Hastings & District Geological Society Journal

Hastings and District Geological Society
affiliated to the Geologists' Association

President
Professor G. David Price, UCL

Founded 1992

HDGS members walking past Lee Ness Ledge, east of Hastings - June 2009

Volume 15 December 2009

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2009 Officials and Committee

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Hastings & District Geological Society Website - http://www.hastingsgeolsoc.org.uk

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Cover picture: Cliffs east of Lee Ness Ledge, east of Hastings - photo: Peter Austen

Contributions for next year's Journal would be appreciated and should be submitted by the October 2010 meeting. Please contact Peter Austen on: tel: 01323 899237 or e-mail: p.austen26@btinternet.com

HASTINGS & DISTRICT GEOLOGICAL SOCIETY

Minutes of the A.G.M. - 14th December 2008

The Meeting was declared open at 2.45 p.m. by the Chairman, Ken Brooks. There were thirty-one members present.

1) **Apologies:** Were received from:
Roger Blaker, Trevor Devon, Marilyn Hadley, Pauline Mackay-Danton, Vivien Morel, Colin Parsons and Jim Priestley.
Welcome: Ken welcomed new member Mick Kavanagh.

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

3) **Chairman's report:**

a) 2008 Programme: Ken said that it had been another busy year and he summarised the year's activities:

Lectures by visiting speakers:
'Wealden Fishes' by *Dr.* Peter Forey
'Geology of the Fairlight Landslip' by *Dr.* Jackie Skipper
'Black Smokers and the Origin of Life' by *Dr.* Richard Herrington*
'Amber' by John Cooper
'Lost Chalk of Scotland' by *Prof.* Rory Mortimore
'Mud, Mud, Glorious Mud' by *Prof.* David Price

Members' Day talks:
'Planetary Geology' by Gordon Elder
'Identifying Minerals' by Ken Brooks

Field Trips:
New Year's Day Walk
Betteshanger Colliery
Beachy Head
Barbecue Party

*Ken explained that Dr. Richard Herrington had had to cancel this lecture at the last minute and that it had been impossible to find a replacement speaker at such short notice. However, he said that Dr. Herrington had promised to come and give the lecture at our first meeting in 2009.
Ken said that attendances for meetings had been up on the previous year, the average being 28, and the highest 34 (for David Price's *'Mud, Mud, Glorious Mud'*).
Ken thanked Trevor & Fiona Devon for hosting this year's barbecue party.

b) Ken said how impressed he was with the *H.D.G.S. Journal* and thanked Peter and Joyce Austen for all the hard work they had put into producing it. He also thanked all the contributors who had made the publication possible, and said that Peter had already started collecting articles for next year's *Journal*.

c) Ken thanked all the Committee members for their work during the year, and gave a special mention to Siân Elder for helping with the library, and to Diana and Joyce for doing all the teas, coffees and washing up during the year.

d) He asked that if anyone still had a book out from the library, would they please return it as Roger

Blaker, Gordon and Siân would be doing an audit.

e) Ken said that the latest *Down to Earth* and some spare *New Scientist* magazines were also on sale and that all proceeds went into the H.D.G.S. funds.

f) Ken said that during the year a special working Committee had been set up to deal with the *Awards For All* application for a laptop computer, PowerPoint projector, printer, etc., and that it was now almost ready for submission.

g) Regarding the H.D.G.S. website, he said that Trevor Devon had reported that he had had problems with the provider, but that he would be able to update the site himself.

4) **Treasurer's report:**

Diana had typed up Norman Farmer's *Statement of Income & Expenditure for the Year Ending 31st December 2008* which was handed out to members. Norman briefly ran through the items, saying that it was basically a receipts and expenditure account. He said that the 'lecture fees' paid out were mainly just travelling expenses, as the lecturers did not usually charge a fee. He also said that the membership fee would remain the same for the coming year, and mentioned again that the subscription cost had never been increased since the setting up of the Society in 1992.

5) **Election of the Committee:**

Ken asked whether anyone would like to stand for election on to the Committee in any capacity, but there were no volunteers. Therefore he suggested that someone should propose that the Committee be re-elected again *en bloc*. This was proposed by Barbara Young, seconded by Geoff Bennett and unanimously carried. The Committee was said to be as follows:

2008	**2009**
Chairman	
Ken Brooks	Ken Brooks
Treasurer	
Norman Farmer	Norman Farmer
Secretary	
Diana Williams	Diana Williams
Journal editors	
Peter & Joyce Austen	Peter & Joyce Austen
Librarian & Education Officer	
Gordon Elder	Gordon Elder
Website Manager	
Trevor Devon	Trevor Devon
Other Officers	
1. Colin Parsons	Colin Parsons
2. John Boryer	John Boryer

6) **2009 Programme:** Copies were handed out to all members present. Those unable to attend would be receiving their copies with the next letter to members. Ken gave a brief résumé of next year's lectures:

'Black Smokers and the Origin of Life' - by *Dr.* Richard Herrington
'Messel - a World Heritage Site in Germany' - by David Bone
'Fossil Fakes' - by *Dr.* Chris Duffin

'Six Characters in Search of the Geology of East Sussex' - by Tony Brook
Presidential Lecture - by *Prof.* David Price

He said that there would be two Members' Day talks this year, which would be:
'Snowball Earth' - by Ron Elverson
'Making a Mineral Collection' - by Trevor Devon

The 'outings' for 2009 would be:
New Year's Day walk at Fairlight
Field trip to Fairlight Cove
Barbecue Party with Gordon Elder
A behind-the-scenes visit to the Natural History Museum
Another field trip to be arranged

7) **Any Other Business:**

Gordon said that he was scanning all the past lectures and *H.D.G.S. Journals* which he would be putting on to CDs/DVDs.

Ken asked whether anyone would be interested in making up a wordsearch/crossword or something similar for next year's *Journal*.

Ken mentioned the television programme *Fossil Detectives* and said that the Open University had put out an excellent free field guide to accompany the series.

Ken reminded everyone of the New Year's Day Walk which would begin with optional lunch at the Smuggler Pub, Pett, at 12 o'clock. The walk itself would start at 2 p.m. from the Visitors' Centre. He asked members to let us know if they would like to have lunch first as a table had to be booked beforehand.

Ken said that if members would like to pay their annual subscriptions, their money would be gratefully received!

Ken declared the Meeting closed at 3.09 p.m.

HASTINGS & DISTRICT GEOLOGICAL SOCIETY

Statement of Income & Expenditure for the Year Ending 31st December 2008

INCOME

	£
Subscriptions	
2007 (belated)	
Single 1 @ £12.50	12.50
2008	
Single 35 @ £12.50	437.50
Family 12 @ £15.00	180.00
2009 (prepaid)	
Single 2 @ £12.50	25.00
Family 2 @ £15.00	30.00
Donations	5.00
Magazine sales	20.70
Barbecue receipts	130.00
Fossil Walks	20.00
Sale of Minerals chart	3.00
Tributes & Donations (written back)	25.00
	888.70
Deficit being excess of expenditure over income	30.73
	919.43

EXPENDITURE

	£
G.A. Affiliation fees	33.00
Hire of rooms	90.00
Society *Journal* production	136.28
Insurance premium	138.00
Stationery, Copying, Postage	191.16
Lecture fees & Expenses	175.99
Refreshments & Lunches	25.00
Summer barbecue expenses	130.00
	919.43
	919.43

Bank Account and Monies in Hand

Balances as at 31st December 2007

	£
Nat. West Bank	354.05
Monies in hand	84.79
	438.84
Decrease in Balances	30.73
	408.11

Balances as at 31st December 2008

	£
Nat. West Bank	377.22
Monies in hand	30.89
	408.11
	408.11

December 2008

Snowball Earth?
Lapland geology has some answers
by Ron Elverson

Recently, people like Dr Iain Stewart have popularised on television the idea that 700 million years ago the Earth was a snowball, completely covered by ice - the evidence for this being that rocks of this age found around the world all have glacial tillite horizons. In the early 1970s I went on two expeditions to Finnmark in northernmost Norway (Fig. 1). My Geology Department at Oxford was interested in mapping two glacial horizons from that era. In fact the first expedition that I went on was further to the South, near to the reindeer herding township of Karasjok. Here the rocks were metamorphic and igneous rocks from 2,700 million years ago, and the expedition was also to investigate the movement of the ice sheet during the last glaciation, 1 million years ago.

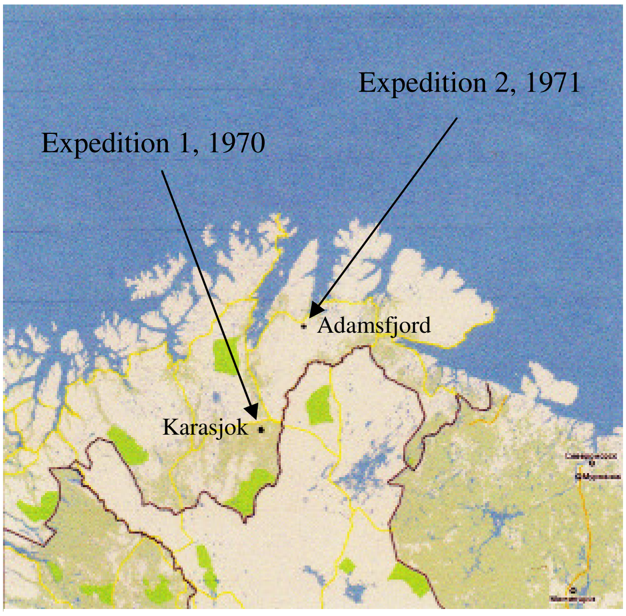


Fig. 1. Location of the two expeditions to Finnmark in northernmost Norway.

Fig. 2. The author near Kiruna, Arctic Sweden in 2006.

It might be imagined that geology in northern Lapland might involve drilling through ice and permafrost to get to the rocks. This photograph (Fig. 2) was in fact taken 3 years ago near Kiruna, Arctic Sweden in February. Our expeditions, however, took place in July, August and September, when things were much warmer, sometimes even getting to 80^0F.

The periods of interest for Finnmark geology were:
2,700 million years ago the Neoarchean when the crystalline rocks which make up the "Precambrian Basement" were formed.
700 million years ago the Cryogenian when a series of shallow marine sediments were laid down, these sediments included the two glacial tillite horizons.
400 million years ago the Caledonian Orogeny when the Cryogenian sediments were folded, with the severity of the folding increasing to the North West. Also highly folded and faulted blocks of basement and older sedimentary rocks were up-faulted and thrust over the Cryogenian sediments.
1 million years ago the Pleistocene Ice Age, when an ice sheet covered the whole area.

The first expedition was to the Karasjok region (Fig. 3). Here the rocks were Precambrian basement 2,700 million years old, consisting mainly of granite, greenschist,

Fig. 3. Location of the first expedition - Karasjok.

amphibolite, gabbro and quartzite. However, it was interesting to also find an outcrop of dolomite. The dolomite had originally been stromatolites which had not only produced dolomite, $Ca(Mg,Fe)(CO_3)_2$, but had also trapped sand. This had been metamorphosed to produce fibrous crystals of Tremolite, in the buff coloured dolomite marble. The presence of dolomite in rocks of this age indicates that life on earth was already playing a significant part in the earth's geology; photosynthesis by blue-green algae was having a profound effect on the earth's atmosphere, decreasing the amount of greenhouse gases, in particular CO_2, and producing oxygen.

We were based at the little settlement of Beivvasgiedde. There was a hut, a shed and a church. During the summer it was deserted except for occasional parties of hikers, but in the winter this is where the Sami (Lapp) reindeer herders bring their reindeer. Today there is a road just north of the river Karasjokka; but in 1970 there was no road, the only way to get all the expedition stores and equipment there was to hire a canoe with an outboard motor, or to hire a tractor and trailer to drive 30 kilometres through the wilderness of scrubby birch and reindeer moss.

My task as the expedition geologist was to identify 100 rocks taken from holes, which were dug every 2½ kilometres, on a grid pattern, into the blanket of moraine that covered the whole area. These would then be matched to a geological map of the area that had been produced four years earlier. From this it was possible to determine which way the ice sheet had moved, namely in a North Easterly direction.

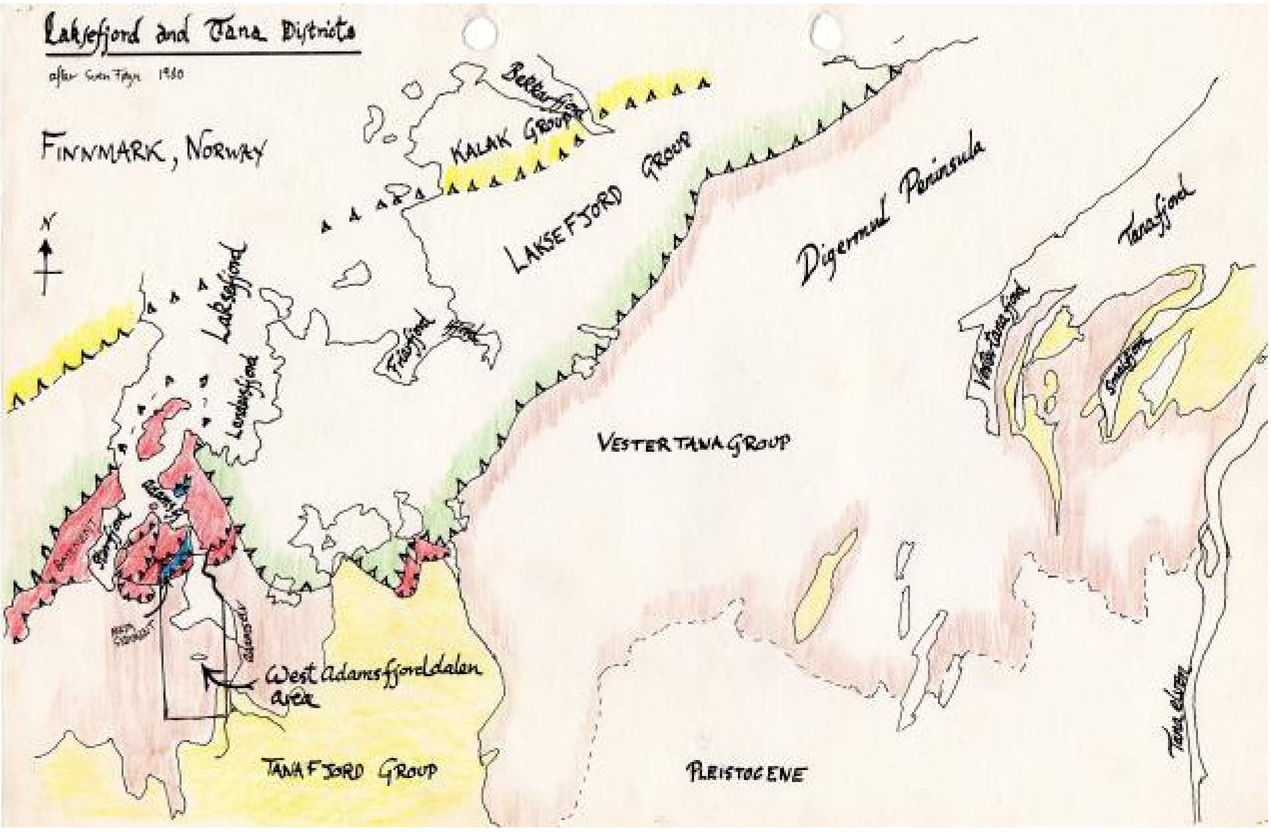


Fig. 4. Laksefjord and Tana Districts (after Sven Føyn, 1960)

The second expedition was further north. Here shallow marine sandstones of the Tanafjord Group (shown in pale yellow in Fig. 4) were overlain by the Vestertana Group (shown in pale brown), which included the two glacial tillite formations. Highly folded metamorphosed phyllites and dolomites of the Laksefjord Group (green), with slabs of Precambrian basement, had been up-faulted and thrust over these rocks from the North West. This represented the North Eastern extent of the Caledonian Orogeny that also affected Scotland, Ireland, Greenland and the Appalachians. The area I was to make a geological map of was Adamsfjorddalen. Only a small part of my area had ever been mapped geologically before; by a Norwegian schoolmaster from Oslo called Sven Føyn. Sven had covered huge areas of northern Norway, mapping the lithologies. He walked at incredible speeds, even on shopping expeditions. Although his identifying and mapping of the different strata was very useful, Sven generally did not use a clinometer, so his maps had no indications of dip or strike.

In the 1970s the only maps available were the 1:100,000 series, which had been produced in 1912 (Fig. 5). At the time the trig points and heights of the hills and mountains had been accurately determined, but the rest of the map had been sketched in. This is an area where the isostatic uplift is one of the greatest in the world, so to use these maps over 50 years after they had been produced meant that many of the heights of the hills could be as much as a metre out. Rivers had changed their courses; lakes had changed their shapes. Consequently I used aerial photographs as the basis for my geological mapping. Satellite mapping was not then available. Aerial photographs have one big disadvantage. High ground is closer to the aeroplane and therefore appears larger scale than the valleys. However, in an open wilderness with no footpaths you can identify each clump of trees and locate yourself very accurately; so long as you keep concentrating the whole time. Once you lose concentration you are lost – one clump of trees then looks just like another. At the top left corner of this map (Fig. 5) the road crosses a bridge. This is Adamsfjordfossen, a spectacular waterfall.

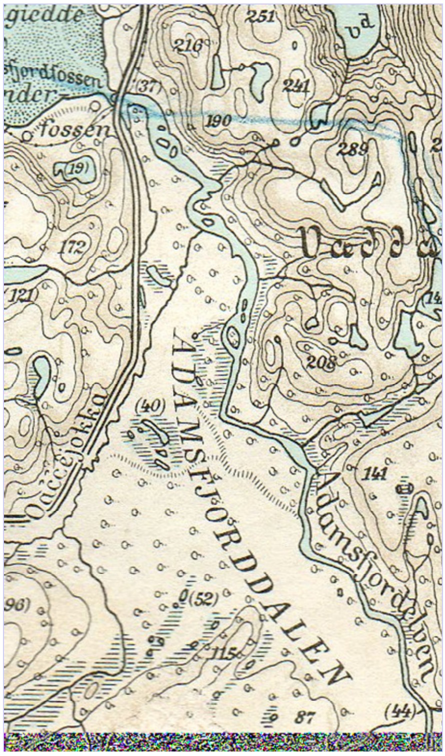


Fig. 5. 1912 map of the Adamsfjord-dalen area (1:100,000).

Fig. 6. Adamsbru, where the Adamselv enters the sea at Adamsfjord.

This photograph (Fig. 6) was taken by a friend of mine Paul Taylor. After his degree Paul went on to get his doctorate measuring radioactive age dates on rocks in Western Greenland. For many years he held the record for dating the oldest rock on earth – an amphibolite 3.9 billion years old. Some marginally older rocks may now have been found across Baffin's Bay in Canada.

The Geology of Adamsfjorddalen

The oldest rocks in the area that I mapped are in the South East corner around Buoiddesguollejarrek. These are shallow marine sediments of the Tanafjord Group. These are overlain unconformably by the first of the glacial horizons, the Smålfjord Tillite, present across the Southern end of the map. When the ice receded the Nyborg formation turbidites formed on deepening slopes under the sea, with high rates of sedimentation. Then the second glaciation eroded into the underlying strata and unconformably laid down the Upper Tillite formation, present as a dark green band across the centre of the map (Fig. 7). Northwest of the Upper Tillite outcrop come the members of the Stappogiedde Formation, shallow marine sandstones. The youngest rocks outcropping are a small area of the Breivik Formation. Sven Føyn found the trace fossil Platysolenites in the Breivik just below the faulted boundary with the Thrust Complex. Platysolenites is a worm casing. It can be found abundantly in Cambrian sediments

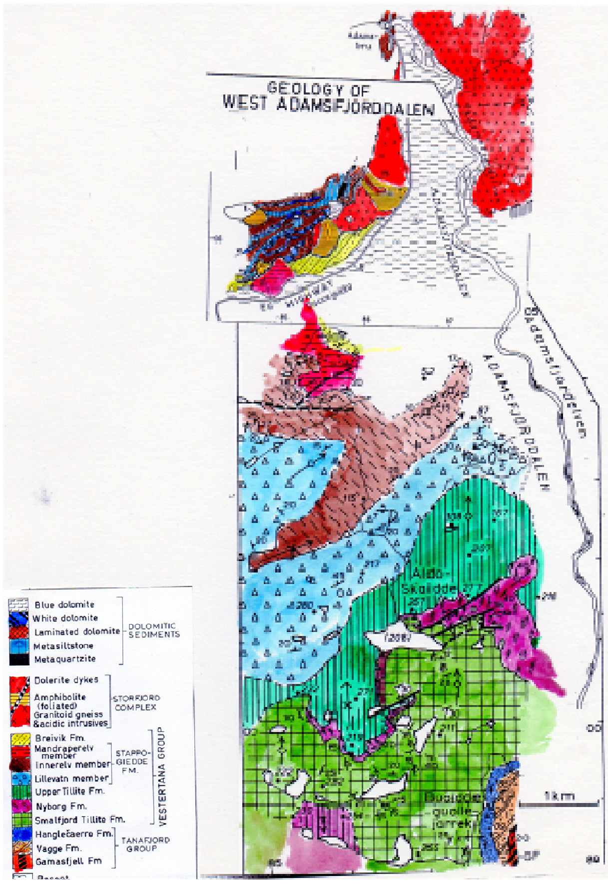


Fig. 7. Geological Map of Adamsfjorddalen, Finnmark, North Norway.

such as the Pipe Rock near Assynt in Scotland. However, it can also be found, more sparsely, in rocks older than the Cambrian of Ediacaran age.

In the North East of the area mapped is the Thrust Complex, consisting of a complex inter-leaving of dolomitic sediments of the Laksefjord Group with plutonic igneous rocks of the Størfjord Group from the Precambrian Basement of Neoarchean age (2,700 million years).

Fig. 8. The view southwards from Aldo Skaidde.

I camped beside a lake at the foot of a hill called Aldo Skaidde. When I first pitched my tent the wind was coming strongly from the West, so I had the tent facing East. The rest of the two months I was based there the wind came strongly from the East! To begin with, other members of the expedition were working South of my area, sharing the campsite. Then they left, and I had the campsite to myself. After a few days camping on my own I decided to join a friend Bob Findlay, who was mapping the next area, and who had found an unlocked road-workers hut to live in. Actually it had been padlocked, but the screws fastening the lock were very loose! Staying in the road-hut meant my walking an extra 11 kilometres each way every day, but at least I had someone to talk with in the evenings and to share ideas with about what we were mapping. The tent stayed where it was pitched.

The view southwards from the top of Aldo Skaidde (Fig. 8) is of both tillite horizons. Aldo Skaidde is largely the Upper Tillite Formation. On the opposite side of the lake is the Smålfjord Tillite. In the East the Nyborg Formation separates the two tillites, but the Nyborg was increasingly eroded, and is eventually completely cut out by the Upper Tillite ice sheet, so that in the West the Upper Tillite lies directly on the Smållfjord Tillite. This made the geological mapping quite difficult, as the two tillites were fairly similar in appearance.

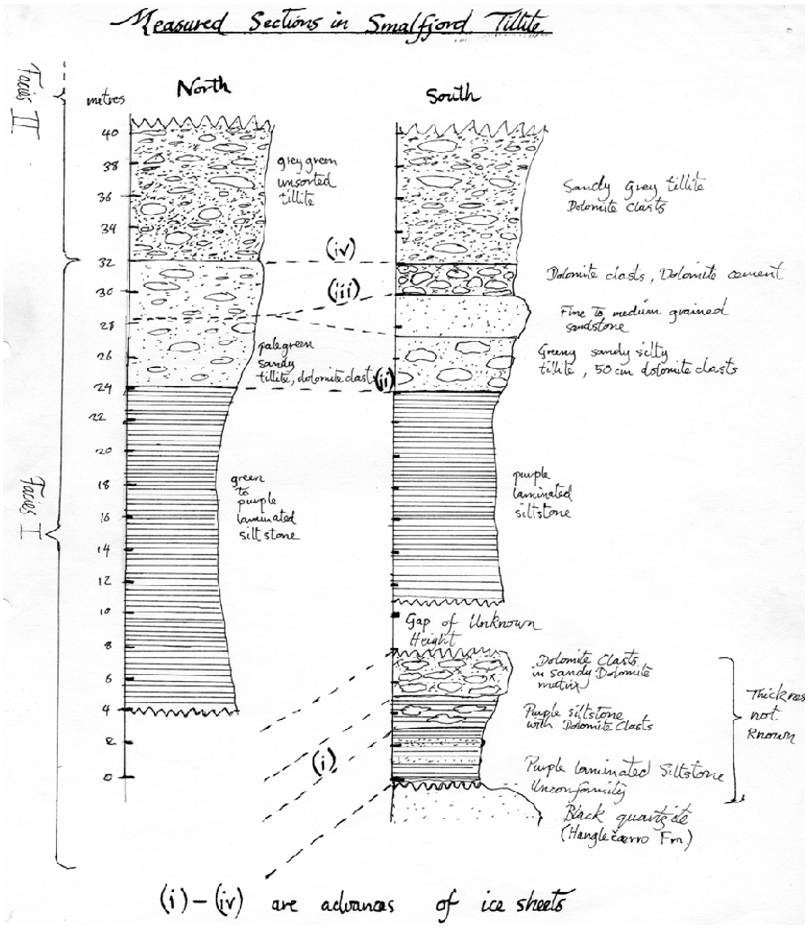


Fig. 9. Measured Sections in ***Smålfjord Tillite****.*

The Smålfjord Tillite comes in a range of rock types (Fig. 9), varying from a laminated siltstone to something that looks rather like dark green concrete. The green colour is due to the state of low degree metamorphism to the Green-schist facies of sediments which may have been eroded from basalts and gabbros. What distinguishes it as a tillite is the presence of clasts of unsorted irregular fragments of rock. The clasts are mostly small, several millimetres to a centimetre in grain size, but they could be larger or indeed sometimes much larger. A few kilometres to the south of the area that I was mapping, some other members of the expedition came across an area of dolomite rock one kilometre in length that did not fit in with any understanding of the stratigraphy. It was surrounded by Smålfjord Tillite. It was interpreted as being a glacial erratic deposited by the Smålfjord ice sheet, in effect a huge clast. But it could also have been an erratic deposited in the last ice age, in the Pleistocene. In one area of the tillite outcrop a fine- to medium-grained quartzitic sandstone was found. This could have been formed as an esker, a stream of melt-water within the ice sheet depositing water-sorted sand.

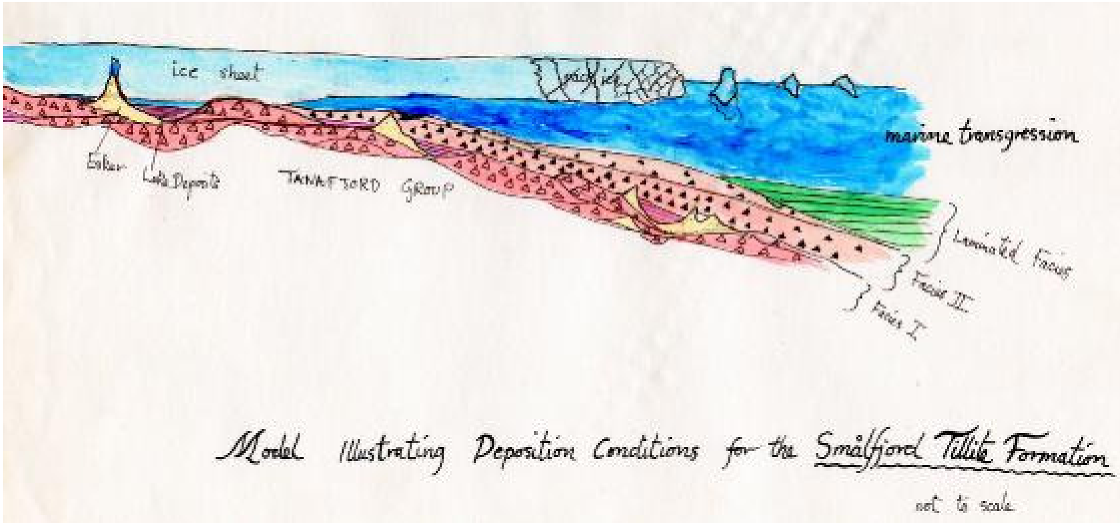


Fig. 10. Model illustrating deposition conditions for the ***Smålfjord Tillite Formation****.*

Figure 10 shows the possible conditions which could have produced the range of rock types found in the Smålfjord Tillite. The Ice sheet is floating on the sea. Where it is furthest from the shore, the clasts fall from the base of icebergs into the silts on the sea floor. The silts are laminated due to the variations between summer and winter; in summer more sediment would be deposited than in winter. The laminations are similar to the growth rings on a tree. This would suggest that there is open water at least for part of the year; in other words that the earth at this time was not a complete snowball.

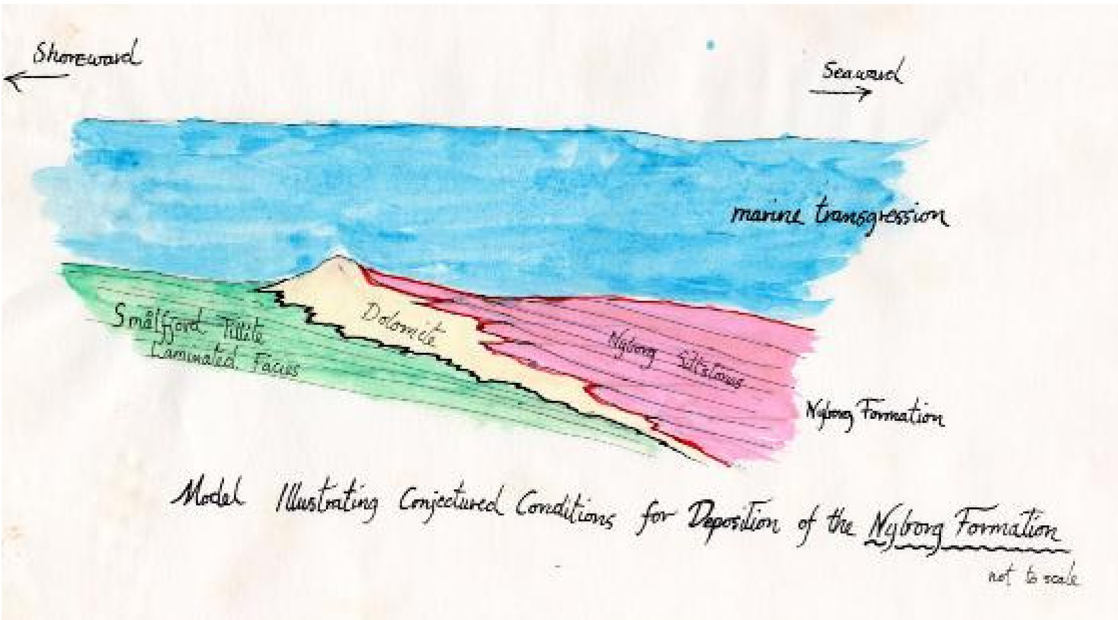


Fig. 11. Model illustrating conjectured conditions for deposition of the ***Nyborg Formation****.*

The Nyborg Formation lies conformably on the Smålfjord Tillite (Fig. 11). What is interesting is that at its base in part of the area was a layer of dolomite. This would have been formed by blue-green algal stromatolites. This suggests that as soon as the ice retreated, algae were able to colonise the shallow sea. Today algae produce limestone in the Persian Gulf, in the Bahamas and on the north coast of Australia, in warm seas.

For over 2 billion years, blue-green algae had been producing oxygen, and decreasing the amount of CO_2 by photosynthesis and by forming carbonate rock. Over the millennia, these processes would have been lowering the surface temperature of the earth, and this must have been one of the causes of the Cryogenian glaciation. However, the presence of a dolomite reef conformably above the tillite would suggest that there must have been open water around during the glaciation and that colonies of algae must have been around in sufficient quantities to be able to take advantage of the retreat of the ice and create a reef almost immediately that the ice went.

The sea then deepened significantly with all the water from the melted ice-sheet. The siltstones of the Nyborg formation have fining upward cycles. Each layer has a sharp base composed of sandier coarser-grained material, which then fines upwards to silt and clay before the cycle repeats. This sort of sedimentary cycle is produced in deep seas where there is a high level of sediment being deposited. Eventually the amount of wet sediment becomes unstable and forms an underwater avalanche, known as a turbidity current, which carries the sediment-laden water many miles. The sediments then settle out, coarser grains first and the finest last. In British geology the rocks produced this way are called greywacke. However, the Nyborg rocks are not grey but a deep reddy purple, similar to the Torridonian in colour. This would be due to having a high iron content, with the iron present as haematite, in its highest oxidation state. The waters in which deposition took place were highly oxygenated.

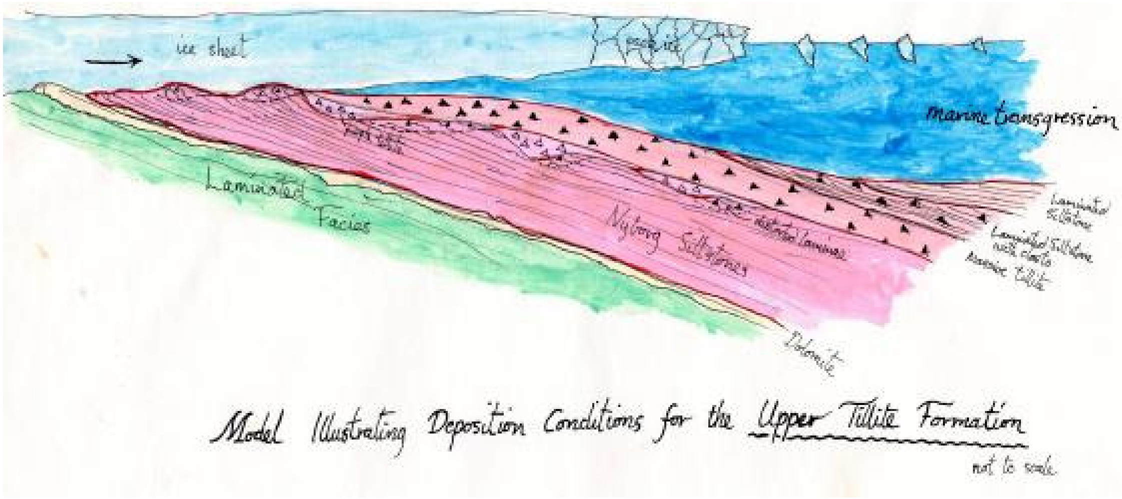


*Fig. 12. Model illustrating deposition conditions for the **Upper Tillite Formation**.*

The Upper Tillite Formation has, in this area, much less variation than the Smålfjord Tillite (Fig. 12). It looks like dark green concrete. As with the Smålfjord Tillite, the green colour is due to the state of low degree metamorphism to the Greenschist facies of sediments, which may have been originally eroded from basalts and gabbros. The absence of esker type structures and laminated siltstones might possibly indicate a much more extensive ice sheet over the sea, which might possibly have covered all the oceans to produce a "snowball earth". However, there is insufficient convincing evidence to base such a hypothesis on from this area.

Caledonian folding

During the Caledonian Orogeny (400 million years ago), the strata was extensively folded and faulted. Folding was mainly on a NNW-SSE axis. These folds were then folded again along a NE-SW axis. The first phase of folding would have been caused by the thrusted slabs of basement further to the West. The second phase of folding would have been caused by the up-faulting of basement in the NW of the area mapped (Fig. 13).

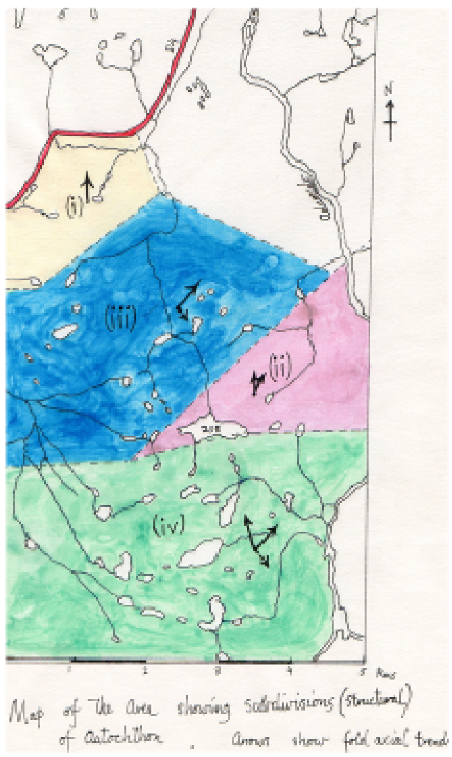


Fig. 13. Directions of folding south of the road. Arrows show direction of fold axes.

The Thrust Complex

Mapping the North West corner of the area (Fig. 14) was very challenging. When I first climbed up the scarp, there were three outcrops near to where I was, within thirty metres of each other. I hammered the first. It was dolomite. I went to the second expecting to find something similar and was surprised to find that it was granite. I went to the third outcrop, wondering if it would be dolomite or granite and it was amphibolites! Every outcrop had to be looked at, and a complex map drawn up (Fig. 14).

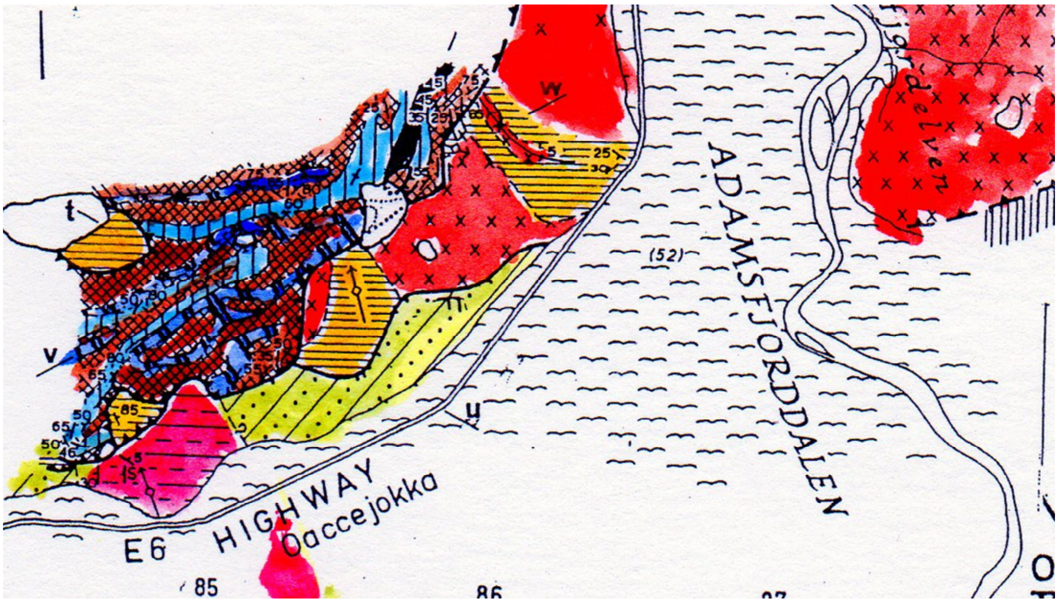


Fig. 14. The Thrust Complex

Here (Fig. 15) metamorphosed dolomites and phyllites have been thrust over granite. The granite is from the Basement (2,700 million years). The dolomites and phyllites are younger, but are older than the rocks that I had been mapping to the South.

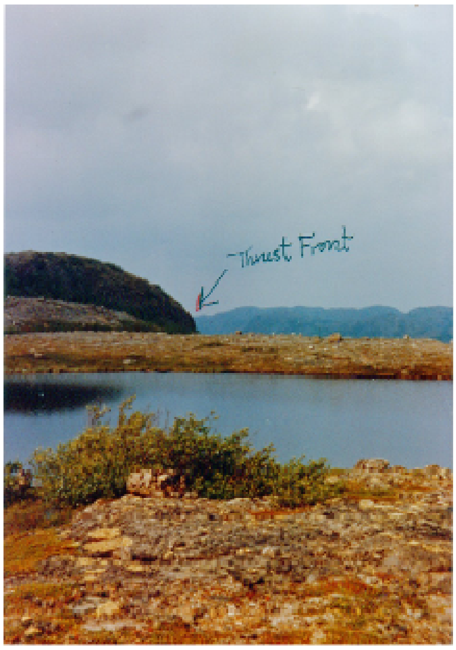


Fig. 15. Caledonian Orogeny - thrust front of metamorphosed sediments over ancient acidic igneous basement.

Fig. 16. Adamsfjorddalen view SE from basic igneous basement.

This is the view from the amphibolite outcrop over the river valley of the Adamselv (Fig. 16).

Fig. 17. Isoclinal folds in metamorphosed dolomite.

The dolomites and phyllites were highly folded, (isoclinal folds – where the slopes of both sides of the folds are parallel; or chevron folds – where they resemble a sergeant's stripes).

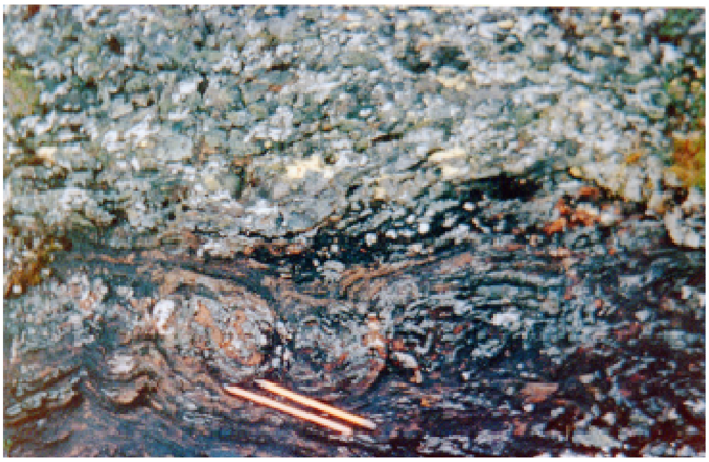


Fig. 18. Complex 2 phase fold structures in laminated dolomite and phyllite.

These tight folds have then been refolded in a complex pattern.

And maybe folded again.

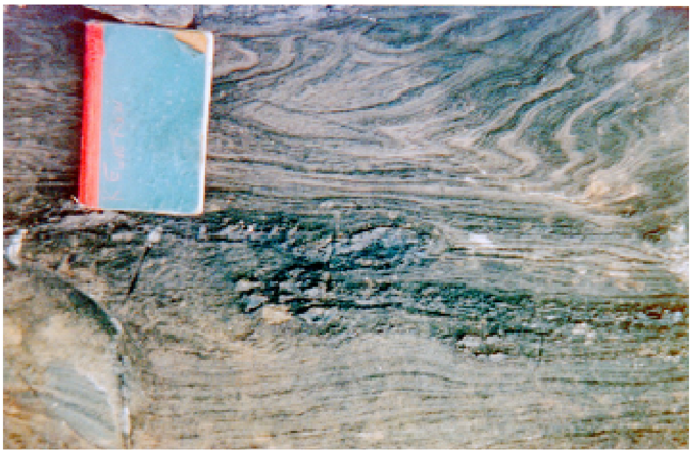
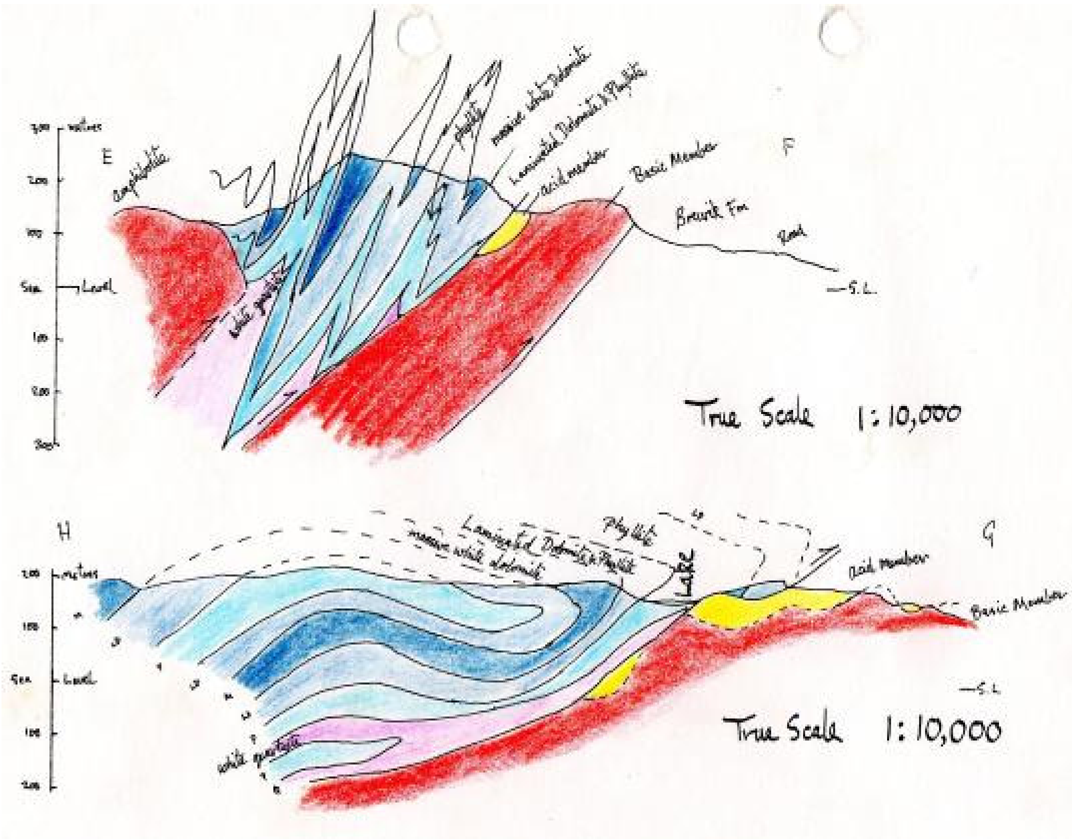


Fig. 19. 2 or 3 phases of folding in laminated dolomite and phyllite.

Fig. 20. 3rd phase fold.

Definitely folded again!

The sections below explain how all these rock types can exist so close together.



So was there a "snowball earth"?

There was certainly a time of extreme glaciation, which came in two episodes. Much of the earth's land-surface was probably covered with ice sheets during both episodes. The first episode was probably not as extensive as the second. The first glaciation probably did not cover all the seas and oceans, and algae were able to rapidly get established as the ice retreated. The second glaciation could possibly have been more extensive. From the rocks of Adamsfjorddalen it would be impossible to say whether the second glaciation would have covered the whole earth or not. But my instinct would be to say that this is unlikely.

Off to do more geology!

Io - Jupiter's volcanic moon

by Gordon Elder

Introduction

Io is the innermost of the four Galilean moons of the planet Jupiter and, with a diameter of 3,642 km, the fourth-largest moon in the Solar System. It was named after Io, a priestess of Hera who became a lover of Zeus in Greek mythology.

With over 400 active volcanoes now detected, Io seems to be the most geologically active object in the Solar System! This extreme geologic activity is thought to be the result of tidal heating from friction generated within Io's interior by Jupiter's varying gravitational attraction. Several volcanoes produce plumes of sulphur and sulphur dioxide that climb as high as 500 km (310 miles). Io's surface is also littered with more than 100 mountains that have been uplifted by extensive compression of the moon's silicate crust. Some of these peaks are taller than Earth's Mount Everest. Unlike most satellites in the outer Solar System (which have a thick coating of ice), Io is primarily composed of silicate rock surrounding a molten iron or iron sulphide core. Most of Io's surface is characterised by extensive plains coated with sulphur and sulphur dioxide frost.

Io played a significant role in the development of astronomy in the 17th and 18th centuries. It was discovered in 1610 by Galileo Galilei, along with the other Galilean satellites (Europa, Ganymede and Callisto). This discovery furthered the adoption of the Copernican model of the Solar System, the development of Kepler's laws of motion, and the first measurement of the speed of light! From Earth, Io remained nothing more than a point of light until the late 19th and early 20th centuries, when it became possible to resolve its large-scale surface features, such as the dark red polar and bright equatorial regions. In 1979, the two *Voyager* spacecraft revealed Io to be a geologically active world, with numerous volcanic features, large mountains and a young surface with no obvious impact craters. The *Galileo* spacecraft performed many close flybys in the 1990s and early 2000s, obtaining data about Io's interior structure and surface composition. These spacecraft also revealed the relationship between the satellite and Jupiter's magnetosphere and the existence of a belt of radiation centered on Io's orbit. Io receives about 3,600 rem of radiation per day. The exploration of Io continued in the early months of 2007 with a distant flyby of the Pluto-bound satellite, *New Horizons*.

Voyager and *Galileo*

Shortly after the encounter with Io, *Voyager* navigation engineer Linda A. Morabito noticed a plume emanating from the surface of Io in one of the images. Analysis of other *Voyager 1* images showed nine such plumes scattered across the surface, proving that Io was volcanically active. This had been predicted in a paper published shortly before the *Voyager 1* encounter by Peale, Cassen and Reynolds (1979), who calculated that Io's interior must experience significant tidal heating caused by its orbital resonance with Europa and Ganymede.

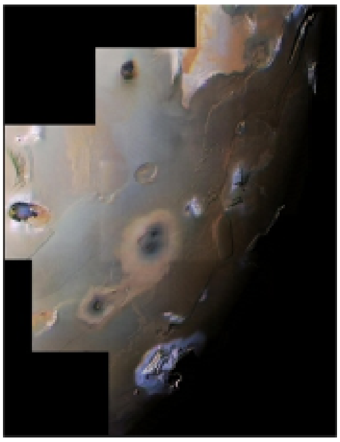


Fig. 1. Mosaic of Voyager 1 *images covering Io's South Polar Region.*

The *Galileo* spacecraft arrived at Jupiter in 1995 after a six-year journey from Earth to follow up on the discoveries of the two *Voyager* probes and ground-based observations taken in the intervening years. *Galileo* detected the effects of a major eruption at Pillan Patera and scientists confirmed that volcanic eruptions on Io were composed of silicate magmas with magnesium-rich mafic and ultramafic compositions, with sulphur and sulphur dioxide serving a similar role to water and carbon dioxide on Earth. Distant imaging of Io was acquired for almost every orbit during the primary mission, revealing large numbers of active volcanoes by detecting both thermal emission from cooling magma on the surface, and also volcanic plumes. It also detected numerous mountains with widely varying morphologies, and several surface changes that had taken place between the *Voyager* and *Galileo* missions and also between *Galileo* orbits.

The *Galileo* mission was extended twice between 1997 and 2002 in order to gather further data on Io. Observations during these encounters revealed the geologic processes occurring at Io's volcanoes and mountains, and demonstrated the extent of volcanic activity. Galileo's magnetometer failed to detect an internal magnetic field at Io. In December 2000, the *Cassini* spacecraft had a distant and brief encounter with the Jupiter system en route to Saturn, allowing for joint observations with *Galileo*. These observations revealed a new plume at Tvashtar Paterae and provided insights into Io's aurorae.

Subsequent observations

The *New Horizons* spacecraft, en route to Pluto and the Kuiper belt, flew by the Jupiter system and Io on 28th February 2007. During the encounter, numerous distant observations of Io were obtained. These included images of a large plume at Tvashtar, providing the first detailed observations of the largest class of Ionian volcanic plume since observations of Pele's plume in 1979. *New Horizons* also captured images of a volcano near Girru Patera in the early stages of an eruption, and several volcanic eruptions that had occurred since *Galileo.*

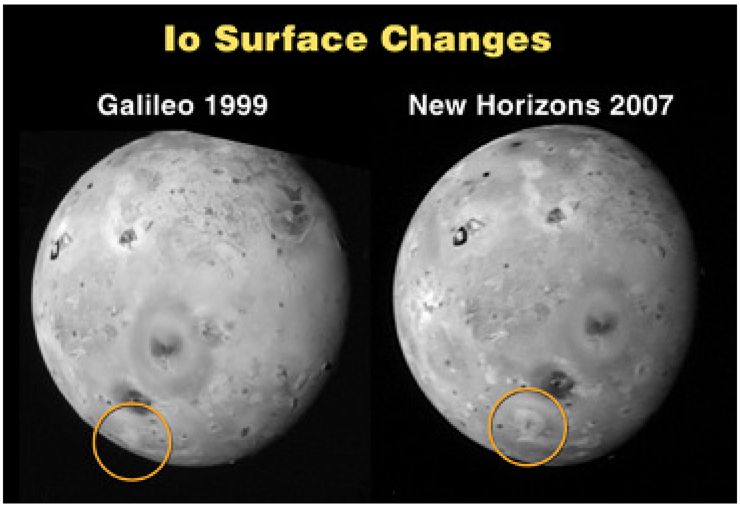


Fig. 2. Changes in surface features in the eight years between Galileo *and* New Horizons *observations.*

Structure

Io is slightly larger than Earth's Moon. It has a mean radius of 1,821.3 km (about 5% greater than the Moon's) and a mass of 8.9319×10^{22} kg (about 21% greater than the Moon's). It is slightly ellipsoid in shape, with its longest axis directed toward Jupiter.

Interior

Io seems to be composed primarily of silicate rock and iron and is closer in bulk composition to the terrestrial planets than to other satellites in the outer solar system, which are mostly composed of a mix of water ice and silicates. Io has a density of 3.5275 g/cm^3, the highest of any moon in the Solar System and significantly higher than the other Galilean satellites. Models based on the *Voyager* and *Galileo* measurements of the moon's mass, radius and quadrupole gravitational coefficients (numerical values related to how mass is distributed within an object) suggest that its interior is differentiated between an outer, silicate-rich crust and mantle and an inner, iron- or iron sulphide-rich core (Fig. 3).

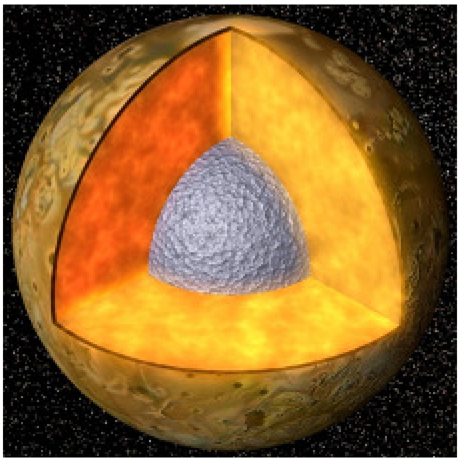


Fig. 3. Model of the possible interior composition of Io with an inner iron or iron sulphide core (in grey), an outer silicate crust (in brown), and a partially molten silicate mantle in between (in yellow and orange).

Modelling of Io's interior composition suggests that at least 75% of the mantle is composed of the magnesium-rich mineral forsterite, and has a bulk composition similar to that of L-chondrite and LL-chondrite meteorites, with higher iron content (compared to silicon) than the Moon or Earth, but lower than Mars. To support the heat flow observed on Io, 10–20% of Io's mantle may be molten, though regions where high-temperature volcanism has been observed may have higher melt fractions. The lithosphere of Io, composed of basalt and sulphur deposited by Io's extensive volcanism, is between 12 km (7 miles) and 40 km (25 miles) thick.

Tidal heating

Unlike the Earth and the Moon, Io's main source of internal heat comes from tidal dissipation rather than radioactive isotope decay; this is the result of Io's orbital resonance with Europa and Ganymede. Such heating is thought to be dependent on Io's distance from Jupiter, its orbital eccentricity, the composition of its interior, and its physical state. Its orbital resonance with Europa and Ganymede maintains Io's eccentricity and prevents tidal dissipation within Io from circularising its orbit. The amount of energy produced is up to 200 times greater than that produced solely from radioactive decay. This heat is released in the form of volcanic activity. Models of its orbit suggest that the amount of tidal heating within Io changes with time, and that the current heat flow is not representative of the long-term average.

Surface

From previous experience with the ancient surfaces of the Moon, Mars and Mercury, scientists expected to see numerous impact craters in *Voyager 1*'s first images of Io. The density of impact craters across Io's surface would have given clues to the moon's age. However, the surface is almost completely lacking in impact craters and is instead covered in smooth plains flecked with tall mountains, pits of various shapes

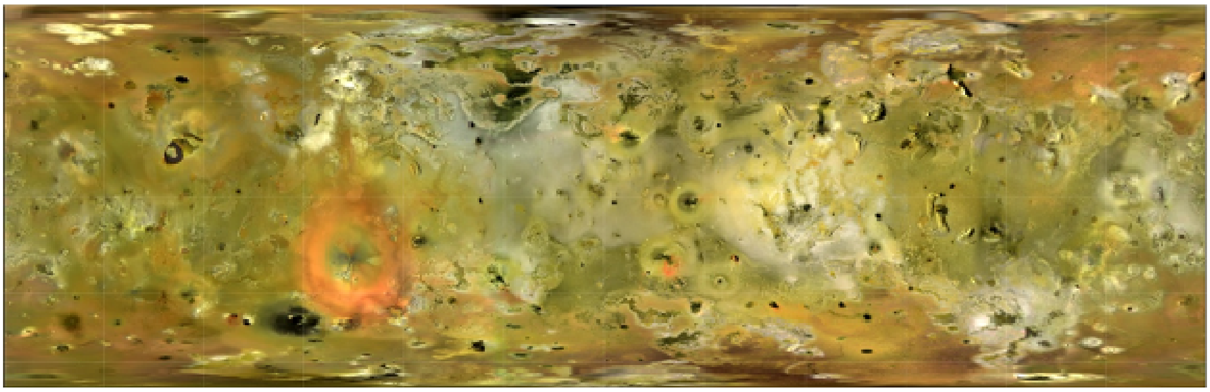


Fig. 4. Io's surface map.

and sizes, and volcanic lava flows (Fig. 4). The lack of impact craters indicates that Io's surface is geologically young, like the Earth's surface; volcanic materials continuously bury craters as they are produced. This result was spectacularly confirmed as at least nine active volcanoes were observed by *Voyager 1*!

Surface composition

Io's colourful appearance is the result of materials that include silicates (such as orthopyroxene), sulphur, and sulphur dioxide. Sulphur deposited in the mid-latitude and polar regions is often radiation damaged, breaking up normally stable 8-chain sulphur. This radiation damage produces Io's red-brown Polar Regions.

Explosive volcanism on Io often takes the form of umbrella-shaped plumes, painting the surface with sulphurous and silicate materials. Plume deposits on Io are often coloured red or white depending on the amount of sulphur, its allotropes and sulphur dioxide in the plume. A prominent example of a red-ring plume deposit is located at Pele (Fig. 5). These red deposits consist primarily of sulphur (thought to be 3- and 4-chain molecular sulphur), sulphur dioxide, and perhaps Cl_2SO_2.

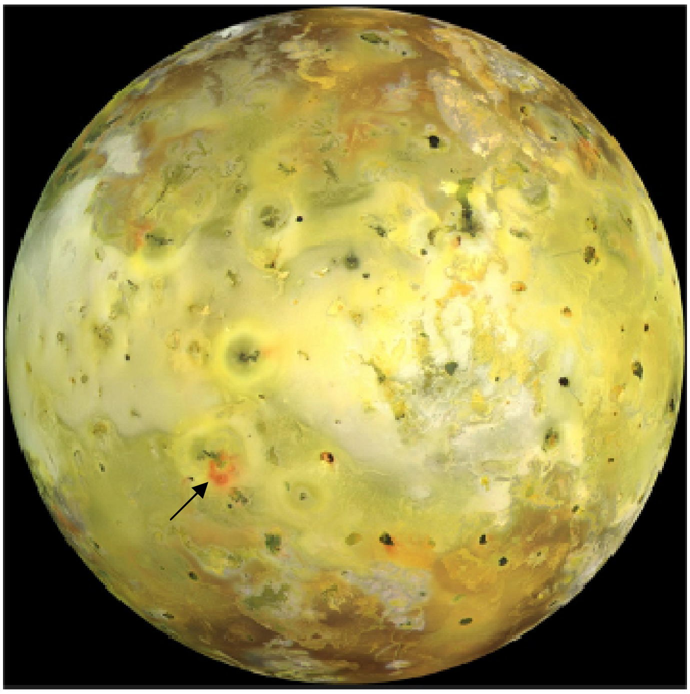


Fig. 5. Image of Io's surface; the red ring (arrowed) is around the volcano Pele.

Compositional mapping and Io's high density suggest that Io contains little to no water, though small pockets of water ice or hydrated minerals have been tentatively identified, most notably on the northwest flank of the mountain Gish Bar Mons. This lack of water is likely due to Jupiter being hot enough early in the evolution of the Solar System to drive off volatile materials like water in the vicinity of Io.

Volcanism

During major eruptions, lava seems to consist mostly of basalt silicate lavas with either mafic or ultramafic (magnesium-rich) compositions. As a by-product of this activity, sulphur, sulphur dioxide gas and silicate pyroclastic material (like ash) are blown up to 500 km (310 miles) into space, producing large, umbrella-shaped plumes providing material for Io's patchy atmosphere and Jupiter's extensive magnetosphere.

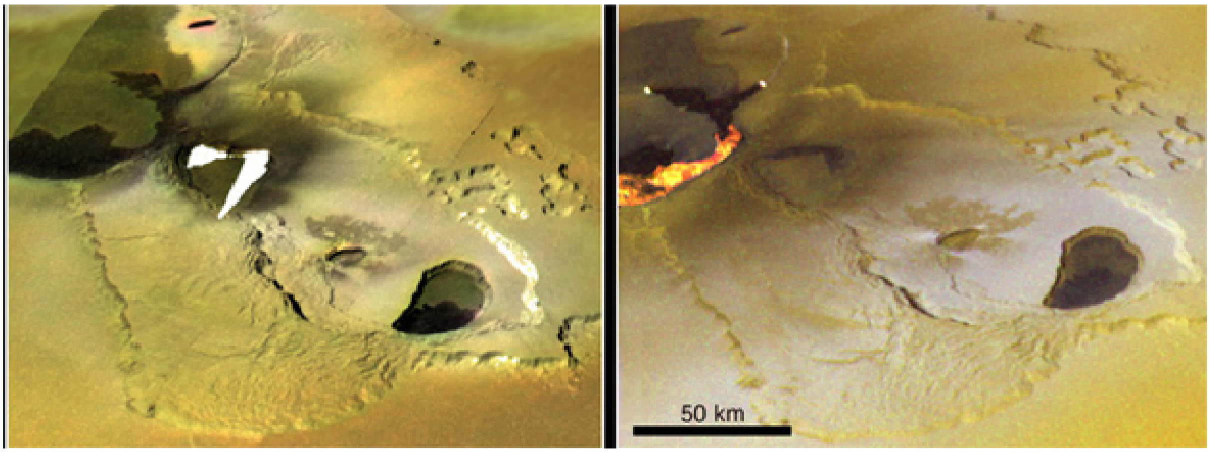


Fig. 6. Active lava flows in volcanic region Tvashtar Paterae (blank region represents saturated areas in the original data). Images taken by Galileo *in November 1999 and February 2000.*

Io's surface is dotted with volcanic depressions known as *paterae*. Paterae generally have flat floors bounded by steep walls. These features resemble terrestrial calderas, but it's not known if they are produced through collapse over an emptied lava chamber as on Earth. One hypothesis suggests that these features are produced through the exhumation of volcanic sills and the overlying material is either blasted out or integrated into the sill. Unlike similar features on Earth and Mars, these depressions generally do not lie at the peak of shield volcanoes and are normally larger, with an average diameter of 41 km (25 miles), the largest being Loki Patera at 202 km (126 miles); a possible tectonic mechanism is thought to be involved. These features are often the site of volcanic eruptions, either from lava flows spreading across the floors of the paterae, as at an eruption at Gish Bar Patera in 2001, or in the form of a lava lake. Lava lakes on Io either have a continuously overturning lava crust, such as at Pele, or an episodically overturning crust, such as at Loki.

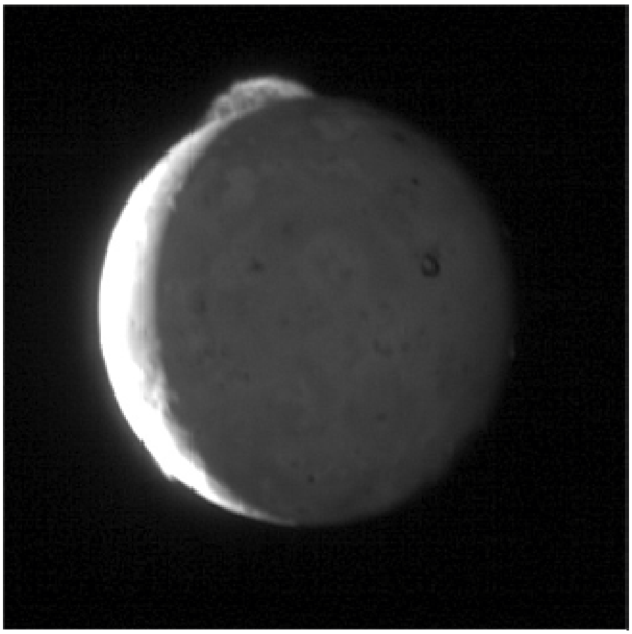


Fig. 7. New Horizons *images showing Io's volcano Tvashtar spewing material 330 km above its surface.*

Images from the *Galileo* spacecraft revealed that many of Io's major lava flows, like those at Prometheus and Amirani, are produced by the build-up of small breakouts of lava flows on top of older flows. Larger outbreaks of lava have also been observed on Io. For example, the leading edge of the Prometheus flow moved between 75 and 95 km between *Voyager* in 1979 and the first *Galileo* observations in 1996.

Mountains

Io has 100 to 150 mountains. These structures average 6 km in height and reach a maximum of 17.5±1.5 km at South Boösaule Montes. Mountains often appear as large (the average mountain is 157 km long) isolated structures with no apparent (global) macro-tectonic patterns. To support the tremendous topography observed at these mountains requires compositions consisting mostly of silicate rock, as opposed to sulphur.

Despite the extensive volcanism that gives Io its distinctive appearance, nearly all its mountains are, perhaps, micro-tectonic structures, and are not produced by volcanoes. Instead, most Ionian mountains seem to form as the result of compressive stresses on the base of the lithosphere, which uplift and often tilt chunks of Io's crust through thrust faulting.

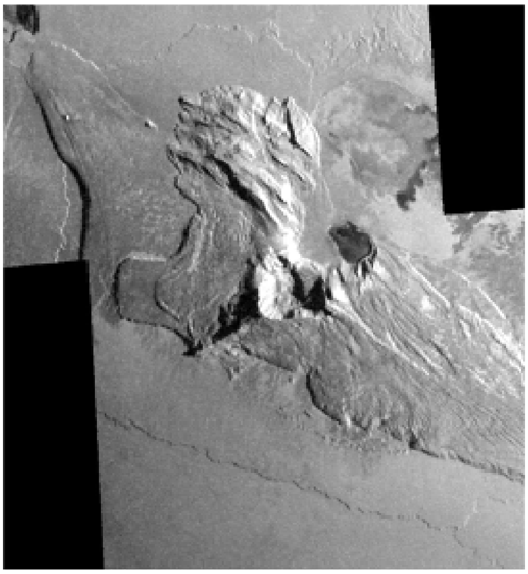


Fig. 8. Galileo *greyscale image of Tohil Mons, a 5.4 km tall mountain.*

Mountains on Io (generally, structures rising above the surrounding plains) have a variety of morphologies. Plateaus are most common. These structures resemble large, flat-topped mesas with rugged surfaces. Other mountains appear to be tilted crustal blocks, with a shallow slope from the formerly flat surface and a steep slope consisting of formerly sub-surface materials uplifted by compressive stresses. Both types of mountains often have steep scarps along one or more margins. Only a handful of mountains on Io appear to have a volcanic origin. These mountains resemble small shield volcanoes, with steep slopes (6-7°) near a small, central caldera and shallow slopes along their margins.

Nearly all mountains appear to be in some stage of degradation. Large landslide deposits are numerous at the base of Ionian mountains, suggesting that mass wasting is the primary form of degradation. Scalloped margins are also common among Io's mesas and plateaus, perhaps as the result of sulphur dioxide sapping from Io's crust, producing zones of weakness along mountain margins.

Conclusion

With the development and launch of several spacecraft to the Giant Planets and their moons much has been discovered since the first Voyager missions in the 1970s. The incorporation of increasingly higher resolution Earth-based telescopes and the Hubble space telescope have also added enormously to the study of these objects. I hope that this is a small taster for you to investigate further and reach out to the new geology of the moons of our planets.

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http://www.wikipedia.org/

Io Mountain Database (http://planetologia.elte.hu/io/)

The Planetary Society: Io information (http://www.planetary.org/explore/topics/jupiter/io.html)

The Magical Mystery - The Moon 40 years on

Gordon Elder

Dear Editor & Members, October 2009

Well, I thought that since I had been asked to write an article on the moon(s) of a planet, say, Jupiter, I might also say something about, well, something very important – really. Forty years ago something significant happened.

The Beatles were the trend setters of the sixties pop music revolution (unless you are American and then it would be The Rolling Stones, Bob Dylan and perhaps Led Zeppelin). Patrick McGoohan starred in The Prisoner (Number Six). Twiggy became a 1960s fashion icon known for her large eyes, long eyelashes, very slim build and, oh, her voice. Launched in 1959 and designed by Alec Issigonis, the Mini was celebrating its 10th birthday, no not the skirt, I'm talking about the car. The 'Carry On' films were a long running series of British comedies. The designer, Mary Quant, is credited with making the mini (no not the car) a must-have fashion item of 'Swinging London' and from there it seemingly took the world by storm. And lastly, I must mention 'Doctor Who and the Moonbase', in which the Doctor (Patrick Troughton) and others go to the Moon, which neatly brings me to the main reason for this letter, that 40 years ago, in 1969, Neil Armstrong, the commander of the American mission *Apollo 11*, became the first person to set foot on the Moon.

As a reminder of the history behind the first manned Moon landing, the Soviet Union's *Luna* program was the first to reach the Moon with unmanned spacecraft. The first man-made object to escape Earth's gravity and pass near the Moon was *Luna 1*, the first man-made object to impact the lunar surface was *Luna 2*, and the first photographs of the normally unseen far side of the Moon were made by *Luna 3*, all in 1959, 10 years before the first manned landing! The first spacecraft to perform a successful lunar soft landing was *Luna 9* and the first unmanned vehicle to orbit the Moon was *Luna 10*, both in 1966. Moon samples have been brought back to Earth by three *Luna* missions (*Luna 16, 20* and *24*!) and the *Apollo* missions *11* to *17*.

The landing of the first humans on the Moon, 40 years ago, is seen by many as the culmination of the Space Race. As the commander of the American mission *Apollo 11*, Neil Armstrong became the first person to walk on the Moon, setting foot on the lunar surface at 02:56 UTC on 21st July 1969.

Scientific instrument packages were installed on the lunar surface during all of the *Apollo* missions. Long-lived ALSEP stations (*Apollo lunar surface experiment package*) were installed at the *Apollo 12, 14, 15, 16* and *17* landing sites, whereas only a temporary station referred to as EASEP (*Early Apollo Scientific Experiments Package*) had been installed during the *Apollo 11* mission. The ALSEP stations contained, amongst other things, heat flow probes, seismometers, magnetometers, and corner-cube retroreflectors. Transmission of data to Earth was terminated on 30th September 1977 because of budgetary considerations, but since the lunar laser ranging (LLR) corner-cube arrays are passive instruments, they are still being used today! Ranging to the LLR stations is routinely performed from Earth-based stations (including Herstmonceux in East Sussex) with an accuracy of a few centimetres, and the data received is being used to place constraints on the size of the lunar core.

Then, on 14th December 1972, less than three and a half years after the first manned landings, Eugene Cernan (the first field selenologist) and Harrison Schmitt, as part of the mission *Apollo 17*, left the surface of the Moon (Cernan being the last to enter the Lunar Module) and no one has set foot on the Moon since!

In 1994, the U.S. returned to the Moon, robotically at least, sending the Joint Defence Department/NASA spacecraft *Clementine*. This mission obtained the first near-global topographic map of the Moon, and the first global multispectral images of the lunar surface. This was followed by the *Lunar Prospector* mission in 1998. The neutron spectrometer on *Lunar Prospector* indicated the presence of excess hydrogen at the lunar poles, perhaps caused by the presence of water ice in the upper few metres of the regolith within permanently shadowed craters. This is now thought significant and may play a crucial role in decisions about future landings (as you might notice later, in another letter to the Ed.).

The Silent Space Race: On 14th January 2004, U.S. President George W. Bush called for a plan to resume manned missions to the Moon by 2020. NASA is now planning for the construction of a permanent outpost at one of the lunar poles. The People's Republic of China has expressed ambitious plans for exploring the Moon and has started the *Chang'e* program for lunar exploration, successfully launching its first spacecraft, *Chang'e-1*, on 24th October 2007. Like NASA, China hopes to land people on the Moon by 2020. The U.S. launched the *Lunar Reconnaissance Orbiter* and the *Lunar Crater Observation and Sensing Satellite* on 18th June 2009 (the two missions were launched together on an Atlas V rocket) and I watched the launch on NASA TV streamed in through my laptop through the Internet, then did the unforgivable, I fell asleep! I'll blame my hectic lifestyle.

Russia also announced its intention to resume its previously frozen project *Luna-Glob*, consisting of an unmanned lander and orbiter, which is hoped to land in 2012. On 22nd October 2008 India successfully launched the *Chandrayaan I* (a Sanskrit word literally meaning the 'Moon-craft') unmanned mission to the Moon, and intends to launch several further unmanned missions, including *Chandrayaan II* in 2010 or 2011 which will deploy a robotic lunar rover. India has also expressed its hope for a manned mission to the Moon by 2020.

Now, NASA returns to the Moon! The *Lunar Reconnaissance Orbiter* (LRO) and *Lunar Crater Observation and Sensing Satellite* is scheduled for a one-year exploration mission at a polar orbit of about 31 miles, the closest any spacecraft has orbited the Moon. Its primary objective is to conduct investigations to enable a human return to the Moon. *The Lunar Reconnaissance Orbiter* entered orbit around the Moon following a five-day journey.

The LRO satellite will explore the Moon's deepest craters, examining permanently sunlit and shadowed regions, and help us to understand the effects of lunar radiation on humans. LRO will return more data about the Moon than any previous mission. The spacecraft's instruments will help scientists compile high resolution, three-dimensional maps of the lunar surface and also survey it at many spectral wavelengths.

You might rightly ask, well, what has this got to do with geology? I hope that you will bear with me on this as I'm sure, as with the first field selenologist, there will be more field lunar geology in the future. At present, selenology is a very new science. The Moon is the closest body to us, and hopefully we will soon be able to actually undertake field science with humans instead of robots. Don't get me wrong, artificial intelligence has its place, but I very much argue for the real field geologist, or any other science that has a 'tactile' human input. It is still hard for me to believe that this is actually happening. Dreams coming true!

There is more to come - it's called the Constellation Programme. The new dawn of the Apollo Programme to be continued . . .

Yours,

Gordon Elder
Education Officer

Editor's Postscript

Since the receipt of this letter, results from India's *Chandrayaan I* spacecraft have been released indicating the presence of water on the Moon (as water-ice locked in the rocks) in much larger quantities than had previously been thought, something which may have implications for future manned missions.

From a more terrestrial perspective, the passive LLR corner-cube arrays that were left on the Moon have also been used to provide physical evidence to support one of the 20th century's most important advances in the earth sciences, the understanding and acceptance of plate tectonics. Lasers bounced off these arrays over the past 40 years have confirmed that the European and American continental plates are actually moving apart by around 2 cm per year.

Peter Austen

Natural Beauty American Style

by Mervyn Gain

During October 2008 my wife and I achieved an ambition to visit various National Parks in the USA. This was our first visit to mainland America and on reflection we can only marvel at the absolute natural beauty of the regions we passed through on the trip. From the peculiar surreal landscape presented by the Badlands with the peaks, gullies and buttes surrounded by vast prairies, to the other extreme of Yellowstone with its fumaroles, coloured mud flats and geysers, it was difficult to appreciate that we were on the same planet, yet alone in the same country. Although expecting to see vast grasslands over which bison and indigenous Indians had once roamed, the existence of such a varied architectural environment just left us in awe of and inspired by nature's beauty.

A suggestion was made to include some of the photos in this edition of the journal in order to provide a taster for members of the wide natural diversity that we encountered. Some geological comment has been added to place the different areas in context as we journeyed from east to west across the country. As can be seen from the itinerary on the map below (Fig. 1), this journey commenced at the Badlands National Park and then continued on to Yellowstone, Grand Teton, Arches, Mesa Verde, Monument Valley, Grand Canyon, Bryce Canyon and Zion National Parks.

Fig. 1. Itinerary

The map on the following page (Fig. 2) may be helpful in relating the physical divisions of the USA to the regions visited, with particular focus on the Great Plains, Intermontane, Rocky Mountain System and Colorado Plateaus.

Our initial contact with America was in the division of the Great Plains, a large expanse of land forming part of the Interior Plains from west of the Rocky Mountains to the Appalachian highlands in the East. From 570 million years to almost 70 million years ago shallow seas lay across the interior of the continent giving rise to deposition of marine sediments later to be covered by rocks laid down from the action of streams, wind and glacier action. Compared with other regions the horizontal position of the rocks has hardly been disturbed except for some uplift giving rise to mountains like the Black Hills. The Badlands have essentially been formed by the cutting action of small streams flowing over a steeply sloping face of soft fine-grained material composed mainly of clay and silt. The intricate carving by these small streams of water has produced the characteristic rounded and gullied terrain we call the Badlands, as portrayed by the pinnacle formations shown in figure 3.

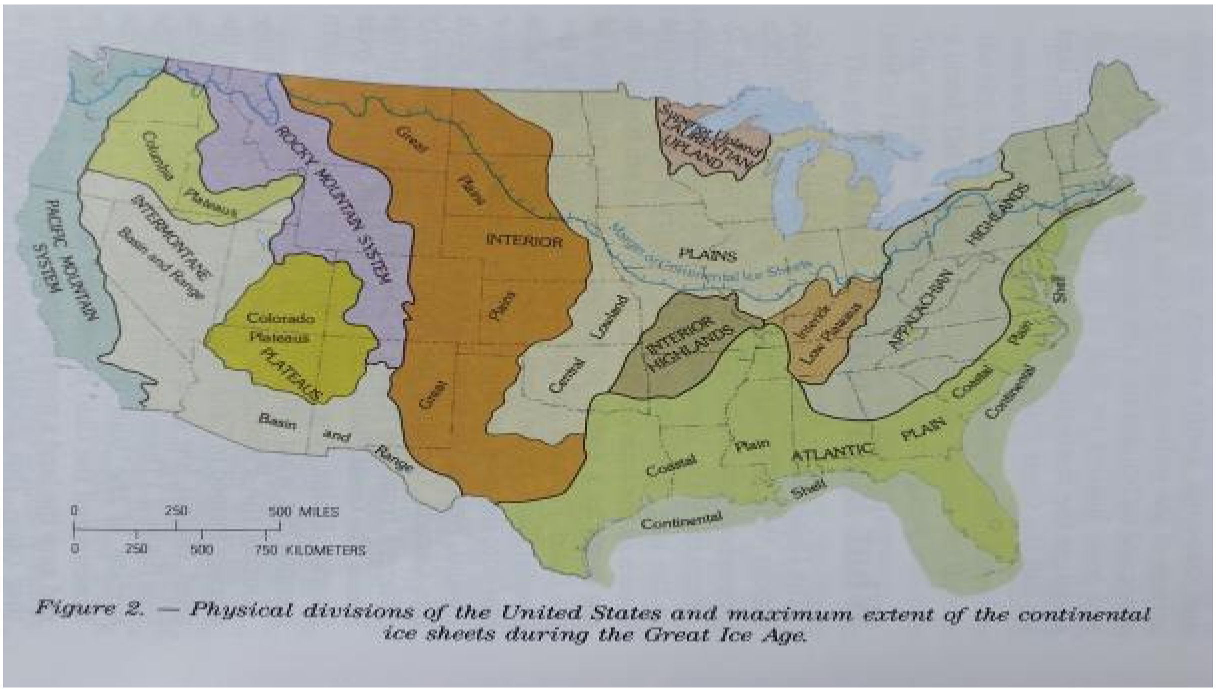

Fig. 2. Physical divisions of the USA (from Trimble, 2006)

Fig. 3. Badlands National Park

Fig. 4. Mount Rushmore National Memorial

The uplift leading to the formation of the Black Hills was accompanied by erosion of the overlying marine sedimentary cover, subsequently exposing granite and metamorphic rocks. It was from this granite that the heads of four significant American Presidents were sculpted at Mt. Rushmore, now a National Memorial (Fig. 4).

The search for gold in the Black Hills triggered hostilities with the native Indian population that led to the defeat of Custer at the Little Big Horn in 1876. The climax of this particular conflict took place at Last Stand Hill (Fig. 5), a typical grass prairie region with the Little Big Horn River in the distance.

One of the most unique areas we visited was the Yellowstone National Park (Figs 6 to 10). Not only were we in awe of all its beauty and variety, but especially its uncertainty when considering that a large part of the Park is a collapsed caldera above a hot spot that last had a major eruption some 640,000 years ago. The caldera is 47 miles by 23 miles wide, and with magma only a few miles beneath the surface the area gave us a very eerie feeling. This geological paradise presented such a varied surface environment that unfortunately, only a sample of photos from the region will have to suffice. It was difficult not to feel that given the proximity to nature's power house something catastrophic could occur at any moment.

Continuing the journey south enabled us to enjoy the Grand Teton National Park and then the views across Bear Lake (Fig. 11), prior to arrival in Salt Lake City. On the outskirts of the city we were able to appreciate the enormity of the Bingham Copper mine, reported to be the largest in the world (Fig. 12).

The well exposed and colourful rock formations in the Arches National Park (Figs 13 to 16) mask the incredible geological history primarily determined by the two ingredients, salt and water. The beds of rock salt deposited some 300 million years ago greatly influenced the subsequent geological history owing to properties of plasticity and solubility. Weathering and erosion of the Uncompahgre Uplift mountain range washed millions of tons of sediment onto the salt. The later effects of subterranean salt movement, dissolution and faulting impacted on the surface rocks to culminate in the seemingly magical natural architecture seen today. Most of these structures are members of the sediments referred to as the Entrada and Navajo sandstones.

The photo in figure 17 reveals a typical cliff dwelling found in the Mesa Verde National Park used by the Anasazi Indians from the early 13th century. The porous sandstone rock of the cliffs allowed seepage of rain, snow and running water to pass down to the lower shale area where the water could be accessed. This, plus protection from the elements, no doubt encouraged such environments to be chosen for habitation.

Any film buff would recognise the natural structures shown in figures 18 to 19 as backdrops to many action movies, particularly American Westerns. Over hundreds of millions of years, sediment eroded from the early Rocky Mountains was deposited in a basin forming mainly cemented sandstone and limestone rocks which were subsequently uplifted to become a plateau. The natural forces of wind, rain and temperature then acted to reduce the surface geology to the mysterious shapes seen today.

The two photos of the Grand Canyon at sunset and early morning at two different locations (Figs 20 and 21) only confirm our visit to the region, and in no way do justice to the complex processes that have led to this phenomenon over almost 2 billion years. Finally, photos of breathtaking views of the 'hoodoos' (pillars of rocks) from Bryce Canyon (Fig. 22) and Zion National Park (Figs 23 and 24) bring this natural journey across America to an end, leaving us with a strong desire to return and enjoy once more such intriguing and beautiful landscapes.

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Fig. 5. Last Stand Hill – Custer's Last Stand at the Little Big Horn

Fig. 6. Travertine deposits – Mammoth Hot Springs

Fig. 7. Paintpots – Yellowstone National Park

Fig. 8. Old Faithful – Yellowstone National Park

Fig. 9. Fumaroles and Geysers – Yellowstone National Park

Fig. 10. Mineral Art – Yellowstone (Sulphur Deposits)

Fig. 11. Bear Lake

Fig. 12. Bingham Copper Mine


Fig. 13. Arches National Park


Fig. 14. Arches National Park


Fig. 15. North Window – Arches National Park


Fig. 16. Arches National Park


Fig. 17. Spruce Tree House – Mesa Verde National Park


Fig. 18. Monument Valley National Park

Fig. 19. Monument Valley National Park

Fig. 20. The Grand Canyon at sunset – Desert View location

Fig. 21. View of Colorado River from the air

Fig. 22. Bryce Canyon

Fig. 23. Zion National Park

Fig. 24. Zion National Park

Geology and Palaeontology in the News

A review of recent research and discoveries

Edited by Peter Austen

Introduction

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

Giant pliosaur

The skull of a giant marine reptile, a pliosaur, has been found on the Arctic archipelago of Svalbard. Jørn Hurum of the Natural History Museum in Oslo, Norway, has dubbed the 147 million year old fossil 'Predator X'. The pliosaur was 50 feet long, weighed 45 tons, had teeth 30 cm long and had a 33,000 lb bite, four times as strong as *Tyrannosaurus rex*. (*New Scientist*, 2009, Vol. 201, No. 2700, p.5 & Press release from the Natural History Museum, University of Oslo, Norway)

Reconstruction courtesy of *Atlantic Productions* and *Natural History Museum, University of Oslo*, Norway.

The 45 ton pliosaur 'Predator X' attacking a plesiosaur.

Earth's missing lead

The lead isotope ratio of the Earth's mantle differs from that of the CI chondrite meteorites that were thought to have been the building blocks of the terrestrial planets. It had been thought that the reason for this 'missing lead' was that it migrated to the Earth's core between 50 and 130 million years after the formation of the Solar System. Now, new work by Markus Lagos, a geochemist affiliated to the University of Bonn, Germany, and his colleagues, has shown that this is unlikely. Lagos and his co-workers say that it is more probable that the lead was lost by degassing around 50 million years after the formation of the Solar System as a result of a massive impact that led to the formation of the Moon. (*Nature*, 2008, Vol. 456, No. 7218, p.89-92)

Earliest turtle from China

The oldest turtle yet discovered has been found in 220 million year old Late Triassic marine deposits in the Falang Formation of the Guizhou Province of southwest China. It is an important discovery, because it throws light on the evolution of the turtle body plan. Lack of early fossils has meant that the early evolution of turtles has always been an area of uncertainty. Now Chun Li of the Chinese Academy of Sciences in Beijing, China, and his colleagues, have studied the newly discovered fossil, *Odontochelys semitestacea*, and found that it has a fully developed plastron (the underside of the shell structure, which evolved before the carapace). The carapace (the upper part of the shell structure) consists of neural plates only, implying that the carapace developed through ossification of the neural plates and broadening of the ribs, something which is reflected in the development of present day juvenile turtles. (*Nature*, 2008, Vol. 456, No. 7221, p.497-501)

Early plate tectonics

Analysis of 4 billion year old zircon crystals found in rocks from Jack Hills, Western Australia has provided the first direct evidence that plate tectonics was already underway at this time, 1 billion years earlier than had previously been thought. Michelle Hopkins at the University of California, Los Angeles, USA, and her colleagues, analysed the minerals trapped within the zircon crystals and found that they had very likely formed at a subduction zone. Chemical traces previously found in zircons have hinted at this age, but this is the first direct evidence from minerals of the period. (*Nature*, 2008, Vol. 456, No. 7221, p.493-496)

Development of fish fingers

Early theories suggested that tetrapod (four legged vertebrates) fingers and toes had developed from the fin radials of fish, but this idea fell out of favour based on developmental genetic data and on the lack of these digit-like fin radials in the extinct fish *Panderichthys*, which is a transitional form between fish and tetrapods. Instead it was thought that the development of digits or fingers in the tetrapods was a novel development and not related to the fin radials which are present in most modern fish. Evidence had been growing that this was not correct (see 'Fingers formed from fins', *HDGS Journal*, Dec 2008, Vol. 14, p.34), but the lack of these fin-like radials in *Panderichthys* stood in the way of full acceptance. Now a computer tomography study of the pectoral fin of a well preserved *Panderichthys* specimen by Catherine A. Boisvert of Uppsala University in Sweden, and her colleagues, has shown that it does have digit-like radials, leading eventually to the development of fingers and toes. (*Nature*, 2008, Vol. 456, No. 7222, p.636-638)

Meteorites kick-started life

Work by Yoshihiro Furukawa of Tohoku University in Japan has suggested that life on earth was kick-started thanks to meteorites bombarding the Earth's oceans 4.3 billion years ago. Furukawa knew that high pressure impacts could create ammonia, and when he shot a mixture of meteorite ingredients (carbon, iron and nickel) into water at high speed he found that organic molecules needed for life had been formed. At that time, 4.3 billion years ago, meteorite bombardment was 1,000 times more common than today, and Furukawa and his team have suggested that the early bombardment would have created amino acids, the building blocks of life. (*Nature Geoscience*, 2009, Vol. 2, 62-66)

First Triceratops-type dinosaur from China

The remains of a ceratopsid dinosaur has been found in China. The ceratopsids, four legged rhino-like herbivores whose large skulls bore long horns and bony frills, were a close relative of Triceratops. Previously their remains had only been found in North America, but a 2 metre long skull was found at one of the world's largest dinosaur graveyards in Zhucheng City, China. The find was reported by Zhao Zijin of the Chinese Academy of Sciences in Beijing, China. (*New Scientist*, 2009, Vol. 201, No. 2690, p.4)

Watery Earth

A model of the early Earth suggests that until around 2.5 billion years ago the Earth was almost completely covered by water. Calculations by Nicolas Flament of the University of Lyon in France, and his colleagues, suggest that at that time the Earth had only 2-3% of land above water, as opposed to 28% today. The team say that the Earth's mantle was 200°C hotter than today, mainly due to a larger quantity of radioactive elements decaying and producing more heat. This in turn would have made the crust beneath the oceans hotter and thicker, raising them up relative to the continental landmasses. As the mantle cooled, the crust contracted making the oceans deeper and exposing more land. The team also suggest that this was the reason why the level of atmospheric oxygen increased at that time. During the water-world period any oxygen would have been taken up by decaying organic matter in the oceans. As sea levels dropped relative to the land, an increased landmass would have been exposed, this in turn would have led to increased erosion and an increase in the amount of sediment being washed into the oceans, burying the decaying organic matter and preventing it from reacting with the oxygen. This would have allowed oxygen to build up in the atmosphere, paving the way for the gradual development of complex life. (*Earth and Planetary Science Letters*, 2008, Vol. 275, 326-336)

Hearing capabilities of *Archaeopteryx*

What did *Archaeopteryx* sound like? We can't find this out directly from the fossil record, but we can find out indirectly. Stig Walsh of the Natural History Museum, London, UK, and his colleagues, looked at 59 present-day species of birds and reptiles to assess their hearing capabilities by measuring the length of the duct in the bony part of the inner ear, which can also be used as a guide to the complexity of their calls.

He used his results to assess the hearing ability of the early Jurassic bird *Archaeopteryx* and found that it could have been very similar to the emu. Further work should allow the team to infer how *Archaeopteryx* sounded and hence its social behaviour. (*Proceedings of the Royal Society B: Biological Sciences*, 2009, Vol. 276, No. 1660, p.1355-1360)

Nickel depletion in the oceans increases Earth's early oxygen

A shortage of dissolved nickel in the oceans 2.5 billion years ago may have led to the rise in atmospheric oxygen that made the Earth's atmosphere hospitable to life. Stefan Lalonde of the University of Alberta in Edmonton, Canada, and colleagues, measured the concentrations of nickel in 'banded iron formations' and found that the levels of nickel had dropped by two-thirds during the 200 million years prior to the rise in the Earth's oxygen levels known as the 'Great Oxidation Event' around 2.5 billion years ago. They speculate that the reduction in dissolved nickel in the oceans led to a decline in primitive ocean-dwelling bacteria that 'fed' on the nickel. These bacteria used the dissolved nickel to help turn food into energy and methane. Methane reacts with oxygen, so once the methane levels dropped atmospheric oxygen levels began to rise, setting the stage for the development of complex life forms. The study was presented to the American Geophysical Union in December 2008 (*New Scientist*, 2009, Vol. 201, No. 2691, p.10).

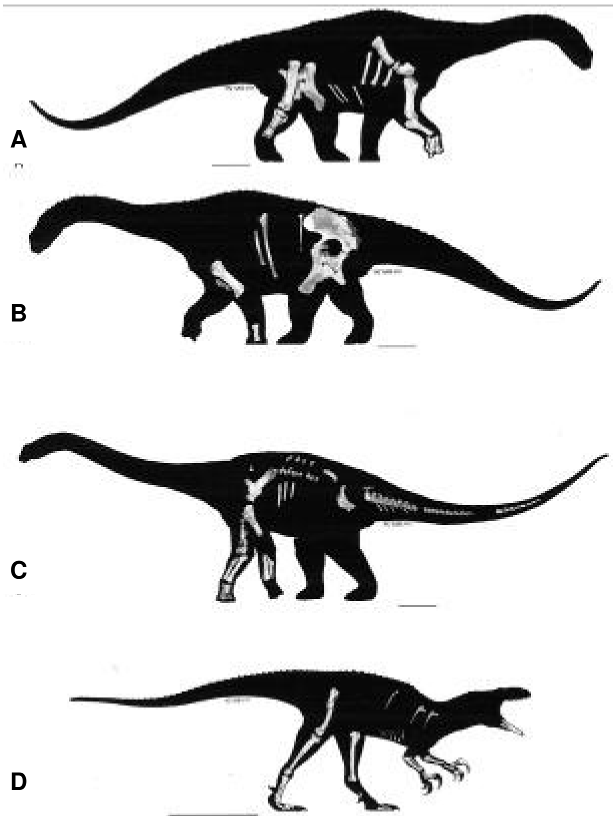
In a separate study, Kurt Konhauser also of the University of Alberta in Edmonton, Canada, and colleagues, attribute the reduction in nickel to a fall in the temperature of the upper mantle and a decline in the eruption of nickel-rich ultramafic rock (*Nature*, 2009, Vol. 458, No. 7239, p.750-753).

Australian dinosaurs

Australia is not the place to go dinosaur hunting, at least not until now. Only about a dozen fragmentary dinosaur skeletons have been found in Australia to date, but Scott Hocknull from Queensland Museum, Australia, and his colleagues, have discovered two plant-eating titanosaurs and a predatory theropod dinosaur in a 98 million year old billabong in Central Queensland. The two titanosaurs were 16-18 metres long. *Wintonotitan wattsi* was lightly built like a giraffe, and *Diamantinasaurus matildae* was more massive. The predatory theropod dinosaur *Australovenator wintonensis* was around 5 metres long and 2 metres high at the hip, similar to a velociraptor but larger, with three slashing claws on each hand. The researchers hope that more fossils will be found. (*PLoS ONE* 4(7): e6190 (2009))

Dinosaur reconstructions from:
Hocknull, S.A., White, M.A., Tischler, T.R., Cook, A.G., Calleja, N.D., Sloan, T. & Elliot, D.A. (2009) New Mid-Cretaceous (Latest Albian) Dinosaurs from Winton, Queensland, Australia. *PLoS ONE* **4**(7): e6190. doi:10.1371/journal.pone.0006190.

Artwork: Travis R. Tischler, *Australian Age of Dinosaurs Museum of Natural History*. doi:10.1371/journal.pone.0006190.g002



Silhouettes of the three new dinosaurs showing bones recovered to date.

A-B. Diamantinasaurus matildae
C. Wintonotitan wattsi
D. Australovenator wintonensis

Origin of New Zealand's flora and fauna

There are two conflicting theories as to the origins of New Zealand's flora and fauna. One says that the landmass was completely submerged by rising sea levels between 25-22 million years ago, and then repopulated later by transoceanic voyagers. The other is that it was only ever partly submerged, and that the ancestors of some of today's resident species have been there since New Zealand separated from other continents 82-60 million years ago. Now, Marc Jones of University College London and colleagues have identified fossil jawbones and teeth of a reptile related to the present day tuatara which suggests the latter theory is correct. Given the fossil's age (16-19 million years) these lizard-like creatures would not have had enough time to repopulate the landmass had it been fully submerged until 22 million years ago. (*Proceedings of the Royal Society B: Biological Sciences*, 2009, Vol. 276, No. 1660, p.1385-1390)

Giant fossil snake

The discovery of the world's largest snake has thrown new light on the climate in equatorial regions 60 million years ago. The snake vertebra found in the Cerrejón Coal Mine in northeastern Columbia was far larger than that of any known snake, and has led Jason Head of the University of Toronto, Ontario, Canada, and his colleagues, to estimate the snake, *Titanoboa cerrejonensis*, to be around 13 metres long with a weight of about one ton (the largest known snake today is only 10 metres long). The team say that the metabolic rate of cold-blooded vertebrates controls their maximum size at a given temperature, and the size of the new snake implies a mean annual temperature of 30-34°C, higher than was previously thought. The discovery has implications for global warming, because it supports the idea that temperature increase in equatorial regions will be far higher at times of global warming than the temperature increase for the rest of the planet. (*Nature*, 2009, Vol. 457, No. 7230, p.715-717)

Early oxygen

It is widely thought that atmospheric oxygen became widely available around 2.4 billion years ago. Fossil microbial mats found in the Pongola Supergroup of South Africa suggest that it may have been as early as 2.9 billion years ago, although without the presence of certain hydrocarbon biomarkers this cannot be taken as conclusive evidence. However, research by Jacob Waldbauer of the Woods Hole Oceanographic Institution in Massachusetts, USA, and his colleagues, has found these biomarkers in 2.6 billion year old rocks from South Africa's Transvaal Supergroup, giving strong evidence that oxygen was widely available at least 200 million years before previously thought. The search is now on for these biomarkers in older rocks. (*Precambrian Research*, 2009, Vol. 169, p.28-47)

Early reproduction in fish

Last year we reported on the discovery of a fossil placoderm fish from the Late Devonian Gogo Formation of Western Australia (380 million years old), which contained an embryo (see 'Live birth in the Devonian', *HDGS Journal*, Dec 2008, Vol. 14, p.38), the earliest evidence of live birth in the fossil record, pushing back the previous oldest by 200 million years. The placoderms are a group of armoured fish, and the most primitive known vertebrates with jaws. The same researcher, John Long of Museum Victoria, Melbourne, Australia, and his colleagues, have now taken a closer look at another group within the placoderms, the arthrodires, for evidence of live birth and reproduction. They looked at well-preserved fossils of the arthrodire fish *Incisoscutum ritchiei*, and found that some contained embryos, previously thought to have been stomach contents. The fossils also show a pelvic girdle which was adapted to support organs similar to the claspers of sharks which are used for internal fertilisation. These discoveries confirm that internal fertilisation and live birth were much more common among the early vertebrates than had previously been thought. (*Nature*, 2009, Vol. 457, No. 7233, p.1124-1127)

Dinosaurs and flowers

It has long been thought that the angiosperms (flowering plants) and dinosaurs co-evolved, mainly because many species of both appeared during the Cretaceous period. This has now been called into question by Richard Butler and his colleagues at the Natural History Museum, London, UK, who have mapped species diversity of both plants and dinosaurs and found no overall correlation of dinosaurs with the angiosperms. What they did find is that the spiny-backed group called the stegosaurs had a positive correlation with the cycads and bennettitales, implying that these plants formed a major part of their diets. (*Journal of Evolutionary Biology*, 2009, Vol. 22, p.446-459)

Aid to pterosaur flight

We know a lot about the wing design and flight capabilities of the extinct Mesozoic flying reptiles, the pterosaurs, but not a great deal about their respiratory system. Leon Claessens of the College of the Holy Cross in Massachusetts, USA, and his colleagues, have now made a detailed study of the skeletal remains of pterosaurs and birds using computer-assisted tomographic (CT) scanning. They found that the pterosaurs had developed a highly effective flow-through respiratory system allowing for sustained powered flight 70 million years before birds. The hollow bones of the pterosaurs contained air sacs linked to their lungs which would have allowed the air to be passed back and forth through the lungs, extracting oxygen far more efficiently than in the mammals. It also helps explain how some of the larger pterosaurs were able to fly – the expanded air sac system throughout the trunk and limbs gave a reduced body density relative to their size. (*PLoS ONE* 4(2): e4497 (2009))

Earliest fossilised brain

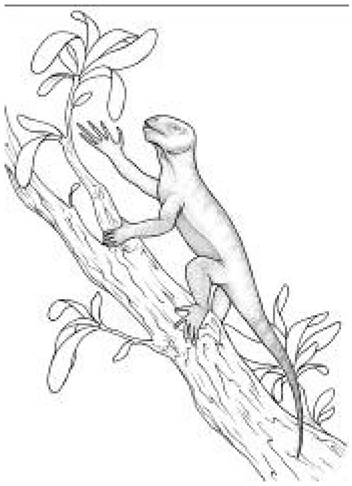
The earliest fossil brain has been discovered by Alan Pradel of the National Museum of Natural History in Paris, France, and his colleagues. They were taking x-rays of four 300 million year old Carboniferous iniopterygian fish to infer the size and shape of their brains, when they noticed a faint object inside one of the skulls. It is thought that a film of bacteria covered the brain after death, removing oxygen and preventing decay. (*Proceedings of the National Academy of Sciences*, 2009, Vol. 106, p.5224-5228)

Life in the trees

Studies of the anatomy of lizard-like fossils from the Late Permian of Russia have shown that they were adapted to life in the trees. The 260 million year old fossils, *Suminia getmanovi*, were actually distantly related to the mammals. Jörg Fröbisch of The Field Museum, Chicago, Illinois, USA, and his colleague Robert Reisz, found that the 50 cm long creature had elongated limbs, a long prehensile tail, elongated fingers and opposable thumbs. It is the oldest evidence of a tree-dwelling vertebrate. (*Proceedings of the Royal Society B: Biological Sciences*, 2009, Vol. 276, No. 1673, p.3611-3618 & Press release from The Field Museum, Chicago, Illinois, USA)

Photo of fossil and reconstruction courtesy of *The Field Museum*, Chicago, Illinois, USA.

Fossil skeleton of the tree-climbing synapsid Suminia getmanovi *from Russia. Photograph by Diane Scott.*



Reconstruction of Suminia getmanovi. *Illustration by Christina Stoppa.*

Bird feet

Prints of 200 million year old theropod dinosaurs found in the Utah sandstone, USA, show that the hand posture of these early dinosaurs was the same as present day birds. The squatting bipedal dinosaur had its hands facing inwards as bird's limbs do now to allow for the wings to be folded. The prints described by Andrew Milner of the George Dinosaur Discovery Site in Utah, USA, and his colleagues, belong to a theropod, a group ancestral to today's birds, and they imply that theropods exhibited bird-like anatomy and posture much earlier than previously thought. (*PLoS ONE* 4(3): e4591 (2009))

Were all dinosaurs feathered?

Until now feathered dinosaurs have been confined to the theropods, a group ancestral to the birds. A new discovery by Xiao-Ting Zheng of the Shandong Tianyu Museum of Nature, Shandong, China, and colleagues, has revealed feather-like filaments on *Tianyulong confuciusi*, a heterodontosaurid dinosaur belonging to a totally separate group from the theropods, the ornithischia, which split away from the theropods 220 million years ago, shortly after the dinosaurs first appeared. The heterodontosaurid dinosaur, which lived between 100 and 140 million years ago, came from the Lower Cretaceous Jehol Group of Jianchang County, Liaoning Province, China. The discovery raises the possibility that ancestral forms of both groups had feather-like filaments and that it was common amongst dinosaurs. (*Nature*, 2009, Vol. 458, No. 7236, p.333-336)

Oldest bony fish

An exceptionally well-preserved fossil of a bony fish has been discovered in the Silurian Ludlow of Yunnan, China. The 418 million year old fish, named *Guiyu oneiros* by Min Zhu of the Chinese Academy of Sciences, Beijing, China, and colleagues, is the oldest well-preserved bony fish ever to be found, and is a basal member of the lobe-finned fish from which today's lungfish, coelacanths and all land vertebrates are descended. The discovery means that the ray-finned fish (sharks, etc.) and lobe-finned fish split more than 418 million years ago. (*Nature*, 2009, Vol. 458, No. 7237, p.469-474)

Slowdown in volcanic activity

A study by Kent Condie of New Mexico Tech in Socorro, USA, and his colleagues, implied that there was a slowdown in volcanic activity between 2.45 and 2.2 billion years ago, something that has been suggested from previous studies (see 'Nickel depletion in the oceans increases Earth's early oxygen' on page 30). There has been a lack of evidence supporting volcanic activity during this period, something that researchers felt would be resolved by the collection of more samples. However, Condie and his team looked at zircons (which provide a record of past volcanic activity) from seven continents and found that the lack of evidence and hence the lull in volcanic activity was real. They also suggest that this lull was linked with both the increase in atmospheric oxygen and the 'Snowball Earth' event which was thought to have happened at around this time. (*Earth and Planetary Science Letters*, 2009, Vol. 282, 294-298)

Dinosaur protein

In 2007 Mary Schweitzer, a palaeontologist at North Carolina State University in Raleigh, USA, and her colleagues, reported finding collagen in a *Tyrannosaurus rex* leg bone, although at the time a number of critics dismissed her claims as contamination, and other labs could not duplicate the results. Using a more advanced mass spectrometer Schweitzer and her colleagues have found collagen in the leg bone of a hadrosaur, with the results being confirmed by two other laboratories. The teams say that they have also recovered haemoglobin, elastin and laminin. (*Science*, 2009, Vol. 324, No. 5927, p.626-631)

Evidence of earliest animals

The previous oldest known animal fossils are only 650 million years old, although molecular evidence implies that they were actually around 200 million years earlier. Now a team led by Fritz Neuweiler of Université Laval, Quebec, Canada, have found evidence of sponges in Canada's Northwest Territories. The team noticed odd patterns in an 850 million year old reef structure that resembled those left by modern sponges when the collagen structure decays and calcifies. (*Geology*, 2009, Vol. 37, p.475-478)

Early microbial life

It had been thought that only simple cyanobacteria lived on land up until 2.4 billion years ago because of the harsh ultraviolet radiation. Now, Birger Rasmussen from Curtin University of Technology, Bentley, Australia, and colleagues, have discovered evidence of 2.75 billion year old complex microbial communities sheltering from the hostile conditions in shallow cavities. The fossils from the Hardey Formation (Fortescue Group), Australia, would have fed on sulphur compounds and methane bubbling up from lower levels of bacteria. (*Geology*, 2009, Vol. 37, p.423-426)

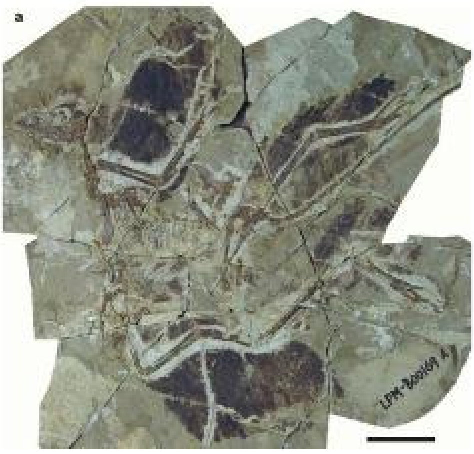
Dinosaur and bird fingers

It is now widely accepted that birds are descended from dinosaurs, but one of the unresolved problems is how to explain the development of the bird wing. The bird hand (now reduced and embedded in the wing), is derived from the second, third and fourth digits of an ancestral five-digit hand, whereas the three-fingered hand of the theropod dinosaur (a group ancestral to today's birds) is derived from the first, second and third digits of the ancestral five-digit hand. The problem has always been how did one evolve from the other? Now Xing Xu of the Chinese Academy of Sciences in Beijing, China, and his colleagues, have discovered a 155 million year old ceratosaur (a herbivorous theropod) in the Jurassic (Oxfordian), Shishugoa Formation, Xinjiang, western China, that has a stub of a first digit alongside more developed second, third and fourth digits. Its wrist bones resemble those associated with digits two, three and four, but the actual finger bones are more like the first, second and third. This find suggests that the evolution of the wing from the hand involved complex changes in the wrist and fingers and goes some way to solving the hand-to-wing problem. (*Nature*, 2009, Vol. 459, No. 7249, p.940-944)

Oldest feathered dinosaur

The world's oldest feathered dinosaur has been discovered in the Liaoning Province of China. The beautifully preserved specimen of *Anchiornis huxleyi* was found in the 155 million year old Tiaojishan Formation of Jianchang County, and is at least 5 million years older than *Archaeopteryx*, the previous oldest feathered dinosaur. Dongyu Hu of the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, and his colleagues, report their find in Nature (*Nature*, 2009, Vol. 461, No. 7264, p.640-643). The dinosaur was the size of a crow and had well developed feathers on all four limbs, including its feet. China has seen some spectacular discoveries of fossil birds in the last decade or so, but all of these are around 25-35 million years younger than *Anchiornis huxleyi*. Although it is not certain whether *Anchiornis* could fly as it had unusually long legs, it shows a crucial stage in the evolution of the birds.

Photo of fossil and reconstruction courtesy of *The Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences*, Beijing, China.



Newly discovered fossil of the feathered dinosaur Anchiornis huxleyi *from China clearly showing feathers.*

Reconstruction of the feathered dinosaur Anchiornis huxleyi. *Artist reconstruction by Zhao Chuang and Xing Lida.*

Giant trilobites

Thousands of trilobites have been found in a unique discovery in a roof-slate quarry in Arouca Geopark, northern Portugal. Some of the trilobites are the largest ever found reaching up to 70 cm, and some partial specimens imply a size of around 90 cm. The trilobites reported by Juan Gutiérrez-Marco from the Institute of Economic Geology, Madrid, Spain, and colleagues, represent five different families and three separate orders from the same formation. The discovery throws new light on their social behaviour, including sheltering from predation, moulting and reproduction, and the authors suggest that their large size was an adaptation to cold water. (*Geology*, 2009, Vol. 37, p.443-446)

Earliest elephant

A relative of modern day elephants has been found in 60 million year old rocks in the Ouled Abdoun basin in Morocco. The fossil, *Eritherium azzouzorum,* which would have weighed just five kilograms, looked nothing like an elephant, but detailed study of its teeth, jaws and skull by Emmanuel Gheerbrant of the French Natural History Museum in Paris, France, show it to be a member of the order Proboscidea, of which the elephant is the only living survivor. (*Proceedings of the National Academy of Sciences*, 2009, Vol. 106, p.10717-10721)

Dinosaur 'cells' preserved

A 66 million year old mummified dinosaur has been found in the Upper Cretaceous Hell Creek Formation of North Dakota, USA. The well-preserved fossil is of a plant-eating hadrosaur similar to *Edmontosaurus*, and includes skin and tendons, and it is thought that rapid burial in a waterlogged low-oxygen environment slowed the breakdown of soft tissue by bacteria. Phil Manning of the University of Manchester, UK, and his colleagues, used electron microscopy and X-ray imaging to study the fossilised skin and tendons and found cell-like structures similar to those of living vertebrates, and further study revealed that these cells contained amino acids, the building blocks of proteins. It is hoped that further analysis will confirm the presence of organic material. (*Proceedings of the Royal Society B: Biological Sciences*, 2009, Vol. 276, No. 1672, p.3429-3437)

The controversy surrounding 'Ida'

You may have noticed a bit of a media frenzy back in May of this year (2009) when a team of researchers led by Jørn H. Hurum of the University of Oslo, Norway, unveiled a spectacularly preserved fossil of an early primate, nicknamed 'Ida', from the 47 million year old Messel Oil Shales, near Frankfurt in Germany. The unveiling of the fossil in New York on the 19th May 2009, which had been shrouded in secrecy, was accompanied by the publication of a formal paper (*PLoS ONE* 4(5): e5723 (2009)), the issue of a book, and a number of television programmes. The popular press immediately hailed it as a "missing link" in human evolution, and Ida's official website (http://www.revealingthelink.com/) had such claims as "it's really a kind of Rosetta Stone", "an 8th wonder of the world", "the scientific equivalent of the Holy Grail". The research team described the fossil, named *Darwinius massillae*, as belonging to an extinct group of early primates called the adapiforms which resembled the lemurs, and further claimed that it was close to the ancestry of the anthropoids (the higher primates, including humans). This suggested that we evolved from lemur-like ancestors, not from precursors of the tarsier as had been thought. The team's findings were partly based on the similarities of the eyes and thumbs to those found in the primate lineage leading to humans, but this has been called into question by critics who say that these similarities are due to convergent evolution (the independent development of similar features in separate species), and that far more evidence is needed to link 'Ida' to the anthropoids. Now, a recent study by Erik Seiffert of Stony Brook University, New York, and his colleagues, has described a 37 million year old fossil jawbone and teeth from Egypt, named *Afradapis longicristatus*, that was closely related to 'Ida', and compared it with more than 117 living and extinct primates. Their study found that *Afradapis* and 'Ida' are only distantly related to the anthropoids, and that they both sit firmly on the lemur branch of the evolutionary tree. It is thought that both *Afradapis* and 'Ida' developed some anthropoid-like features through convergent evolution, but became extinct and were replaced by the true anthropoids in the late Eocene and early Oligocene (*Nature*, 2009, Vol. 461, No. 7267, p.1118-1121). The team that described 'Ida' strongly dispute Seiffert's findings, and intend to publish further papers looking at other aspects of 'Ida' to support their claims. We haven't heard the last of 'Ida' yet.

The early primate Darwinius massillae *nicknamed 'Ida' from Messel, Germany.*

Photograph: Per Aas

Photograph from:
Franzen, J.L., Gingerich, P.D., Habersetzer, J., Hurum, J.H., von Koenigswald, W. & Smith, B.H. (2009) Complete Primate Skeleton from the Middle Eocene of Messel in Germany: Morphology and Paleobiology. *PLoS ONE* **4**(5): e5723. doi:10.1371/journal.pone.0005723.

Greening of the Earth

A new study by Paul Knauth of Arizona State University, USA and his colleague Martin Kennedy, has suggested that the land was covered in a green carpet of photosynthetic life 850 million years ago, much earlier than previously thought. They say that this matting was probably a mixture of algae, mosses and fungi, and base their claims on a change in the isotopic markers found in carbonate rocks. Rocks younger than 850 million years carry a marker indicating freshwater run-off from the land containing evidence of some sort of photosynthetic life, whereas this isotopic marker is absent in carbonate rocks older than 850 million years. Their critics argue that vegetation on such a large scale should have left some trace in the fossil record, which it doesn't. (*Nature*, 2009, Vol. 460, No. 7256, p.728-732)

Australian dinosaur burrows

During the Cretaceous period winters in the polar regions were not as cold as today, but they were long and dark, which has always posed the problem of how small dinosaurs living in the region survived the winter months. Now fossil burrows have been discovered in the Cretaceous Otway Group (Albian) of Victoria, Australia, by Tony Martin of Emory University in Atlanta, Georgia, USA. The burrows are similar to ones that he had previously seen in Montana, USA, and are thought to have been made by small 10-20 kg hypsilophodontid-like dinosaurs, although no bones have yet been found. (*Cretaceous Research*, 2009, Vol. 30(5), p.1223-1237)

Pterosaur landing

An exceptionally well-preserved set of pterosaur footprints found in Crayssac, south-west France, are the first to show a pterosaur's footprints as it came in to land, and it seems they landed in much the same way as modern day birds. The 150 million year old footprints described by Jean-Michel Mazin of the University of Lyon in France, and his colleagues, show that the individual landed on both hind feet in parallel fashion, dragged its toes slightly as it left the track, landed again almost immediately and placed its hindfeet parallel again, then placed its forelimbs on the ground, took another short step with both hindlimbs, adjusted its forelimbs, and then walked off normally on all four limbs. (*Proceedings of the Royal Society B: Biological Sciences*, 2009, Vol. 276, No. 1674, p.3881-3886)

Geological Websites

Useful websites with a geological interest

Edited by Peter Austen

The internet is home to tens of thousands of websites with a geological interest, and it is often difficult to sort the wheat from the chaff. For every quality website there are many which leave a lot to be desired. As a general rule university and museum websites are fairly good, and given below are details of a few other sites worth a visit. Most scientific journals are only accessible by subscription, but I've included a list of journals, newsletters and magazines that are open access and can be freely downloaded. If you do not have a computer at home, all libraries in the UK are now equipped with computers with internet access for use by the general public.

All sites were valid as at 1st November 2009.

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

Gideon Mantell available on Google Books
http://books.google.com/

For those interested in historical aspects of the geology of the south-east, Google Books has uploaded a number of Gideon Mantell's books and papers. These are:-

Mantell, G. 1822. *The Fossils of the South Downs or Illustrations of the Geology of Sussex.*

Mantell, G. 1824. Some Fossil Vegetables of the Tilgate Forest, in Sussex. *Transactions of the Geological Society of London*, 421-424, Pls. XLV-XLVII.

Horsfield, T.W. & Mantell, G. 1824. *The History and Antiquities of Lewes and its Vicinity with an Appendix in which is included An Essay on the Natural History of the District*.

Mantell, G. 1827. *Illustrations of the Geology of Sussex: containing a general view of the geological relations of the south-eastern part of England; with Figures and Descriptions of the Fossils of Tilgate Forest*.

Mantell, G. 1833. *The Geology of the South-east of England*.

Mantell, G. 1836. *A Descriptive Catalogue of the objects of Geology, Natural History, and Antiquity, (chiefly discovered in Sussex,) in the Museum, attached to the Sussex Scientific and Literary Institution, at Brighton*.

Mantell, G. 1838. *The Wonders of Geology or a familiar exposition of Geological Phenomena; being the substance of A Course of Lectures Delivered at Brighton, Volume I*. *Volume I* is also available for 1848 (6th edition) and 1857 (7th edition)

Mantell, G. 1838. *The Wonders of Geology or a familiar exposition of Geological Phenomena; being the substance of A Course of Lectures Delivered at Brighton, Volume II*.

Mantell, G. 1854 (Third Edition). *Geological Excursions round The Isle of Wight and along the Adjacent Coast of Dorsetshire; illustrative of the most Interesting Geological Phenomena and Organic Remains*.

Also available on Google Books is:-

Fitton, William Henry. 1833. *A Geological Sketch of The Vicinity of Hastings*.

To access Google Books go to http://books.google.com/ click on 'Advanced Book Search', under 'Search:' choose 'Full View Only', type 'Mantell' into the 'Author' field, and then click on 'Google Search' – this will bring up most of Mantell's books where the full text is available.

If you have already downloaded these, larger files were uploaded in July 2009 on some of the titles, giving higher resolution pictures. One drawback, however, is that fold-outs within the publications are not always unfolded before scanning. Also all the titles may not appear on your initial search, but if you click on one of the titles and then click on 'Related Books' you will find additional titles. This is the only way to find '*Geological Excursions round The Isle of Wight . . .* '.

Converting between Latitude/Longitude & OS National Grid Reference points

With thanks to Ramues Gallois and Jo Thomas for their articles in the June and August editions of the Dorset GA Newsletter, which highlighted the following two sites. Combine these two sites and you'll never get lost again!!!

Latitude/Longitude & OS National Grid Reference Converter
http://www.nearby.org.uk/coord-ll.cgi

This site allows for conversion between Latitude/Longitude co-ordinates and the UK's Ordnance Survey Grid Reference System and vice-versa. It allows for the two different methods of interpreting Latitude/Longitude; 'OSGB-36' which you will find around the outside margins of OS maps, and 'WGS-84' which is used by GPS systems. The conversion itself couldn't be easier just type in the Latitude and Longitude co-ordinates, either in decimal format or degrees, minutes and seconds, choose the conversion format required (e.g. OSGB grid refs) and click on the 'Convert' button. The site also works in reverse converting OS grid references to Latitude and Longitude. If you want an explanation of the difference between 'OSGB-36' and 'WGS-84' and another converter go to:
http://www.movable-type.co.uk/scripts/latlong-gridref.html.

Where's the Path ?
http://wtp2.appspot.com/wheresthepath.htm

If you only have a grid reference for a particular location type it in to the box in the top left hand corner of the screen, press return, and on the left hand side of the screen an OS map for that area will appear with a square box centred on your grid reference, and on the right hand side of the screen will appear a google-earth image of the area marked by the box on the OS map. As you move your cursor around the google-earth image the OS grid reference and the Latitude/Longitude appear in the bottom right hand corner of the screen in decimal format ('WGS-84' system).

Royal Society – Public Events and Lectures
http://royalsociety.org/

The Royal Society regularly stages public lectures and discussions on a variety of scientific subjects, including the Earth and Life Sciences. Most of these are available to view on the internet, and apart from 'Discussion Meetings' most are slide presentations, although some slides are unavailable due to copyright restrictions. To access the presentations go to the Royal Society's home page at **http://royalsociety.org/**, click on 'Events Diary' and then on 'royalsociety.tv'. This will bring up a range of types of presentations (i.e. Public Events, Prize Lectures, etc.).

'Public Events' includes presentations on the following subjects:
The last 2 million years of human evolution - by Professor Christopher Stringer FRS (2009)
Fossils, fact and fiction - by Tracy Chevalier FRSL (2009)
The origins of flowers - by Sir Peter Crane FRS (2009)
Climate change and extinction - by Dr Richard Leakey FRS (2009)
Why creationism is wrong and evolution is right - by Professor Steve Jones (2006)
New views on human origins - by Professor Chris Stringer FRS (2005)

'Prize Lectures' includes the following presentation:
A natural history of scientists - by Dr Richard Fortey FRS (2007)

'New Fellows Seminars' includes the following presentation:
From fins to limbs - by Professor Jennifer Clack FRS (2009)

'Discussion Meetings' includes the following discussion (audio only):
Darwin and the evolution of flowers - organised by Sir Peter Crane FRS, Professor Else Marie Friis and Professor William Chaloner FRS. Includes oral presentations from 16 separate speakers.

Open Access Journals

Royal Society
http://royalsocietypublishing.org/journals

The Royal Society was established in 1662 and the first issue of *Philosophical Transactions* was published in 1665. Its objective was to inform the Fellows of the Society and other interested readers of the latest scientific discoveries. As such, *Philosophical Transactions* is now the world's oldest scientific journal in continuous publication, and it established the principles of scientific priority and peer review, principles which have remained the central foundations of scientific journals ever since. Since its inception almost 350 years ago the Society has obviously evolved, and it now produces a range of publications, most of which contain key papers in the Earth and Life Sciences. Most of these Journals from 2001 onwards are free to access online either one or two years after publication. To access the Journals go to the Royal Society's Journal page at **http://royalsocietypublishing.org/journals**, and click on the Journal required. The following Journals are available:

Proceedings of the Royal Society B – Biological Sciences - available after one year from 2001 (Vol. 268). Covers all aspects of biology, including palaeontology. Published fortnightly.
Philosophical Transactions of the Royal Society B – Biological Sciences - free access is only allowed to certain issues. Each issue is devoted to a specific area of the biological sciences. Amongst these are 'Evolution on Islands', 'Speciation' and 'Photosynthetic Evolution'.
Biology Letters - available after one year from 2005 (Vol. 1). Offers rapid publication of short articles on all aspects of biology, including palaeontology. Published bi-monthly.
Journal of the Royal Society Interface - available after one year from 2004 (Vol. 1). Concentrates on cross-disciplinary research between the physical and life sciences. Coverage of the Earth Sciences is limited. Published monthly.
Philosophical Transactions of the Royal Society A – Mathematical Physical and Engineering Sciences - available after two years from 2001 (Vol. 359). Each issue is devoted to a specific area of the mathematical, physical and engineering sciences, including the Earth Sciences. Published monthly.
Proceedings of the Royal Society A – Mathematical Physical and Engineering Sciences - available after two years from 2001 (Vol. 457). Covers the mathematical, physical and engineering sciences, including the Earth Sciences. Published monthly.
Notes and Records of the Royal Society - available after one year from 2001 (Vol. 55). Covers the History and Philosophy of Science including the Earth and Life Sciences. Published quarterly.

Evolution: Education and Outreach (Springer Life Sciences)
http://www.springerlink.com/content/120878/

Available from Volume 1 (2008) to date (Volume 2 (2009))
This journal aims to assist in the understanding and teaching of evolutionary theory. It contains a number of thematic issues:
Volume 1, Number 4, October 2008 – Special Issue: The Evolution of Eyes
Volume 2, Number 2, June 2009 – Special Issue: Transitional Fossils

The journal is published quarterly and offers **free online access until the end of 2009**.

Journal of Mammalian Evolution (Springer Life Sciences)
http://www.springerlink.com/content/104918/

Available from Volume 1 (1993) to date (Volume 16 (2009))
The Journal of Mammalian Evolution is the official journal of the Society for the Study of Mammalian Evolution, and publishes articles on all aspects of mammalian evolution. The journal is published quarterly.

Palaeobiodiversity and Palaeoenvironments (Springer Earth Sciences)
http://www.springerlink.com/content/121313/

Available from Volume 76 (1996) to date (Volume 89 (2009))
Palaeobiodiversity and Palaeoenvironments mainly deals with the biodiversity of fossil organisms and their palaeoenvironment. The journal is published every 6 months.

Palaeodiversity Journal (Staatliches Museum für Naturkunde Stuttgart)
http://www.palaeodiversity.org/backissues.htm

Available from Number 273 (1999) to Number 373 (2007)
Continued from Volume 1 (2008) to date (Volume 1 (2008))
Palaeodiversity publishes research in all fields of palaeontology, including monographs dealing with fossil groups (e.g. Wealden libelluloid dragonflies – Vol. 1, Fleck, *et al*., 2008).

Palaeontologia Electronica
http://palaeo-electronica.org/bk_issue.htm

Available from Volume 1 (1998) to date (Volume 12 (2009))
Palaeontologia Electronica publishes articles in palaeontology. Its main sponsors are the Paleontological Society, the Palaeontological Association and the Society of Vertebrate Paleontology. The journal is published 3 times a year.

PLOS One – The Paleontology Collection (Public Library of Science)
http://www.plosone.org/article/browseIssue.action?issue=info%3Adoi%2F10.1371%2Fissue.pone.c01.i02

PLOS One publishes a much wider range of papers, but the Paleontology Collection is available from 2007 to date (2009)
The *PLoS ONE* Paleontology Collection contains a variety of papers in palaeontology, including some referred to in 'Geology and Palaeontology in the News' (this issue, pages 28 to 36).

Directory of Open Access Journals – Geology
If you haven't had enough with the above selection go to
http://www.doaj.org/doaj?func=subject&cpid=78
and click on Geology – this will give you a further 69 open access journals to look through, although I've not looked at them so I can't vouch for their quality.

Update on '*Wealden News*'

by Peter Austen

The next issue of Wealden News (Issue No.8) should be available online within the next month at http://www.kentrigs.org.uk/wealden.html. Back copies of *Wealden News* are also available at this site.

GEOLOGISTS' ASSOCIATION FIELD MEETINGS – 2010

The Hastings and District Geological Society is affiliated to the Geologists' Association, and as such members are entitled to attend GA lectures, normally held at Burlington House, London, W1, or attend any of the GA field trips. Below is the 2010 GA field programme, although some of these dates may still change. Details of these trips and also GA lectures appear in the *GA Circular*, which is available at HDGS meetings. Details can also be found on the Geologists' Association website www.geologistsassociation.org.uk. All bookings must be made through the Geologists' Association – details in the *GA Circular*.

FIELD MEETINGS IN 2010

Sat 13th February	Microfossil workshop	Dr Adrian Rundle
Sat 27th March	Newhaven	Geoff Toye
April (Fri-Mon - date t.b.c.)	Yorkshire coast - long weekend	John Hudson
Sat 24th April	Radstock - Coal Measures and ammonites	Simon Carpenter
Sat 8th May to Sun 9th May	Welsh Borderlands churches weekend	John Potter
Sat 22nd May	A day on the Bawdsey Peninsula	Roger Dixon & Bob Markham
Sat 5th June (date t.b.c.)	Gault Clay of Folkestone - Joint meeting with the Palaeontological Association	Leader t.b.c.
Sun 13th June	Geology around Hitchin	Mike Howgate
July (date t.b.c.)	Wealden excursion	Peter Austen
Sat 4th September (date t.b.c.)	Harwich and Wrabness	Graham Ward
Sat 18th September	Norfolk coast	John Lee
Sat 11th Sep. to Sun 12th Sep.	Tavistock quarries	Eddie Bailey
October (date t.b.c.)	Fossil Fest VI	Neville Hollingworth
October (date t.b.c.)	Long weekend on the Isle of Wight	Andy Gale
Sat 23rd Oct. to Wed 27th Oct.	Copenhagen museum visit	Alan Lord (t.b.c.)

SUSSEX MINERAL SHOW

Saturday 13th November 2010

10.00 am - 4.30 pm

Clair Hall, Perrymount Road, Haywards Heath

(Close to Haywards Heath Station)

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

Illustrated Talks

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

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

(Please check with Trevor Devon before Show to confirm location - contact details on page 1)

HDGS Field Trip to Moorhouse Sand Quarry and Dryhill Quarry

Sunday, 17th May 2009

HDGS members in Moorhouse Sand Quarry, Surrey.

Moorhouse is a working quarry where the sand is used mainly for the fines content in asphalt and as a building sand. A fine-grained sand in an upper bed was once used for glass making.

Photo: Dale Smith

Siân Elder standing on the junction between the Gault Clay and the underlying Folkestone Beds in Moorhouse Sand Quarry. During wet weather a stream normally runs along the gulley where Siân is standing, fed by run-off from the overlying Gault Clay.

Photo: Dale Smith

Dryhill Quarry, Kent.

Hard beds of glauconitic limestone (known as Kentish Ragstone) jutting out of softer beds of glauconitic sandstone (known as Hassock). This is all part of the Hythe Formation within the Lower Greensand Group.

Photo: Dale Smith

HDGS Field Trip from Fairlight to Pett Level

Sunday, 21st June 2009

HDGS members assemble in the car park before descending Fairlight Glen to Covehurst Bay.

Photo: Peter Austen

Members start the long trek from Fairlight Glen to Pett. In the background is Covehurst Wood at the foot of Fairlight Glen.

Photo: Peter Austen

Gordon and Siân Elder admiring an Iguanodon *foot-cast in a fallen block of sandstone around 250 metres north-east of Lee Ness Ledge.*

Photo: Peter Austen

Behind the scenes at the Natural History Museum

Wednesday, 14th October 2009

One of the Natural History Museum conservators explaining to HDGS members the work being done to stabilize and preserve an Ichthyosaur *from Somerset County Museum.*

Photo: Diana Williams

Vertebrae and pelvic girdle of Iguanodon dawsoni *collected by Charles Dawson from Old Roar Quarry, St Leonards, East Sussex, and acquired by the Natural History Museum in 1909.*

Photo: Diana Williams

The right femur from Iguanodon Hollingtoniensis *collected by Charles Dawson from Hollington Quarry, near Hastings, East Sussex, in the late nineteenth century.*

Photo: Peter Austen