Stonechat

The Magazine of
Horsham Geological Field Club

Volume 23, Part 1
June 2012

Planetary Penetrators

HORSHAM GEOLOGICAL FIELD CLUB

OFFICERS AND COMMITTEE 2011/12

President **Dr Ellis Owen**
64 Collingwood Road, Horsham, RH12 2QW
(01403 252265) ellis.owen@talk21.com

Vice President **Frank Diggon**
26 Ashleigh Road, Horsham, RH12 2LF
(01403 254100) frankdiggon@btinternet.com

Lecture Programme Co-ordinator **Mrs. Beryl Jarvis**
Orchard Cottage, Warnham Lodge, Northlands Road, Warnham, Horsham RH12 3SQ (01403 254549) b.jarvis549@btinternet.com

Hon. Secretary **Mrs. Gill Woodhatch**
42 Redford Avenue, Horsham, RH12 2HJ
(01403 250371) r.woodhatch@uwclub.net

Hon Treasurer **Mrs. Janet Owen**
19 Rowan Way, Horsham, RH12 4NS
(01403 263224) janthegan@hotmail.co.uk

Field Trip Secretary **Mike Webster**
7 Gander Hill, Haywards Heath RH16 1QU
(01444 417143) mikewebster566@btinternet.com

Librarian **Mrs. Valerie Bell**
24 Byerley Way, Worth, Crawley, RH10 7YU
(01293 882969) bells@campanile210.fsnet.co.uk

Magazine Editor **John Morton**
7 Windmill Close, Horsham, RH13 6BY
(01403 261304) john@pontius.freeserve.co.uk

Corps de chiens et de chiennes

Bill Luck, 2 Newlands Road, Crawley, RH11 8AL (01293 517130)

Mrs Susan Reese, Jackdaws Field, Park Lane, Maplehurst, Horsham RH13 6LL (01403 891624) – mob. 07976 280683) sue@jackdawsfield.co.uk

John Stace, 32a North Road, Three Bridges, Crawley, RH10 1JX
(01293 533945) christine.johnstace@gmail.com

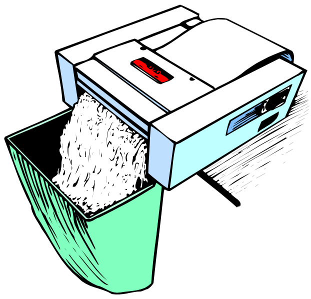
WEB SITE : http://www.hgfc.uwclub.net/Index.html
Annual subscription: £14 due in April or £2 per lecture
Stonechat paper copy: extra £2 per annum

STONECHAT

Volume 23, Part 1 - June 2012

CONTENTS

Editorial



Please note our new website address: www.hgfc.uwclub.net/Index.html

Our Christmas Party now seems a long time ago, but this is the first opportunity to report on it. Twenty-nine Members enjoyed an excellent spread and puzzled over a general knowledge quiz, one on nursery rhymes and riddles and twenty questions based on the Paris Métro network. Many of the streets in Paris are named after national heroes and their associated Métro stations therefore carry famous names (Spike Milligan would have suggested that the streets derive their names from the famous Métro stations beneath them!). Thus the quiz became a test of historical knowledge and seemed to be enjoyed by all

The party in full swing – clockwise from the glass: Terry Tamplin,
Joan Tamplin, Janet Owen, Pamela Hebden, Mark Morton and John Morton
(Photo: Peter Webster)

(Back)

The Roffey Experience

At Milennium Hall (it's in Roffey,
And I can't spell Millenium for toffee),
The Club's Christmas party
Had food good and hearty,
Washed down with fine wine, tea and coffee.

The price of each course was a quiz,
Which put certain brains in a tizz.
We argued, I fear
When the answers weren't clear:
"Yes it is!"…"No it's not!"…"Yes it is!"

(Our quizmaster claimed that "Miss Daw
Had a 'Jacky' astride her see-saw –
It's in black and white!"
We thought, "That's not right –
Your dictionary's got a slight flaw…")

In Paris, Le Métro's jaw-dropping:
A network designed for Le Shopping!
Full of names out of history,
The clues were a mystery
As we traced out its routes, station-hopping.

To earn puddings, we'd questions designed
To seek out the Club's mastermind;
"But it's too late at night
To be terribly bright;
Where's our *puddings*?" the membership whined.

With full stomachs and worn-out grey matter,
Our ears full of sociable chatter,
The evening of fun
Was soon over and done,
And we left – just a *little* bit fatter…

Gordon

****

(Back)

Experience is something you don't get until just after you need it.

Planetary Penetrators
and the search for other life in the Solar System

Our talk for the evening of 11 January 2011 was presented by Dr Rob Gowen of the Mullard Space Science Laboratory on behalf of the Penetrator Consortium.

Dr Gowen commenced his talk by explaining which organisations currently constitute the Consortium and its purpose. They are developing kinetic micro-penetrators to investigate solar system bodies. The penetrators are small rocket shaped probes which impact planetary bodies at high speed and bury themselves 3-4 metres below the surface. The small size (5-15kg) enables them to be deployed at several targets in the area to be studied. They are relatively cheap to build and being small are also cheap to launch. The U.K. has the great advantage of experience of high impact technology from military sources. Numbered among the disadvantages are a limited lifetime, telemetry difficulties and impact survival.

The Consortium currently consists of 160 staff. Examples of U.K. organisations involved are the following:-
Mullard Space Science Lab. (MSSL)
Birkbeck College London – science
Imperial College – London – micro-seismometers
Quinetic – impact, power and communications technologies.
There are also 6 international partners.

The purpose of these investigations is to discover whether we are alone in the universe, the origin of life and the best chance of finding life other than on Earth.

The penetrators comprise a new tool in the toolbox of planetary exploration. An example of the instruments used is the micro-seismometer which was shown as being about the size of a pound coin. The information gained from the instruments, well below the surface being studied, is relayed back to the orbiter which launched the penetrator. Dr Gowen admitted there have been no successful missions to date, but no great failures either! This is due to cancellations for various reasons of Japanese, Russian and American based projects.

Dr Gowen then outlined the history of the Consortium from its beginnings in 2002 to the present day.
He showed us images of the testing of penetrators at Pendine, a military area on the coast, west of Swansea. They were mounted on a rocket

sled and launched along a track at very high speed into a dry sandbox. This measured 2m x 2m x 7m and had a small entrance aperture at the front. Dr Gowen then produced two samples. When fully fitted out with the instrumentation and necessary equipment, the weight was 13 kilos. They were about 600mm long and 110mm in diameter. One of the samples on display had been used in the tests and it was very interesting to see the abrasions and distortions of the casing. The estimated depth of penetration into the sand box was about 4 metres. Three examples have been tested, all of which survived.

Prime planetary targets.

The Moon
MoonLITE is a proposed collaboration between U.K and NASA. There will be four penetrators launched to previously unexplored areas. The main objectives are the search for water and to probe the structure of the interior.

Europa (moon of Jupiter)
Here, there is an ocean under the ice, which has a high tidal force and is a good contender for life.

Enceladus and Titan (moons of Saturn)
Enceladus is a very small moon which is covered in ice and which appears to reflect sunlight to an astonishing degree. Data was collected on the Cassini mission in 2006. There are detected sodium salts which appear to spew out from the south pole. It is thought that liquid water may be present just below the surface. It experiences tidal contortions while orbiting Saturn, the energy known to be produced results in a 'hot spot' at the south pole. There are also big cracks there from which immense plumes of material are ejected.

Titan is twice the size of our moon and has a very dense atmosphere. It has mountains, lakes (methane?) and dunes. It has a seasonal weather system and is known to be very cold – 94º Kelvin. A tandem mission to these two moons has been proposed to ESA whose approval or otherwise is expected very soon. A mission to Mars is being considered for 2018.

After answering members' questions, Dr Gowen then allowed us to examine the two examples which were most interesting. Many of our speakers have shown us samples, but none, I think, quite like these!

Valerie Bell

****

(Back)

Dust is mud with the juice squeezed out

Getting Stuck In

Proposals submitted by the UK Penetrator Consortium (led by a UCL group at the Mullard Space Science Laboratory) under the ESA Cosmic Vision program envisage half-metre-long "micro-penetrators" being deployed from orbiters and directed at around 300 m/s straight down into the top few metres of the surface of unsuspecting Solar System bodies. They have included "MoonLITE", in which interesting parts of our own Moon would be impacted by four penetrators, and later ideas for gathering data from moons of Saturn and Jupiter. At the moment, though, they're still just proposals…

Look out, Enceladus! Look out on Titan!
Look out, the Moon's old regolith dust!
They're planning to fire a whopping great bullet
To penetrate into your unwary crust.

Europa, as well, is a possible target –
The Jovian moon with a cold icy shell
Whose surface has cracks, caused by huge tidal forces,
Through which might leak water – organics as well?

"Is it life, Jim, but not as we know it, perhaps?"
Is one question they really would like to get solved:
Not Little Green Men; but *molecules* instead –
Indicators that life of some sort has evolved.

On the Moon, they'd be looking for evidence of water,
Especially in craters lying close to its poles,
And probing the far side's untested geology
With their sleek high-velocity ESA moles.

But maybe the whole thing is not going to happen –
Will it lie dormant, along with MoonLITE?
Can Europe support such a grand 'Cosmic Vision'
When government cash is so terribly tight?

Gordon

(Back)

****

Cricket is becoming popular in Wales –
one difference – you can be out LLBW

In the past, pompous, ignorant and conceited Englishmen would say “Africa begins at Dover”. Today we know rather better – however Africa does <u>*not*</u> *begin on the southern edge of the Mediterranean Sea. In fact it begins along a line across northern Italy in the foothills of the Alps – The Insubric Line).*

Periadriatic Seam (The Insubric Line) – from Wikipedia

The Periadriatic Seam (or fault) is a distinct geologic fault in Southern Europe, running *S-shaped* about 1000 km from the Tyrrhenian Sea through the whole Southern Alps as far as Hungary. It forms the division between the Adriatic plate (part of Africa) and the European plate. The term Insubric line is sometimes used to address the whole Periadriatic Seam, but it is more commonly used to mean just a western part of it.

Relief of the Alps, and the Periadriatic Seam

Tectonics and geology

Within the Eastern Alps, the line marks the border between the Central Eastern Alps and the Southern Limestone Alps. In the Western Alps it forms the division between the southern Apulian foreland and the central crystalline zones of the Alps.

Continental collision is still going on, with the Apulian and European plates still converging. Movement along the Periadriatic Seam is the cause for the earthquake zone between Vienna and Friuli. Meanwhile, the central zones of the Alps are rising too, causing vertical slip along the fault. The result is the set of major fault zones collectively named Periadriatic Seam. The uplift caused violent erosion of the young orogen, which led to the formation of the Hohe Tauern window. At several regions a heavy uplift of the Central Alps by some kilometres took place, and also a shift of more than 50 km.

The Insubric Line, where two Continents meet - on the left hand, high metamorphic rocks from continent Europe, on the right hand, ultramafic rocks from Africa (Adria)

Photo by Luca.m

(Back)

****

Valerie Bell's Mnemonic:

Cambrian Come	**Ordovician** Over	**Silurian** Soon	**Devonian** Darling
Carboniferous Cutting	**Permian** Perming	**Triassic** Trimming	**Jurassic** Jane
Cretaceous Creates	**Palaocene** Perfection	**Eocene** Even	**Oligocene** On
Miocene My	**Pliocene** Pay	**Pleistocene** Punctuality	**Holocene** Holds

(Back)

****

Geological Time and Astronomical Distances are difficult to conceive, so scientists devise models to help people appreciate their scale – for example, if the World were the size of a tennis ball – Andy Murray would be enormous!

Three Dimensional Seismic Surveys: A sub-surface Google Earth

For the February lecture, the room was full, despite the fact that we had to brave sub-zero temperatures, icy roads and packed snow. This gave an opening for the first light-hearted comment of the evening by our lecturer, Chris Elders, of the Royal Holloway College, whose specialism is petroleum geology. He observed that part of his teaching took place in Tyumen, Russia, and the conditions outside seemed those we could expect in Siberia.

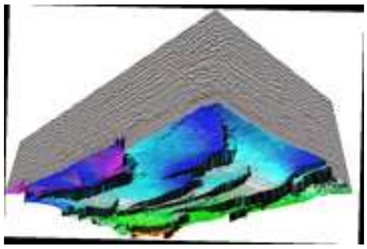
Chris was discussing 3-D seismic surveying. Whilst much of his involvement related to the application of seismic surveying to the petroleum industry, the data that was produced and then released had applications to pure geological investigation. He made brief comment on the advances made since the early 1980s. Seismic surveys had then been limited to defining the extent of proven fields. The exponential increase in computing power and resultant graphical interpretation has paved the way for the production of complex 3-D images. He made the point that many laptops currently have the processing power of the huge mainframes of the 1980s. Thus the interpretation of complex data can now be facilitated.

These subterranean images are, of course, of considerable interest to those seeking deposits of oil and gas. The better your seismic data and subsequent interpretation, the less money is wasted on drilling down to unproductive horizons, given that it can cost £6m to £10m to drill a well. He suggested that there is a 70% probability of drilling a successful well nowadays, which compares to 30% in earlier times.

For the next part of his talk, he outlined how the seismic data was applied to a subterranean block. Then followed a series of superb images. First we saw the raw 2-D seismic reflection pattern, and then a 3-D interpretative image after the data had been processed. He chose examples from a number of places around the world, the North Sea, Namibia, Australia. In these examples, he showed the presence of familiar geological structures, such as complex faults, in those subterranean deposits.

As ever, there was an interested and lively question and answer session. Yet again we are grateful to an eminent speaker who braved the weather to travel down to Horsham, and to share with us the latest advances in geological research. Christine Stace gave the vote of thanks.

Note: Chris kindly sent me the images overleaf - examples taken from South-East Australia used in his talk as a pdf file. I can make them available to any member.



Peter Webster

(Back)

****

A feminine fan

(It was on one of Chris Elders' slides, but if you blinked (and your spouse didn't have the same name), you'd have missed it.)

Around 62 million years ago, sea levels were falling and the northern North Sea was being stretched by tectonic forces. It began to split and a chunk of it sank lower, forming the Central Graben. Over time, it filled with sediments which included a large outpouring of sands and clays from the Moray Firth area. This 'tongue' of Scottish debris spread out into a fan on the sea floor which now has its own feminine moniker. It appeared fleetingly on a slide at a recent lecture on 3-D seismic surveying.

In the North Sea, a fan has been seen
By a seismic surveying machine –
It's a sediment tongue
Formed when mammals were young.
And the fan has a name: it's Maureen!

Gordon

(Back)

****

Not a lot of people know that!

International System of Units

Kilo (K)	=	3 zeros	Mega (M)	=	6 zeros	Giga (G)	=	9 zeros
Tera (T)	=	12 zeros	Peta (P)	=	15 zeros	Exa (E)	=	18 zeros
Zetta (Z)	=	21 zeros	Yotta (Y)	=	24 zeros			

Unusual Microfossils

Adrian Rundle made a return visit to the Society for the March Lecture. However, the first visit was a long time ago, when he ran a workshop on Microfossils using the labs and microscopes in Collyers Sixth-Form College.

At the onset, he posed the rhetorical question “So what are microfossils?” Various definitions were offered, but Adrian has settled arbitrarily on those fossils between 1.4mm and 0.05mm. The upper limit is defined by those that will fit on his microscope stage, and the lower by the smallest which can be comfortably studied by conventional microscopes. And his definition of a fossil? That which is found in a deposit.

Adrian went on to consider the various groups of animals which can be found, rarely whole, but more usually in tiny parts, in suitable deposits. To put this into perspective, we were amused by his interpretation of “enormous” as 2mm in diameter.

Probably the most familiar microfossils are Foraminifera, those single cell creatures with a calcareous shell. There are also the Ostracods, which are small Crustacea with twin valves, and a hard part which can remain preserved in a deposit.

His attention then transferred onto creatures which at first sight have no obvious hard parts suitable for preservation. However, Adrian, stressing the word “bits” showed examples which he had studied in detail, pointing out that many had “bits” suitable for preservation as a fossil.

We were all surprised to learn that Brittle Stars have 5000 tiny plates per arm. Our audience estimate only reached 754 at most. Sea Cucumbers also have plates in their skins, and for some species these plates are the diagnostic in naming the species.

But what of worms? These would appear to be so soft-bodied that nothing can be preserved. Adrian demonstrated the presence in some worms of chitinous jaws, and these “bits” can be preserved. We were amused by his graphic description of the means whereby a worm can extend its gut to deploy it jaws.

Yet other parts can leave a fossil record. For example, in fish there are otoliths, or ear-stones. Others, such as the Opossum Shrimp have balancing stones in their tails. All these are preserved as microfossils.

For Sponges, Corals and Sea-Squirts, it is the siliceous spicules which remain.

Finally, we turned to a consideration of Isopod droppings. Although soft themselves, these can leave identifiable impressions on a soft matrix. In his pursuit of "pure science", Adrian shared with us his great delight and clearly impressive manipulative skills, in dissecting the anal parts of Woodlice in order to account for the distinctive shape of the droppings. The culmination of this ground-breaking research is that these animals excrete sideways, and who is to gainsay this?

This was a splendid and informative evening. Adrian is clearly extremely knowledgeable and has a considerable enthusiasm for his subject, which he is able to put across in a humorous and unassuming manner. We are most grateful for his visit.

Peter Webster

****

(Back)

Undescribed

(I resisted the urge to do a piece on the faecal peculiarities of woodlice, and came up with this instead:)

Micropalaeontologists deal with the miniscule hard parts of long-dead organisms. One type of such fragments is called an otolith, or 'earstone', a tiny concretion which once acted as a gravity sensor within the inner ear of its host. Once the subtle differences in their form have been described in the literature, they can tell an expert, like Dr. Adrian Rundle, what species they came from. (Dr. Rundle's inquisitive nature has also driven him to examine similar present-day organisms, including woodlice!) Somewhere in his vast collection are a couple of unusual squid otoliths from Bracklesham Bay whose descriptions have not yet been published. He will, he says, get round to it one day. Can't be soon enough for one of them…

I'm an undescribed species from Bracklesham Bay;
An anonymous otolith, me,
From the ear of a squid. I told it which way
Was 'up', and which 'down', in the sea.

I'd a *purpose* in life, and that was terrific,
But my squid has long rotted away.
I'm an 'earstone' of sorts, but nothing specific –
What species I am, none can say.

Microfossil I may be, but I still have my pride,
And I'm desperately seeking ID.
Put me under you microscope, peer down inside,
And describe to the world what you see.

All things have descriptions, from microbes to men,
So please, Dr. Rundle, go to it:
Stop messing with woodlice, pick up your pen –
It's a tough job, but someone must do it.

Gordon

(Back)

****

The Earth Pyramids of Euseigne

(Photo: Erik Eshuis)

Euseigne lies in Val d'Hérens, a side valley of the Rhône 7 km. south of Sion, near the world's highest dam, the Grande Dixence. The earth pyramids of Euseigne are one of Switzerland's most important geological sights and are protected monuments.

The fascinating earth formations at the entrance to the small Valaisian village of Euseigne cannot be overlooked: the valley's main road leads directly through them. The earth cones are 10 to 15 metres high and most of them are protected by a rock lodged on the top. The cones were created in the end phase of the last Ice Age, about 80,000 to 10,000 years ago.

When the ice retreated, glacier tongues left enormous piles of debris behind, which contained boulders. Rain and meltwater gradually freed these boulders. While the water continued to erode and carve out the area surrounding the boulders, these rocks served as protective caps for the soil underneath them, enabling the formation of the well-known natural monuments.

For your diary:

Sat. 16th June Newhaven. Leader David Bone (small charge for handouts). Meet at the end of the Newhaven Harbour Car Park, 12noon (charge for parking). This trip entails a lot of walking, firstly along the cliff top to Peacehaven, then back along the beach (very fossiliferous).

Sun. 15th July Summer Social. Picnic at Wakehurst Place. Meet 11.30am at the entrance. Adults £12 Children and NT members free. Possibility of a group ticket if enough people attend.

Sun. 9th Sept. **Smokejacks - Weald Clay brick pit.** Meet 10.30. Hard hats and high vis jackets compulsory. Let Peter Austin know if you are going. p.austin26@btinternet.com
(Back)

The Chalk Revolution

Our speaker for the meeting on April 11th was Professor Rory Mortimore. He recently retired after 40 years of worldwide experience in engineering geology, and in May 2012 he will become President of the Geological Association.

He commenced his talk by showing us a map of the extent of chalk formed in the Cenomanian period, which is the lowest stage of the Upper Cretaceous, 98mya. Deposits are found in the U.S, Australia, Greece, eastern Mediterranean and north-west Europe. A well-known example in our area is, of course, Beachy Head.

Chalk is a soft, very pure limestone compound composed mainly of calcite, and is of marine origin. It comprises an accumulation of minute fossil plants and animals, in particular foraminifera and coccoliths. We were shown a beautiful illustration of a coccosphere – made up of coccoliths. These lived floating near the surface of the ancient sea. Rory referred to turquoise blooms of coccoliths. On death they sank to the bottom, where they combined with bottom-living bivalves to form chalk.

There are many regions of chalk in England, all very different. However, research has shown that the formation of chalk, flint and associated fossils is the same in the London area as on the North Downs, South Coast and Chilterns. This knowledge has proved invaluable in surveying and planning tunnels for transport and sewerage systems in the London area. Aquifers are also being re-examined, as chalk is the main source of water in the south of England. Water flows horizontally along the flint layers into the aquifers, which may be eroded. Cameras lowered down boreholes reveal the state of chalk erosion. Many boreholes are needed in survey work, as flint deposits may be very large and are some twenty-five times harder than the surrounding chalk, a factor which causes great difficulties for tunnel-boring machines. One particular band of flint is 50m deep under the Thames.

Rory then proceeded to discuss the various tunnel systems in the London area.

Crossrail

This is a major engineering project in London. It is planned to link Maidenhead and Heathrow in the west with Shenfield and Abbey Wood in the east. There will be approximately 21 km of tunnel which will cross the river near the Woolwich Ferry. Considerations and hazards to be aware of include the geology, existing tunnels and unexploded bombs!

Rory then spoke of two major schemes planned to deal with London's sewerage problems. The original sewers were planned by the great Victorian civil engineer, Sir Joseph William Bazalgette. The idea was prompted largely by the 'Great Stink' of 1858, which resulted in the closure of Parliament. The enormous improvement in the cleanliness of the Thames resulted in a great reduction in cholera.

The Lee Tunnel
This will be created to deal with the largest combined sewer overflow point at Abbey Mills Pumping Station at Stratford. The boring machine used will create a 7-metre-wide tunnel.

The Thames Tunnel
This will deal with the thirty-four most polluting combined sewer overflows along the Thames between west London and Beckton Sewerage Treatment Works. It will be sixty-seven metres below ground and will mostly follow the route of the Thames.

Stonehenge

Rory then turned our attention to the tunnel which had been proposed situated on the A303 near Stonehenge. Surveys comprising the drilling of several boreholes were conducted in 2001, 2002 and 2003. The results showed that there would be many problems to be overcome. The first of these was the flooding of the trial pits and therefore possible flooding of the tunnel. The second was the discovery of phosphatic sand mixed with chalk. These deposits are very rare but the one in this location is the thickest in Europe. Phosphatic chalk becomes weaker when wet and is somewhat radioactive.

The conclusion was that the project revealed a unique geology, which is unfortunately not really suitable for tunnelling. A fuller description of this topic may be read in the account given of Professor Mortimore's earlier talk in *Stonechat* – Vol.17 Part 3, September 2006.

After members' questions, John Lonergan thanked Rory for a most interesting talk.

Valerie Bell

(Back)

****

What do you call a dinosaur with an extensive vocabulary? A thesaurus.

Boring Chalk

For a tunneller, certain Chalk strata have undesirable characteristics, such as the presence of hard flints or sand-like phosphatic chalk. Tunnelling is expensive, but so are delays and damage to tunnel boring machines which hit unexpected geology. So engineers planning to tunnel through the Chalk have two conflicting objectives: minimum cost and maximal information. Professor Rory Mortimore told a recent meeting how he uses selective borehole drilling to achieve a balance between them, and offered some sage advice.

As I might have said before, Professor Rory Mortimore
Is just the guy you need to give a talk
On the varied lithographics and the complex statigraphics
Of that soft, white, porous limestone we call Chalk.

Inspired, perhaps, by moles, he is happy boring holes
But examines every core for tell-tale signs:
In cold and draughty shacks, he looks for fossils, flints and cracks
To check it stratigraphically aligns -
With exposures, known to most, on our sunny Sussex coast,
Where the flint and marl bands show in all their glory.
That way he gets a clue about what tunnellers must do.
But *visual* correlation's *half* the story.

Borehole geophys is the latest thing there is –
It can spot phosphatic chalk. And, what is more,
Cameras can record all the layers freshly bored,
As back-up to each frail, extracted core.
Initially, he'll drill his boreholes far apart, until
A sequence goes against his expectation.
Then, because it's made him warier,
He drills more in that area,
So tunnellers have better information.

"Expect the unexpected; be excited, not dejected
If things don't always turn out as they should;
For knowledge must advance by serendipity and chance,
It's much less fun if everything 's understood!"

Gordon

(Back)

Milankovitch cycles - from *Wikipedia*

Milankovitch theory describes the collective effects of changes in the Earth's movements upon its climate, named after Serbian civil engineer and mathematician Milutin Milanković, who worked on it during First World War internment. Milanković mathematically theorized that variations in eccentricity, axial tilt, and precession of the Earth's orbit determined climatic patterns on Earth through orbital forcing.

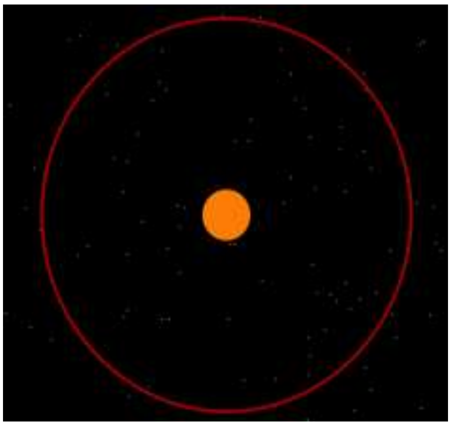
The Earth's axis completes one full cycle of precession approximately every 26,000 years. At the same time the elliptical orbit rotates more slowly. The combined effect of the two precessions leads to a 21,000-year period between the astronomical seasons and the orbit. In addition, the angle between Earth's rotational axis and the normal to the plane of its orbit (obliquity) oscillates between 22.1 and 24.5 degrees on a 41,000-year cycle. It is currently 23.44 degrees and decreasing.

Other astronomical theories were advanced by Joseph Adhemar, James Croll and others, but verification was difficult due to the absence of reliably dated evidence and doubts as to exactly which periods were important. Not until the advent of deep-ocean cores and a seminal paper by Hays, Imbrie, and Shackleton, "Variations in the Earth's Orbit: Pacemaker of the Ice Ages", in *Science* (1976) did the theory attain its present state.

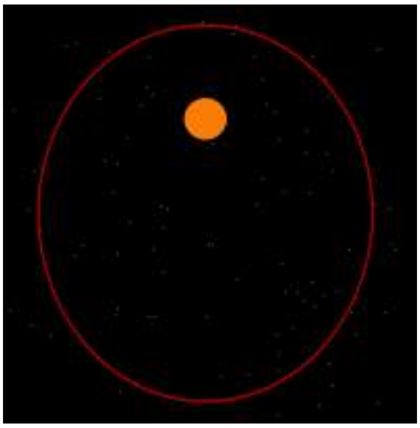
Earth’s movements

As the Earth spins around its axis and orbits around the Sun, several quasi-periodic variations occur due to gravitational interactions. Although the curves have a large number of sinusoidal components, a few components are dominant. Milankovitch studied changes in the orbital eccentricity, obliquity, and precession of Earth's movements. Such changes in movement and orientation alter the amount and location of solar radiation reaching the Earth. This is known as *solar forcing* (an example of radiative forcing). Changes near the north polar area, about 65 degrees North, are considered important due to the great amount of land, which reacts to such changes more quickly than the oceans do. Land masses respond to temperature change more quickly than oceans, which have a higher effective capacity because of the mixing of surface and deep water and the fact that the specific heat of solids is generally lower than that of water.

The Earth's orbit is an ellipse. The eccentricity is a measure of the departure of this ellipse from circularity. The shape of the Earth's orbit varies in time between nearly circular (low eccentricity of 0.005) and mildly elliptical (high eccentricity of 0.058) with the mean eccentricity of 0.028. The major component of these variations occurs over a period of 413,000 years (eccentricity variation of ±0.012). A number of other terms vary between components 95,000 and 125,000 years (with a beat period 400,000 years), and loosely combine into a 100,000-year cycle (variation of −0.03 to +0.02). The present eccentricity is 0.017.



Circular orbit, no eccentricity



Orbit with 0.5 eccentricity

If the Earth were the only planet orbiting our Sun, the eccentricity of its orbit would not perceptibly vary even over a period of a million years. The Earth's eccentricity varies primarily due to interactions with the gravitational fields of Jupiter and Saturn. As the eccentricity of the orbit evolves, the semi-major axis of the orbital ellipse remains unchanged. From the perspective of the perturbation theory used in celestial mechanics to compute the evolution of the orbit, the semi-major axis is an adiabatic invariant. According to Kepler's third law, the period of the orbit is determined by the semi-major axis. It follows that the Earth's orbital period, the length of a sidereal year, also remains unchanged as the orbit evolves. As the semi-minor axis is decreased with the eccentricity increase, the seasonal changes increase. But the mean solar irradiation for the planet changes only slightly for small eccentricity, due to Kepler's second law.

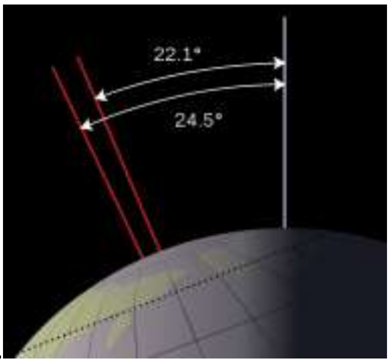
The same average irradiation does not correspond to the average of corresponding temperatures (due to the non-linearity of the Stefan-Boltzmann law). For an irradiation with corresponding temperature 20°C and its symmetric variation ±50% (e.g. from the seasons change) we obtain asymmetric variation of corresponding temperatures with their average 16°C (i.e. deviation −4°C). And for the irradiation variation during a day (with its average corresponding also to 20°C) we obtain the average temperature (for zero thermal capacity) −113°C.

The relative increase in solar irradiation at closest approach to the Sun (perihelion) compared to the irradiation at the furthest distance (aphelion) is slightly larger than four times the eccentricity. For the current orbital eccentricity this amounts to a variation in incoming solar radiation of about 6.8%, while the current difference between perihelion and aphelion is only 3.4% (5.1 million km). Perihelion presently occurs around January 3, while aphelion is around July 4. When the orbit is at its most elliptical, the amount of solar radiation at perihelion will be about 23% more than at aphelion.

Orbital mechanics requires that the length of the seasons be proportional to the areas of the seasonal quadrants, so when the eccentricity is extreme, the Earth's orbital motion becomes more nonuniform and the lengths of the seasons change. When autumn and winter occur at closest approach, as is the case currently in the northern hemisphere, the earth is moving at its maximum velocity and therefore autumn and winter are slightly shorter than spring and summer. Thus, summer in the northern hemisphere is 4.66 days longer than winter and spring is 2.9 days longer than autumn. But as the orientation of Earth's orbit changes relative to the Vernal Equinox due to apsidal precession, the way the lengths of the seasons are altered by the nonuniform motion changes, since different sections of the orbit are involved. When the Earth's apsides are aligned with the equinoxes, the length of Spring and Summer (together) equals that of Autumn and Winter. When they are aligned with the solstices, either Spring and Summer or Autumn and Winter will be at their longest. Increasing the eccentricity lengthens the time spent near aphelion and shortens the time near perihelion.

Changes to the eccentricity do not by themselves change the length of the anomalistic year or the Earth's mean motion along its orbit, since they are both functions of the semi-major axis. The angle of the Earth’s axial tilt (obliquity of the ecliptic) varies with respect to the plane of the Earth’s orbit. These slow 2.4° obliquity variations are roughly periodic, taking approximately 41,000 years to shift between a tilt of 22.1° and 24.5° and back again. When the obliquity increases, the amplitude of the seasonal cycle in insolation increases, with summers in both hemispheres receiving more radiative flux from the Sun, and winters less. Conversely,when the obliquity decreases, summers receive less insolation and winters more.

But these changes of opposite sign in summer and winter are not of the same magnitude everywhere on the Earth's surface. At high latitude, the annual mean insolation increases with increasing obliquity, while lower latitudes experience a reduction in insolation. Cooler summers are suspected of encouraging the onset of an ice age by melting less of the previous winter's precipitation.



.
22.1–24.5° range of Earth's obliquity.

Because most of the planet's snow and ice lies at high latitude, it can be argued that lower obliquity favours ice ages for two reasons: the reduction in overall summer insolation and the additional reduction in mean insolation at high latitude.

Scientists using computer models to study more extreme tilts than those that actually occur have concluded that climate extremes at high obliquity would be particularly threatening to advanced forms of life that presently exist on Earth. They noted that high obliquity would not likely sterilize a planet completely, but would make it harder for fragile, warm-blooded land-based life to thrive as it does today.

Currently the Earth is tilted at 23.44 degrees from its orbital plane, roughly halfway between its extreme values. The tilt is in the decreasing phase of its cycle, and will reach its minimum value around the year 10,000 CE. This trend, by itself, tends to make winters warmer and summers colder with an overall cooling trend leading to an ice age, but the 20th-century instrumental temperature record shows a sudden rise in global temperatures and a concurring glacial melt has led some to attribute recent changes to greenhouse gas emissions.

Axial Precessional

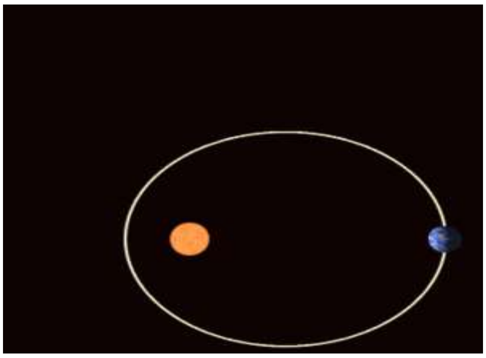
Precession is the trend in the direction of the Earth's axis of rotation relative to the fixed stars, with a period of roughly 26,000 years. This gyroscopic motion is due to the tidal forces exerted by the Sun and the Moon on the solid Earth, which has the shape of an oblate spheroid rather than a sphere. The Sun and Moon contribute roughly equally to this effect.

When the axis points toward the Sun in perihelion, one polar hemisphere has a greater difference between the seasons while the other has milder seasons. The hemisphere that is in summer at perihelion receives much of the corresponding increase in solar radiation, but that same hemisphere in winter at aphelion has a colder winter. The other hemisphere will have a relatively warmer winter and cooler summer.

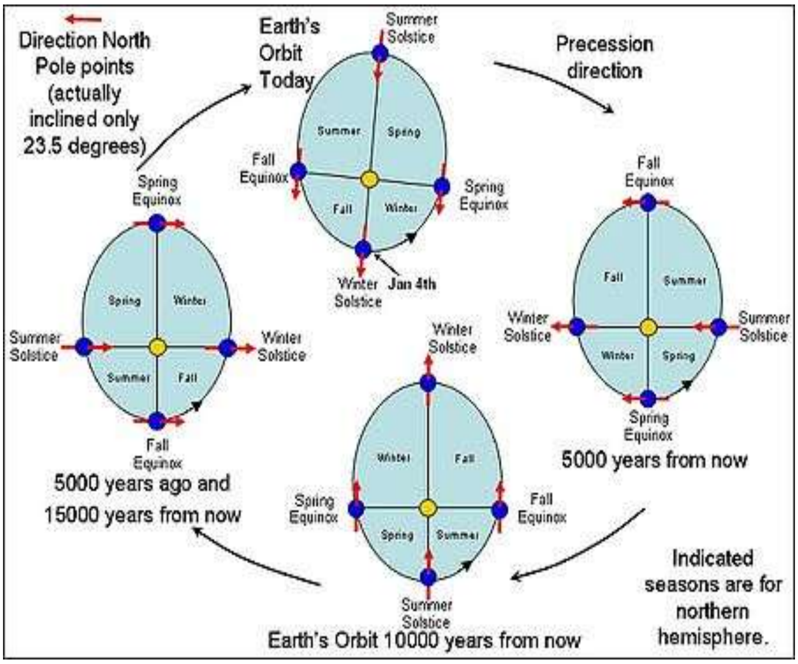
When the Earth's axis is aligned such that aphelion and perihelion occur near the equinoxes, Northern and Southern Hemispheres will have similar contrasts in the seasons.

At present, perihelion occurs during the southern hemisphere's summer, and aphelion is reached during the southern winter. Thus the southern hemisphere seasons are somewhat more extreme than the northern hemisphere seasons, when other factors are equal.

Apsidal precession



Planets orbiting the Sun follow elliptical (oval) orbits that rotate gradually over time (apsidal precession). The eccentricity of this ellipse is exaggerated for visualization. Most orbits in the Solar System have a much smaller eccentricity, making them nearly circular. In addition, the orbital ellipse itself precesses in space, primarily as a result of interactions with Jupiter and Saturn. This orbital precession is in the same sense to the gyroscopic motion of the axis of rotation, shortening the period of the precession of the equinoxes with respect to the perihelion from 25,771.5 to ~21,636 years. Apsidal precession occurs in the plane of the Ecliptic and alters the orientation of the Earth's orbit relative to the Ecliptic. In combination with changes to the eccentricity it alters the length of the seasons.



Effects of apsidal precession on the seasons

Orbital Inclination

The inclination of Earth's orbit drifts up and down relative to its present orbit. Milankovitch did not study this three-dimensional movement. This movement is known as "precession of the ecliptic" or "planetary precession".

More recent researchers noted this drift and that the orbit also moves relative to the orbits of the other planets. The invariable plane, the plane that represents the angular momentum of the solar system, is approximately the orbital plane of Jupiter. The inclination of Earth's orbit drifts up and down relative to its present orbit with a cycle having a period of about 70,000 years. The inclination of the Earth's orbit has a 100,000 year cycle relative to the invariable plane. This is very similar to the 100,000 year eccentricity period. This 100,000-year cycle closely matches the 100,000-year pattern of ice ages.

It has been proposed that a disk of dust and other debris exists in the invariable plane, and this affects the Earth's climate through several possible means. The Earth presently moves through this plane around January 9 and July 9, when there is an increase in radar-detected meteors and meteor-related noctilucent clouds.

A study of the chronology of Antarctic ice cores using oxygen-nitrogen ratios in air bubbles trapped in the ice, which appear to respond directly to the local insolation, concluded that the climatic response documented in the ice cores was driven by northern hemisphere insolation as proposed by the Milankovitch hypothesis (Kawamura et al., *Nature*, 23 August 2007, vol 448, pp 912–917). This is an additional validation of the Milankovitch hypothesis by a relatively novel method, and is inconsistent with the "inclination" theory of the 100,000-year cycle.

The nature of sediments can vary in a cyclic fashion, and these cycles can be displayed in the sedimentary record. Here, cycles can be observed in the colouration and resistance of different strata.

Problems

Because the observed periodicities of climate fit so well with the orbital periods, the orbital theory has overwhelming support. Nonetheless, there are several difficulties in reconciling theory with observations.

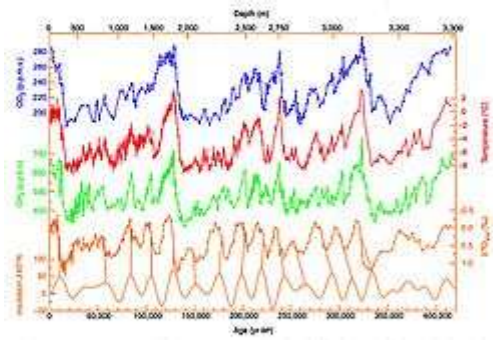
The **100,000-year problem** is that the eccentricity variations have a significantly smaller impact on solar forcing than precession or obliquity and hence might be expected to produce the weakest effects. The greatest observed response is at the 100,000-year timescale, while the theoretical forcing is smaller at this scale, in regard to the ice ages. However, observations show that during the last 1 million years, the strongest climate signal is the 100,000-year cycle. In addition, despite the relatively great 100,000-year cycle, some have argued that the length of the climate record is insufficient to establish a statistically significant relationship between climate and eccentricity variations. Various explanations for this discrepancy have been proposed, including frequency modulation or various feedbacks (from carbon dioxide, cosmic rays, or from ice sheet dynamics). Some models can reproduce the 100,000 year cycles as a result of non-linear interactions between small changes in the Earth's orbit and internal oscillations of the climate system.

The **400,000-year problem** is that the eccentricity variations have a strong 400,000-year cycle. That cycle is only clearly present in climate records older than the last million years. If the 100ka variations are having such a strong effect, the 400ka variations might also be expected to be apparent. This is also known as the **stage 11 problem**, after the interglacial in marine isotopic stage 11, which would be unexpected if the 400,000-year cycle has an impact on climate. The relative absence of this periodicity in the marine isotopic record may be due, at least in part, to the response times of the climate system components involved—in particular, the carbon cycle.

The **stage 5 problem** refers to the timing of the penultimate interglacial (in marine isotopic stage 5) which appears to have begun ten thousand years in advance of the solar forcing hypothesized to have caused it (the **causality problem**).

Effect exceeds cause

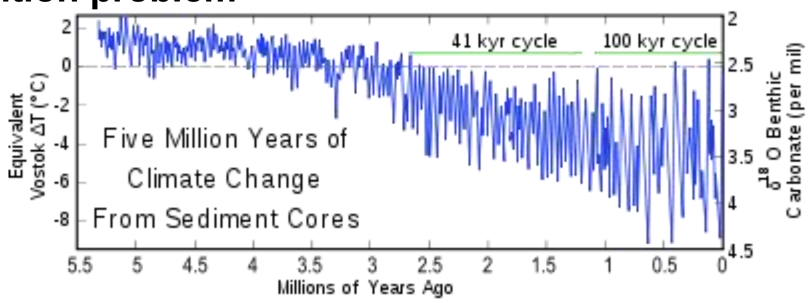
The effects of these variations are primarily believed to be due to variations in the intensity of solar radiation upon various parts of the globe. Observations show climate behavior is much more intense than the calculated variations. Various internal characteristics of climate systems are believed to be sensitive to the insolation changes, causing amplification(positive feedback) and damping responses (negative feedback).



420,000 years of ice core data from Vostok, Antarctica research station.

The unsplit peak problem refers to the fact that eccentricity has clearly resolved variations at both the 95 and 125ka periods. A sufficiently long, well-dated record of climate change should be able to resolve both frequencies, but some researchers interpret climate records of the last million years as showing only a single spectral peak at 100ka periodicity. It is debatable whether the quality of existing data ought to be sufficient to resolve both frequencies over the last million years.

The transition problem



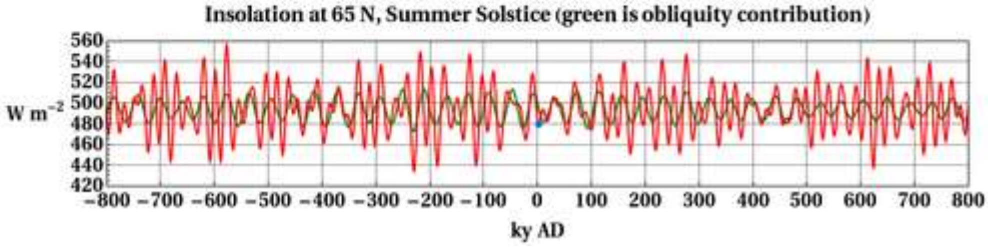
Variations of Cycle Times, curves determined from ocean sediments

The **transition problem** refers to the switch in the frequency of climate variations 1 million years ago. From 1–3 million years, climate had a dominant mode matching the 41ka cycle in obliquity. After 1 million years ago, this switched to a 100ka variation matching eccentricity, for which no reason has been established.

Identifying dominant factor

Milankovitch believed that decreased summer insolation in northern high latitudes was the dominant factor leading to glaciation, which led him to (incorrectly) deduce an approximate 41ka period for ice ages. Subsequent research has shown that the 100ka eccentricity cycle is more important, glaciation over the last few million years resulting in 100,000-year ice age cycles of the Quaternary.

Present and future conditions



Past and future of daily average insolation at top of the atmosphere on the day of the summer solstice, at 65 N latitude. The green curve is with eccentricity *e* hypothetically set to 0. The red curve uses the actual (predicted) value of *e*. Blue dot is current conditions, at 2 ky AD

As mentioned above, at present, perihelion occurs during the southern hemisphere's summer and aphelion during the southern winter. Thus the southern hemisphere seasons should tend to be somewhat more extreme than the northern hemisphere seasons. The relatively low eccentricity of the present orbit results in a 6.8% difference in the amount of solar radiation during summer in the two hemispheres.

Since orbital variations are predictable, if one has a model that relates orbital variations to climate, it is possible to run such a model forward to "predict" future climate. Two caveats are necessary: that anthropogenic effects may modify or even overwhelm orbital effects; and that the mechanism by which orbital forcing influences climate is not well understood.

The amount of solar radiation (insolation) in the Northern Hemisphere at 65° N seems to be related to occurrence of an ice age. Astronomical calculations show that 65° N summer insolation should increase gradually over the next 25,000 years. A regime of eccentricity lower than the current value will last for about the next 100,000 years. Changes in northern hemisphere summer insolation will be dominated by changes in obliquity ε. No declines in 65° N summer insolation, sufficient to cause a glacial period, are expected in the next 50,000 years.

An often-cited 1980 study by Imbrie and Imbrie determined that, "Ignoring anthropogenic and other possible sources of variation acting at frequencies higher than one cycle per 19,000 years, this model predicts that the long-term cooling trend which began some 6,000 years ago will continue for the next 23,000 years."
More recent work by Berger and Loutre suggests that the current warm climate may last another 50,000 years.

The best chances for a decline in northern hemisphere summer insolation that would be sufficient for triggering a glacial period is at 130,000 years or possibly as far out at 620,000 years.
(Back)

AGM Report - May 9th 2012

The Club Report was read by the Secretary: Beryl Jarvis was thanked for the quality of our speakers. Our Public Lecture by Chris Stringer was a great success. Special thanks to Mike Webster for setting up facebook and taking on the post of Field Trip Secretary following Geoff Toye's illness. The Summer Social was a success despite the awful weather. The Christmas party was enjoyed by all and John Morton and Terry Tamplin were thanked for organising the quizzes. Dorothy and Peter Webster, and Chris Luck were thanked for the smooth running of the lecture meetings and John Morton and Rod Woodhatch for Stonechat and the Website. All the Committee and auditor were thanked.

The Club accounts showed a surplus of £184.97 for the year.

A unanimous vote of thanks was given to Geoff and Gillian Toye for their many years of fantastic trips and outings. This year Fairlight, Warnham, Peterborough and Sheppey had been visited.

The standing committee and auditor were re-elected.

A.O.B.

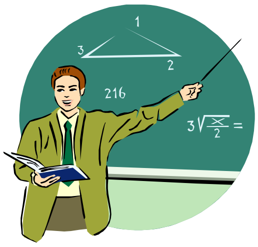
a) The longstanding problem of how to make best use of our library was discussed, and It was agreed that the library list be posted on the website for easy access. T. Tamplin asked if members might help with a cull by voting for each entry once this has been done. The Secretary would let members know when the list was uploaded. Other comments: Are the contents of the library relevant? Should new local guides and specifically the New Wealden Guide be purchased?

b) The longstanding problem of recruiting new committee members was raised. Some current members intend to stand down next year so new faces are needed. It was proposed that the duration of committee membership be shortened so that potential new members are not put off by the commitment. New blood is essential for the continuation of a vibrant club. Seeking new committee would continue through the year.

c) Comments were invited for the instigation of fewer issues and two formats of 'Stonechat'.

There was general agreement that having an electronic copy improved the presentation and diagrams. Members were happy with bi-annual issues.
(Back)

The Club’s Programme 2012



Wed. Jan. 11	**Planetary Penetrators - and search for other life in the Solar System** - Dr Rob Gowan, Mullard Space Science Laboratory
Wed. Feb. 8	**3D Seismic Data: a subsurface Google Earth** – Prof. Chris Elders, Dept of Earth Sciences U.C.L., Royal Holloway College
Wed. Mar.14	**Unusual Microfossils -** Dr Adrian Rundle, Learning Curator, The Natural History Museum
Wed. Apr. 11	**The Chalk Revolution** – Prof. Rory Mortimore, Emeritus Professor of Geology, University of Brighton
Wed. May 9	**A.G.M.**
Wed. Jun. 13	**William Buckland** – Dr.Chris Duffin, Streatham & Clapham High School
Wed. Jul. 11	**High resolution biochronology of the Inferior Oolite of Dorset** - Bob Chandler
Wed. Sep. 12	**"Bluebell Railway: Reaching East Grinstead" –** David Barry of DLB Environmental
Wed. Oct. 10	**Impact cratering & ejecta deposits** – Dr Kieran Howard, Dept of Mineralogy, The Natural History Museum
Wed. Nov. 14	**The Geology and Scenery of the Isle of Mull** – Lesley Collins, U3A
Sat. Dec. 8	**Christmas Party** – Millennium Hall, Roffey, 7.30-11pm

(Back)

Club meetings

Unless otherwise stated, all evening meetings are held at Forest Community School, Comptons Lane, Horsham at 7 for 7.30pm. To ease the Treasurer's mind, we ask for a nominal contribution of 20p for coffee and biscuits.

Field trips

Field trips require appropriate clothing: waterproofs, stout boots or Wellingtons. All geological sites are potentially dangerous and Members are reminded that they attend field trips at their own risk.
Any children attending are the sole responsibility of parents or guardians. It is always advisable to telephone a Committee Member, if you are coming on a field trip, in case there are any last minute changes.

Equipment for Field Trips

Some UK sources of tools, clothing and other equipment for field trippers are:

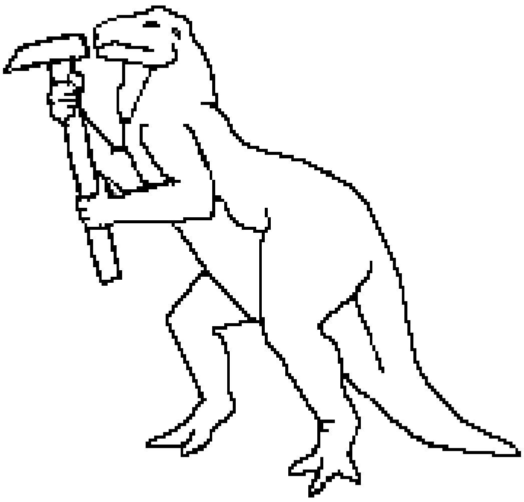
GA Enterprises Ltd. (Geological Association) Order online at :
http://www.geologistsassociation.org.uk/Merchandise.html.
UKGE (UK Geological Equipment) (Freephone 0800 0336 062)
Order online at http://www.ukge.co.uk/
Geo Supplies Ltd., 16 Station Road, Chapeltown, Sheffield S30 4XH (0114 245 5746). Order on line at http://www.geosupplies.co.uk/)

Geological Maps and Area Guides:

British Geological Survey, Keyworth, Nottingham NG12 5GG
(0115 936 3241). Order online at:
http://www.bgs.ac.uk/services/bookshop_and_pubs.html
Maps available from **Geological Museum Bookstall,** Exhibition Road, London SW7 2DE and **Geologists' Association**, Burlington House, Piccadilly, London W1 V 9AG (020 7434 9298)
http://www.geologistsassociation.org.uk/index.html

Tide Predictions:

UK Hydrographic Office, Admiralty House, Taunton, Somerset
TAI 2DN (01823 723366). Free tide predictions for six days ahead are available online at:
http://easytide.ukho.gov.uk/easytide/EasyTide/SelectPort.aspx.



(Back)

Edited by:
John Morton FGS
Brocken Spectre
7 Windmill Close
Horsham
West Sussex
RH13 6BY
(01403 261304)
john@pontius.freeserve.co.uk