places, beautiful countryside and seascapes, wild life and plants, ancient and modern rocks, and a touch of archaeology. Please call me if you wish to join any of the trips.

Dr GM Williams, FGS Field Secretary

Meteorite made big impression on Ullapool

The largest meteorite to hit the British Isles struck near the Scottish town of Ullapool about 1.2 billion years ago, new research suggests. Scientists from the University of Oxford and the University of Aberdeen have found evidence that rock formations in northwest Scotland, once thought to have been created by volcanic activity, may be debris left by a huge meteorite strike.

The material is scattered over an area about 31 miles across, according to a paper published in the journal *Geology.* Tests on the rocks have identified traces of iridium, a metal abundant in asteroids and meteorites. Ken Amor, of the Department of Earth Sciences at Oxford, said: "*We found more evidence when we examined the rocks under a microscope: tell-tale microscopic parallel fractures that also imply a meteorite strike*."

There are 174 meteorite craters known on Earth, and the newly identified one is the largest in and around the British Isles. "*If there had been human observers in Scotland 1.2 billion years ago they would have seen quite a*

show. The massive impact would have melted rocks and thrown up an enormous cloud of vapour that scattered material over a large part of the region around Ullapool. The crater was rapidly buried by sandstone, which helped to preserve the evidence," said Dr Amor.

Mark Henderson, 'The Times', Thursday 27 March 2008

The geology of the deep water areas offshore Borneo, SE Asia

Summary of April 2008 lecture given by Dr T. J. Chapman, Consultant

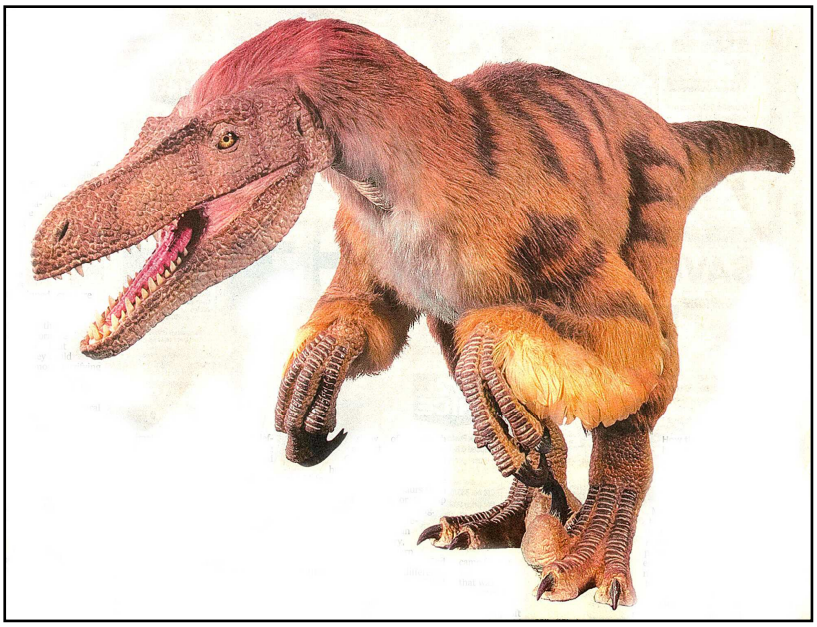
The continental margin off Northern Borneo (Malaysia and Brunei) was formed during the last 20 million years above a southward dipping subduction zone. Thick sequences of Miocene to recent clastic sediments were deposited, inboard in a shallow water shelf setting and outboard in deep water. Here turbidite deposition occurred both on and beyond the continental slope.

The underthrusting of the north Borneo margin gave rise to the development of a fold-thrust belt along the slope margin. This folded the earliest deepwater sediments but caused ponding of the later syn-tectonic turbidites.

A major process throughout the Miocene and Pliocene has been slope failure and the movement of mass transport deposits down the continental slope alternating with more normal turbidite deposition. These deposits are chaotic in character and may be more commonly formed during sea level low-stands. Similar processes have occurred on many continental margins around the World.

Tim Chapman

Velociraptor was a feathered friend



The terrifying velociraptors that ripped apart everyone they could catch in *Jurassic Park* should have been given feathers by the director Steven Spielberg. Researchers now say that the dinosaurs, which leapt into the public imagination when they were featured *in* the *hit* 1993 film, were misrepresented. After analysing fossilised bones they have discovered that the velociraptor was not the smooth-skinned creature portrayed in the film, but had feathers.

The discovery means that as well as being more decorative than the creatures that appeared in the film they could have been an even more terrifying predator because the feathers would probably have been improved their manoeuvrability. Scientists have suspected for several years that velociraptors were feathered beasts, but only now have they been able to identify what they believe is conclusive proof. Close analysis of a velociraptor forelimb unearthed in Mongolia in 1998 reveals that quill knobs were present on the fossilised bone. Quill knobs, which are found on many modem bird species, are where the flight or wing feathers are anchored to the bone by ligaments. "*A lack of quill knobs does not necessarily mean that a dinosaur did not have feathers,"* said Alan Turner, of the American Museum of Natural History, and the lead author of the study. *"Finding quill knobs on velociraptor, though, means that it definitely had feathers. This is something we'd long suspected but no one had been able to prove*."

Velociraptors had short forelimbs compared with modern birds' wings, which has led researchers to conclude that they were flightless but had probably descended from an extinct creature that had been able to fly. That the velociraptors had retained at least some feathers suggests that they continued to have a role, even if not for flight. The researchers said that one of the most likely functions of the feathers was to display to other velociraptors, perhaps in courtship rituals or as a show of strength against aggressors. Other functions could have included use as a shield to protect eggs, a temperature control to prevent the dinosaurs from getting too hot or cold, or to help them to manoeuvre while running.

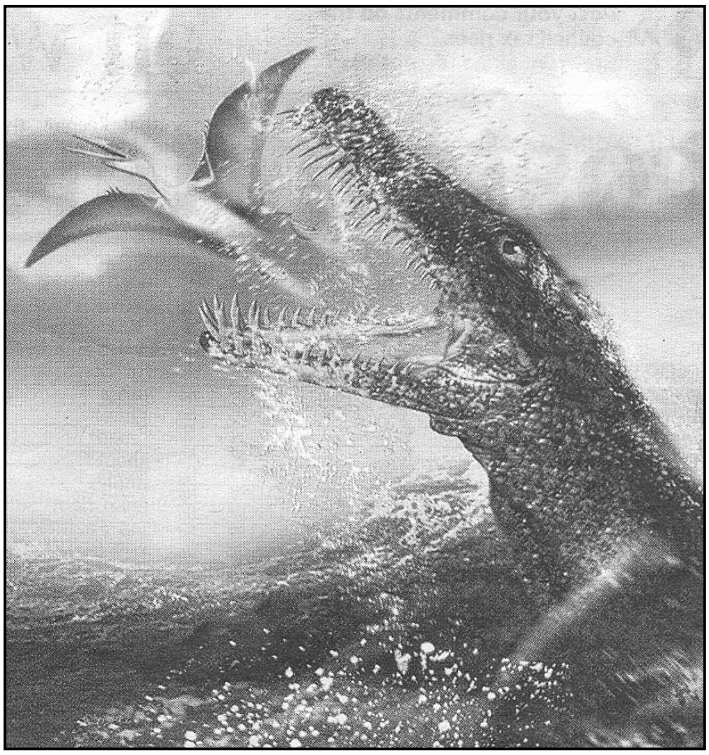
Mark Norell, one of the researchers from the American Museum of Natural History, said: "The more that we learn about these animals the more we find that there is basically no difference between birds and their closely related dinosaur ancestors like velociraptor. Both have wishbones, brooded their nests, possess hollow bones and

were covered in feathers. If animals like velociraptor were alive today our first impression would be that they were just very unusual looking birds." The fossil analysed for the study came from a velociraptor that was estimated to have been 5ft (l.5m) long, 3ft tall and weighing 33lb (15kg) when it died.

The research was a joint project of the American Museum of Natural History, New York, and the Field Museum, Chicago. In their report the authors say: "*We present direct evidence of feathers in Velociraptor mongoliensis based on the presence of quill knobs on the posterior forearm. Their absence does not necessarily indicate a lack of feathers. Their presence, however, is a direct indicator of feathers.*" The six quill knobs were found spaced about 0.16 inches (4mm) apart and the researchers estimated that the limb would have had 14 secondary feathers on the forearm, similar to the 12 in Archaeopteryx, which is the earliest-known bird.

Lewis Smith, The Times, Friday 21 September 2007

Fossil reveals a monster that terrorised the seas



The fiercest reptile ever to terrorise the oceans has been identified from a fossil on a frozen Arctic island. The huge pliosaur, dubbed The Monster, dated from 150 million years ago and boasted 60 dagger-like teeth the size of cucumbers, which it used to rip chunks out of prey. The 50ft (15m) animal was one of the biggest marine predators to have swum and it would have been able to take on "anything that moved" in the water. It was built for speed and power and with its armoury of fangs would have been rivalled in ferocity only by an extinct shark, the megalodon, which lived about 16 million years ago.

Fossilised remains of the pliosaur, which had 10ft long jaws, were located on the Norwegian island of Svalbard, inside the Arctic Circle. It was one of 40 fossil creatures found close together on a mountain on Svalbard by a team of researchers from the University of Oslo Natural History Museum, in Norway. Jern Hururn, who led the expedition, compared the animal to a "medium-sized blue whale with a three metre-long crocodile skull". It was twice as big as a killer whale.

The pliosaur, a type of plesiosaur, was the leading marine predator during the Jurassic Period and is thought to represent an unknown species Its body was designed to minimise drag while its enormous flippers propelled it forward in a motion like flying through the water. A front flipper from the monster was measured at almost 10ft long.

Fossil bones from the specimen excavated last summer showed that it was almost 50 per cent bigger than the largest confirmed pliosaur, *Kronosaurus,* from Australia. An ichthyosaur, another marine predator, from 210 million years ago has previously been identified as being 75ft long but its teeth were much smaller than the pliosaur's and it would have chased much smaller prey. Or Hurum said: *"The pliosaur was much, much fiercer. The ichthyosaur would have been an oversized fat dolphin by comparison. This animal would have taken chunks out of anything that moved. It was the fiercest marine reptile and the biggest of its era. Its teeth and jaws could crush almost anything.*". Or Patrick Oruckenmiller, a plesiosaur specialist at the University of Alaska Museum, was involved in the discovery. He said: "*Not only is this specimen significant in that it is one of the largest and relatively complete plesiosaurs ever found, it also demonstrates that these gigantic animals inhabited the northern seas of our planet during the age of dinosaurs*."

In 2002 a fossil pliosaur from Mexico was nicknamed the Monster of Aramberri, amid claims that it was up to 65ft long. However, the measurements have yet to be confirmed. Angela Milner, associate keeper of palaeontology at the Natural History Museum, said the find illustrated how different the world was when the animal ruled the seas. "*Svalbard was not so near the North Pole 150 million years ago, there was no ice-cap and the climate was much warmer than it is today*." She added: "*There are a few isolated bones of huge pliosaurs already known but this is the first find of a significant portion of a whole skeleton of such a giant*."

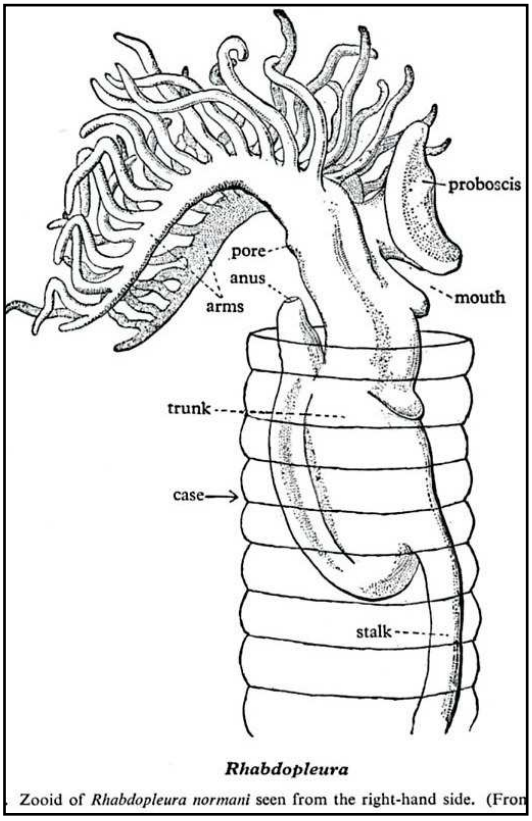
Lewis Smith, The Times, Thursday 28 February 2008

Rhabdopleura – a "Living" fossil

About 20 years ago Dorothy Odhams, a member of the Farnham geological Society, found an extremely rare fossil called *Rhabdopleura* in Silurian rocks in the Mendips. The specimens are now part of the Natural History Museum's collection, in London. Dorothy donated the specimens and has kept a record - here are her photos, and some information.

Rhabdopleura is extremely rare in the fossil record because its chitin exoskeleton is almost impossible to preserve. The oldest examples discovered, so far, are Middle Cambrian, and they still exist. They probably originated before the Middle Cambrian, and it is likely that they were as abundant as their near relatives - the Graptolites.

What do they look like?



Rhabdopleura

Zooid of *Rhabdopleura normani* seen from the right-hand side. (Fron

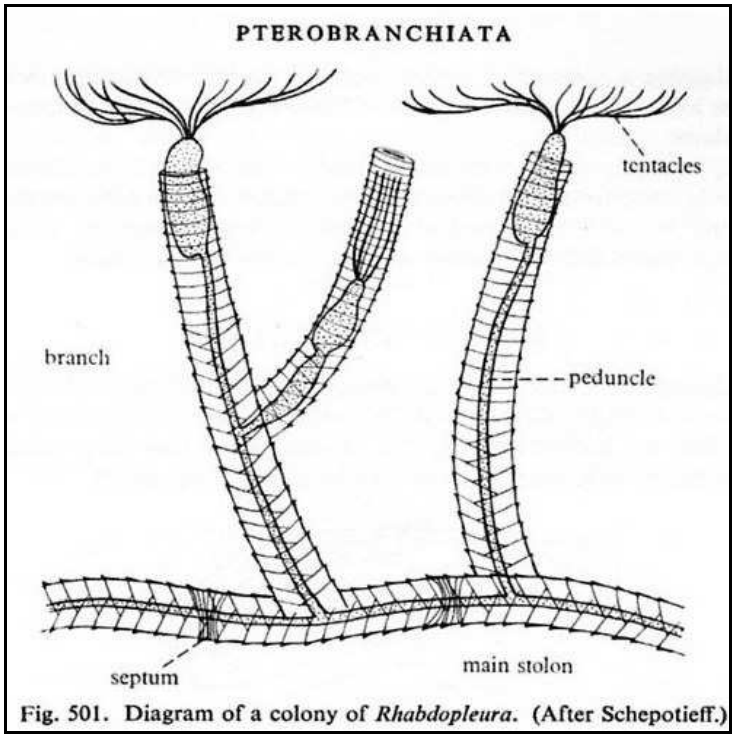


Fig. 501. Diagram of a colony of *Rhabdopleura*. (After Schepotieff.)

Rhabdopleura is a colonial organism with individual zooids connected by a contractile stalk, to form an erect growth habit. Several tubes arise from a horizontal basal tube, the last tube being closed with a terminal bud inside - the next zooid to "hatch". Individual zooids have branched arms with cilia which collect food. This Protochordate structure is very similar to that of the Graptolites, and is regarded as a first step towards the creation of vertebrate organisms.

Where do they live?

To-day's *Rhabdopleura* are minute sessile creatures, many of which live in the deep ocean. Seven Recent species have been described; they have been found off Norway, Bermuda, Sri Lanka, Celebes, New Zealand and Tasmania. They are found associated with harder substrates such as pebbles, corals and shells, but are known to attach to mud, sand and even Foraminifera tests (shells). Colonies have been found on the inner surface of lamellibranch shells such as *Glycimeris* (off Plymouth).

When did they live?

The oldest forms were discovered in Siberia, and are extremely similar to modern forms - *Rhabdopleura* has remained virtually unchanged for *500 million years*.

Classification

Sub-phylum: Stomochorda - Middle Cambrian to Recent

Class: Pterobranchia - Lower Ordovician to Recent

Order: Rhabdopleurida

Family: Rhabdopleuridae

Genus: Rhabdopleura

Class: Graptolithina - Cambrian to Lower Carboniferous

The FGS specimens were found on a single slab and were the broken remains of one or more colonies.

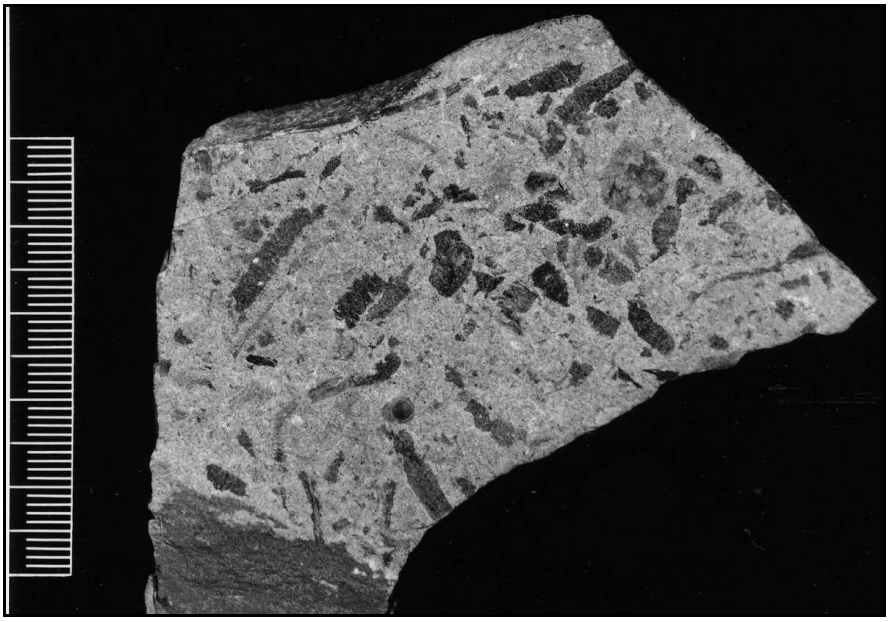


Fig 1: Rhabdopleura fragments

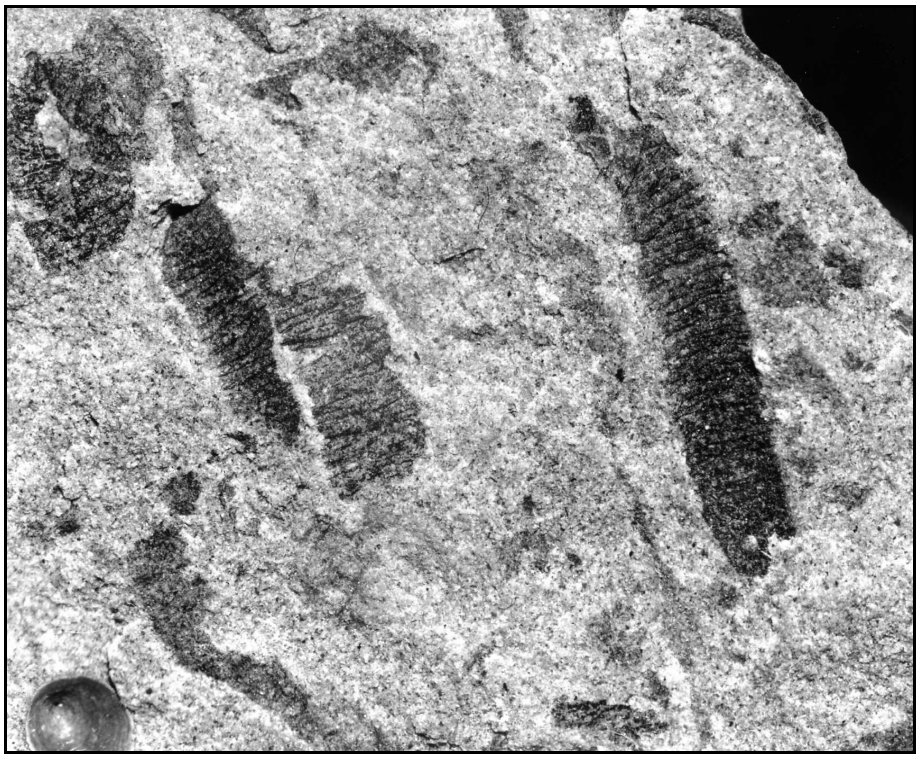


Fig 2: Rhabdopleura tubes

Graham Williams

Graptolites: how they evolved and how they lived

Summary of May 2008 lecture given by Dr Denis Bates, Aberystwyth University

Graptolites are among the most fascinating of fossils (I would say that, working on them!). The earliest (mid Cambrian) and the last (early Carboniferous) – the dendroids - were benthic forms, living, like some modern bryozoans, in bush-like colonies attached to the sea floor. They were, as the name implies, tree-like. In the late Cambrian, one graptolite, *Dictyonema*, left the sea floor and became a member of the plankton.

Its descendants evolved into a variety of forms, with a general trend towards simplification of the colony, and a highly regular form, as mathematically precise as, say, the pearly *Nautilus*. It is probable that these forms were an adaptation to more efficient feeding.

Among the most complicated of these colonies are the retiolites, in which the skeleton became "more skeletal", and also "doubled". With Nancy Kirk I have worked on these forms for the last 30 years: they are among the most aesthetically pleasing of the graptolites.

The relationships of the graptolites to other invertebrate phyla remain mysterious. Many workers group them with the hemichordates, modern (and fossil) benthonic filter feeding organisms related to the vertebrates. Others have included them in the Coelenterata (hydrozoans) or the Bryozoa. It is also possible that they are not closely related to any other phylum.

Denis Bates

Kentish Ragstone

The full title of the rock formation which is found in the Lower Greensand Hythe Beds in Kent is '*Rag and Hassock'*. It comprises two quite different layers that alternate between ragstone – a very hard, grey limestone containing poorly mixed lime/mud, sandstone and glauconite – and hassock which is a soft sand/silt.

Before describing the rag and hassock in more detail and particularly its commercial use since Roman times, it is interesting to notice how the Hythe Beds vary in constitution across the Weald from east to west. In the Western Weald the beds are much thicker, up to 300 feet south of Farnham, whereas in the eastern part of Kent round Hythe itself they are only 35 feet thick. There is also a marked divergence in the hardness of the Hythe Beds from east to west which results in a very different landscape. In the west the sandstone contains hard chert bands that act as a capping to reduce the erosional effects and thereby produce the high sandstone ridges around Hindhead and Leith Hill. Farther east the sandstone escarpments have been substantially eroded to produce flat landscapes which are usually covered by fertile, permeable soils and hence the soubriquet "The Garden of England". The arenaceous poor soils of the Western Weald were referred to by Cobbett in his Rural Ride of 1822 as "the most villainous spot that God ever made".

Returning to the rag and hassock beds, they also vary as one travels in a westerly direction through Kent becoming grittier as the sand element increases. On the Kent/Surrey border they become a calcareous sandstone. Over the centuries the quarrymen learnt where the best stone could be found for building purposes. The Romans made substantial use of ragstone for building and shipped thousands of tons quarried near Maidstone to build the defensive walls round London. The Normans continued the use for building, as in Rochester Castle and the White Tower in London. In the early centuries the hardness of the ragstone meant that it was difficult to carve and hence it was used for rough walling.

However, by medieval times tools had been developed to enable the stone to be dressed and many houses such as Knole House and Ightam Mote were built using the dressed ragstone. Because of the improvement in transport there was increased competition from the Jurassic stone of Bath and Portland Stone so that the Kentish Ragstone was relegated to its original rough walling role. Later the hardness of ragstone made it very suitable as an aggregate in the expanding road and house building business and so, being easily quarried and locally available, provided a much cheaper material for use in the South East rather than transporting aggregate from further afield.

Exposures of ragstone can be seen in several restored quarries where faces have been left for inspection such as Dryhill Country Park near Sevenoaks.

Peter Cotton, with acknowledgment to the Kent RIGS group for much of the information included in this article

Eruption of the Chaiten volcano in Chile

These pictures of the current eruption of the Chaiten volcano in Chile are of particular interest to the Society as they were taken on the spot by a friend of our Editor's grand-daughter. Three of them show the dramatic

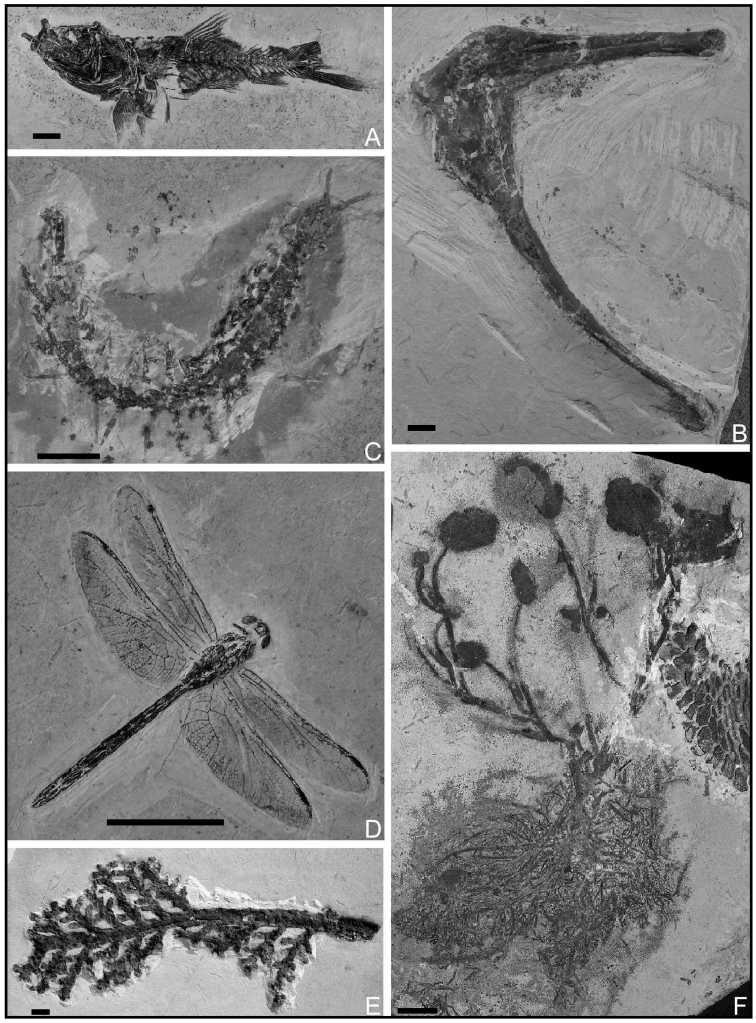
effects that can be observed at night by the combination of erupting magma, dust and an electric storm. The volcano had been dormant for hundreds, if not thousands, of years before erupting earlier this year.

Peter Cotton

The Crato fossil beds of Brazil

Summary of the March 2008 lecture given by Dr Dave Martil, Portsmouth University

The fossil assemblage of the Early Cretaceous (?Aptian) Nova Olinda Member fossil Konservation Lagerstätte of the Crato Formation, southern Ceará, N. E. Brazil provides a rare opportunity to examine the palaeobiota of a mid Gondwanan ecosystem. It outcrops around the eastern Chapada do Araripe in southern Ceará and western Pernambuco, but appears to be most fossiliferous between Santana do Cariri, Nova Olinda and Tatajuba in Ceará. Based on taphonomic and palaeoecological considerations its fossil assemblage is considered to be largely allochthonous.



Fossils are common, but only the gonoryhnchiform *Dastilbe* and larval ephemeroptera occur abundantly. Other fish taxa are poorly represented and thus even elements of the ichthyofauna may in part be allochthonous. Rarely, tetrapods, including frogs, crocodiles, turtles, lizards and birds occur, while pterosaurs are comparatively abundant.

Plants comprise predominantly storm-damaged gymnosperm fragments, but specimens of terrestrial flora with roots, stems, leaves and fruiting organs occur, probably derived from riverbank collapse, or aquatic and semi-aquatic plants flushed from riparian settings. Occasionally plants with quantities of palaeosols attached occur.

The allochthonous invertebrate assemblage is dominated by winged insects, but larval insects, apterygotes, centipedes, and arachnids also occur. Curiously, larval Odonata are rarer than imagos, but in ephemeroptera this situation may be reversed for some species. Decapod crustaceans are extremely rare, suggesting that they too might be allochthonous. Most of the winged insects are assumed to have entered the basin as airborne fallout. The presence of fossorial and cryptic terrestrial arthropods may be a consequence of riverbank collapse during flooding. Molluscs are unknown in the Nova Olinda Member, but are present in clays above.

Sedimentology

The Nova Olinda Member comprises a series (~3 – 13 m) of millimetrically laminated limestones with abundant organic material. The limestones are commonly weathered to a buff or white colour but are bluish-grey in unweathered sections. Pyrite is abundant as isolated crystals in some unweathered laminae and, as finely disseminated grains elsewhere. Bioturbation is absent and individual laminae can be traced over large distances within quarries. Ripple-like microbial mats are present at some levels. Fossils are preserved as black carbonaceous material with disseminated pyrite, or pyrite replacements in the unweathered limestone, or as brown/orangey-brown goethite when weathered.

An absence of bioturbation, and the subsequent preservation of millimetre thick laminae indicate hostile bottom conditions for the duration of Nova Olinda Member deposition. A lack of primary sedimentary structures may indicate relatively deep-water conditions, while a distinct lack of clastic material suggests deposition some distance from the palaeoshoreline. An absence of facies change towards predicted palaeoshorelines suggests that upland areas to the north of the current outcrops may have been inundated during the mid Cretaceous marine transgression. If this was the case, then water depths for the Nova Olinda Member may have been in excess of 100m. This conclusion is currently at odds with most depth estimates for this deposit.

Taphonomy

The Nova Olinda Member water body represented a largely inhospitable environment, probably due to elevated salinities and benthic anoxia. Bottom conditions mediated high-fidelity preservation of soft-bodied

organisms, derived locally from terrestrial and freshwater environments, which would not normally have been preserved. Although preservational styles of the various faunal and floral components are similar, the taphonomy of the various components can differ significantly.

Volant vertebrates: Both birds and pterosaurs are known from the Nova Olinda Member, although only pterosaurs occur frequently. Complete skeletons of pterosaurs occur rarely, but occurrences of articulated portions of the skeleton occur frequently, including portions of wings, complete feet detached from the limb and skulls with lower jaws still attached. Isolated pterosaur bones also occur. Some pterosaurs are preserved with portions of soft tissues, including head crests, rhamphotheca, claw sheaths, wing membrane and scaled skin of the hind limbs and feet. Birds, although known from skeletal remains, are mainly represented by isolated feathers, sometimes with colour patterns preserved and ectoparasites.

Fish: Excepting the highly abundant *Dastilbe*, other fish taxa, such as coelacanths, *Cladocyclus* and *Calamopleurus* are extremely rare. Most specimens of *Dastilbe* are juveniles, but larger individuals up to 30 cm standard length occur frequently. The fish are usually complete, but may have slightly dislocated skulls, and isolated portions of skeletons, such as fins or opercular apparatus, also occur. It is considered that *Dastilbe* probably inhabited the upper layers of the Nova Olinda water body, but was prone to periodic mass mortalities, as suggested by mass death assemblages of large numbers of juveniles on single laminae. *Cladocyclus*, while rare, may also have inhabited the water body, but most individuals are small in comparison with those from the slightly younger Santana Formation in the same basin. Fish taxa known from single specimens may represent strays from connected marine basins (coelacanths) or freshwater taxa from local rivers (some semionotids).

Insects: The palaeoentomofauna is diverse and a study of its taphonomy is currently underway. Preliminary results suggest that some taphonomic filters may be affecting patterns of diversity. Orthopterans are especially common, as are cockroaches. Dragonfly imagos are more abundant than their aquatic larval counterparts, while beetles are rare relative to most other groups. Preservation is variable, with some nearly 3D, while others are flattened. Some colour pattern preservation occurs. Although many insects are complete, isolated wings, bodies, antennae and limbs also occur. Aggregates of insects may represent floating remains that became entangled in bacterial/algal mats.

Plants: The flora includes rare equisitales, isoetales, filicales, possible cycadoidea, gymnosperms, gnetalians, and both dicotyledenous and monocotyledonous angiosperms. Floral remains commonly occur as carbonaceous/pyrite replacements that weather rapidly on exposure to air. However, in deeply weathered sections plant remains oxidise to soft, but stable, powdery orange/brown goethite pseudomorphs. Most plants have been flattened, but three-dimensionality can be retained in some stems, cones and terminal fructifications. Microstructure is rarely preserved in weathered specimens. Isolated leaves occur infrequently and most remains are small fragments of less than 1 m in length. Large woody trunks are absent. Amber occurs as isolated ‘pebbles’ and as *in-situ* resinous material in cones and stems. Germinating seedlings also occur. A few plants display insect damage. Most floral remains are attributed to material that has drifted short distances, presumably from freshwater tributaries. Portions of stems with leaves in near pristine condition are suggestive of storm damage. Entire plants suggest undercutting by rivers or flushing from vegetated beds of ephemeral streams.

Palaeoenvironment

The absence of benthic fauna in the Nova Olinda Member suggests that bottom waters were inhospitable. The high quality of preservation is attributed in part to the concomitant lack of benthic scavengers, but also to early diagenesis in anoxic and perhaps hypersaline bottom water.

A lack of detrital sediment in the Nova Olinda Member suggests that deposition occurred some distance from the palaeoshoreline. However, at Tatajuba the unconformable contact with metamorphic basement lacks detrital sediments suggesting that runoff from the basin margins was negligible. An alternative hypothesis is that the water was deep and that the surrounding basement was also inundated.

Floral remains suggest a semi-arid hinterland, as do some of the terrestrial invertebrates (e.g. scorpions and solifuges). Some spiders indicate riparian settings, as do emergent hydrophytes such as the isoetalians. Thus a picture of the Nova Olinda Member hinterland is one of a semi-arid, rocky terrain with steep flanks and a river valley with lush riparian margins. Gymnosperm forests probably dominated the flora together with gnetophytes, both exhibiting xerophytic characteristics.

Depending on water depth the Nova Olinda water body would have had a complex margin of peninsulars and inlets of drowned valleys with archipelagos of granite basement, if a ‘shallow’ model applies. However, if a ‘deep’ water model applies, then the water body may have been considerably larger and extended between the Pernambuco and Aurora fault zones, with a north to south width of > 60 km.

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