Farnham Geological Society

[**www.farnhamgeosoc.org.uk**]

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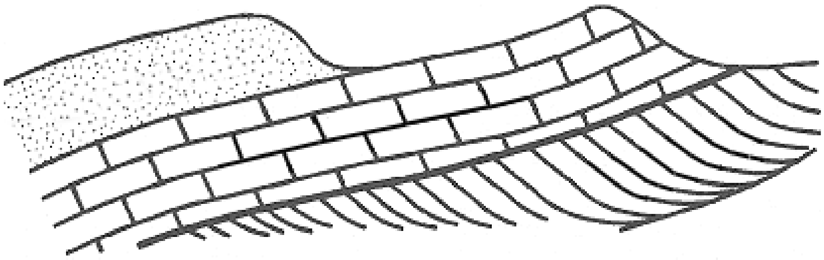

A local group within the GA

Vol. 8 No.3 **Newsletter** October 2005

INSIDE THIS ISSUE

I am writing this editorial having just returned from the Hallsannery Field Centre near Bideford where 12 Society members spent an enjoyable and instructive five days. Ed Step was in the group and is a new man, with his reconditioned knees taking him up tors and across pebbly beaches in a display of octogenarian defiance. A full account of this trip will appear in the January newsletter.

Graham Williams' monthly day trips have continued throughout the summer with numbers of 20-plus taking part at each event. Grateful thanks to Graham for organising these trips covering the Building of Southern England.

This season's Friday lectures have been up to the high standard we've come to expect and thanks are due to John Gahan for arranging the speakers, most of whom now use the computer-based "*Powerpoint*" method of displaying information. Properly used, this is a powerful addition to presentational efficiency, which confirms the decision of your committee some time ago to support this approach. The season ended with the Members' Evening on July 8th, when those present puzzled away at a quiz devised by Mike Weaver. A display of the editor's rocks was also arranged.

As announced by our Chairman at the September meeting, it is with deepest sorrow that we record the death of Charles Ganter, a member for many years, and we send our sympathy to Sally.

Peter Cotton

COMMITTEE

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FGS monthly meetings and field trips - 2005

Nov 4 **Society dinner at Farnham House Hotel - 7.15 for 8.00pm**

Nov 11 Dr Christopher Green, Royal Holloway College
Reconstructing Quaternary Rivers

Dec 9 Dr. Chris Elders, Royal Holloway College
Active Faults and the tsunami threat in SE Asia

Jan 13 Annual General Meeting, followed by: Dr John Williams, FGS & Natural History Museum
A g*eological field trip to Malta*

Field Trips 2006

29 April - 13 May: Languedoc   Other local trips to be arranged

Some very soft and some very hard rocks

On the 13 March a group of enthusiastic geologists met for a field trip along the banks of the Thames near the QE2 bridge. Dr Peter Allen, Andrew Haggart and Gerald Lucy very ably led the trip which looked at a range of geological features on both sides of the river. After negotiating numerous roads, mostly the wrong ones, around Erith, the group assembled and we had a pleasant walk along a raised sea defence bank to the river's edge. Here on "the beach" we were confronted by sticky Thames mud/clay and slippery stones which made for slow progress, though all who attempted it arrived without slipping or falling. The walk was worth the effort as in front of us was a magnificent fossil forest, the boles of numerous trees extending 1250m x 80m and with many tree trunks lying among them. ^{14}C dating suggests the trees were growing 4500-2750 BC (Neolithic) and they have been identified as yew with beech, oak and birch coming later. Later still there is evidence of alder and willow suggesting a transgression. The area was once a very dense forest, above sea level and it was suggested that flooding was not necessarily due to sea level rise but possibly due to containment of the Thames as man encroached on its banks making a smaller width for the water to flow through, and creating a greater tidal range. The leader had brought along an auger and took a core to a depth of 3m. This showed layers of clay and silt, some peat and some wood. During the 30 minutes we had been on the beach, the tide had covered the tree boles and we departed for lunch across the river close by Tilbury Fort. Although it was a sunny day there was quite a cold wind and all were keen to have a good warm. Immediately before lunch and standing on the raised banks of the river, Andrew Haggart explained, with the assistance of some technical diagrams, the ups and downs of the Thames over the last few thousand years and with fingers growing numb from the cold we gratefully sought warmth and a bite to eat in the aptly named World's End pub

From World's End we went to Davy Down "a public centre of leisure and learning excellence" where there is an old pumping station, visitor centre and a large area open to the public. The purpose of our visit was to see some sarsen stones. 60 million years ago, fluvial sands had been laid on top of the chalk and about 20 million years ago, when Britain had a hot, arid climate, silica from groundwater cemented the sandstone to form silcrete. Over time this broke up to form sarsen stones, which are extremely dense and heavy. These sarsens arrived in Essex possibly as erratics as a result of the ice age 450,000 years ago and subsequently swept by rivers from the melting ice sheets into Essex. The examples at Davy Down are "the best in Britain"---(and it wasn't Gareth George leading the group). The surface of most of the sarcen stones was found to be mammillated; a satisfactory explanation as to how this surface texture formed is yet to be agreed.

The final stop was nearby at Chafford Hundred. A large housing estate had been built in an old chalk quarry leaving the old quarry face exposed. The contact between the chalk and the Tertiary sand was visible i.e. the Cretaceous / Tertiary boundary and showed examples of periglacial involutions. These formed at the time the permafrost was thawing when the chalk was supersaturated and the heavy sand above sank into the chalk. The chalk was displaced upwards between these sandy lobes sometimes producing identifiable mushroom shapes. Involutions apparently only occur where the sand layer is thin. Further along the exposure the sand layer disappeared and with it the involutions.

Judith Wilson

FGS field trip to the Isle of Arran, April 2005

At the end of April 2005, 14 members of the Society went on a week-long field trip to the Isle of Arran led by Tony Benfield, Director of Geocourses. The party was lucky to enjoy a fine spell of weather, 6 out of the 8 days on the island being mainly sunny with clear-blue skies - only twice were the waterproofs needed, and then, only for an hour or two on each occasion. The Group was fortunate in that it was able to have the loan of the Island's Community Bus for the whole its stay, which meant that the party could travel as-one, with the advantage that this brought of having the leader on-board together with his informative geological commentary as we journeyed around.

The overall geology of the Island was adequately described by Cath Clemesha in her article which appeared in the February 2004 edition of the Newsletter, the main points of which are repeated below. The photographs accompanying this present article were taken by Peter Wood, Ian Hacker and Shirley Stephens.

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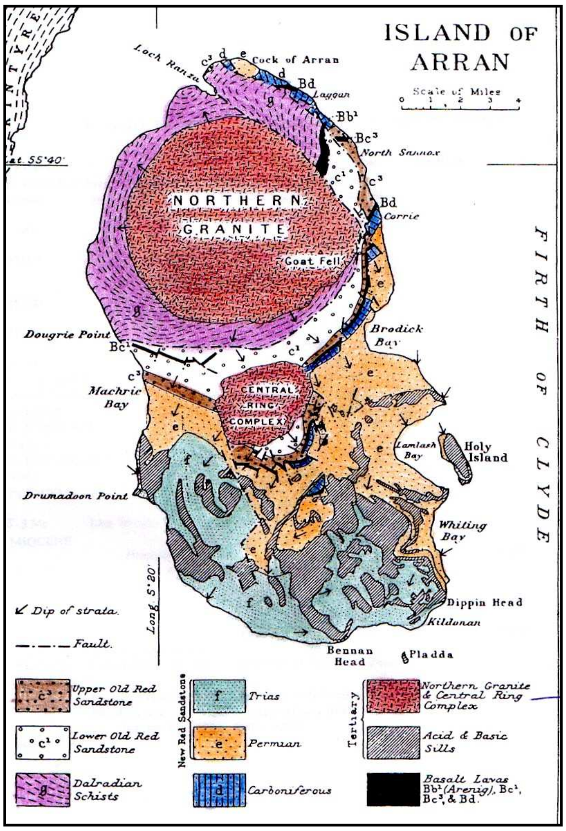


"Arran is popular for geology students as there are rocks from Cambrian to Cretaceous age, the north being a continuation of the Highland Region north of the Highland Boundary Fault, and the south being a continuation of the Midland Valley of Scotland. There are Tertiary igneous intrusions on Goat Fell in the north, the ring dykes in the Central Ring Complex and in the Lamlash cone sheet complex in the south (see map).
The dykes are basic and acidic (dolerite, and olivine dolerite which is called crinanite; and pitchstone, felsite and quartz-feldspar porphyry) The best places to see them are along the south coast around Bennan Head and the west coast north of Blackwaterfoot. On the beach below Kildonan there is a crinanite dyke, which was dark greenish brown with darker spots of olivine. Crinanite can also have white specks when the olivine has been altered to analcime. The quartz-feldspar porphyry dyke we studied on the beach near Drumadoon was a feeder dyke for the prominent Drumadoon sill.
Sills can be seen in a lot of the high ground round the coast and in offshore islands, such as Holy Island in the south-east and Pladda in the south. They are also mainly crinanite or quartz-feldspar porphyry. There is a crinanite sill at Dippen Head near Kildonan and a quartz-feldspar porphyry sill at Drumadoon. Here it looks as though there had been a dolerite sill into which the later quartz-feldspar porphyry was intruded. The dolerite can be seen at the base (the top assumed to have been eroded away.)
Most of the coastal plain is known as the "25 foot" raised beach dated at about 6500 BP. The best place to see the old cliff line is at Dougrie on the west coast where the cliffs are of Devonian conglomerate with numerous caves at the old sea level. There is another layer of raised beach at about 1000ft.which can be seen in Glen Catacol.
The contact between the Dalradian schists and the granite is most obvious in the stream-bed in North Glen Sannox; Glen Catacol provided excellent examples of lateral and terminal moraines, and a change in vegetation in the hillside indicated the schist/granite junction.

On the foreshore at Corrie one can walk south through Old Red Sandstone, Carboniferous and Permian strata steeply dipping to the south. The Old Red Sandstone conglomerate is easy to identify; then comes the fluviatile sandstones of Devonian or Carboniferous age, followed by amygdaloidal basalt and agglomerate. After that most of the shore is covered with boulders and it often difficult to see the many layers of Carboniferous limestone and incomplete Yoredale cycles.

Finally, an excellent example of Hutton's Unconformity can be seen north of Lochranza where Dalradian schists dipping steeply to the south-east are overlain by gently dipping sandstones of Lower Carboniferous age, a gap of about 150 million years."

Brodick from Goat Fell

View from near the summit of Goat Fell, looking south-east towards Brodick. Towards the top of the picture, the large bay is Lamlash Bay (where the FGS party stayed) with the prominent conical peak of Holy Island. The granite crag in the centre of the picture is Coire nam Meann.

Pillow lavas of North Glen Sannox.

In North Sannox Burn, about half a mile west of North Sannox Bridge on the A841, is this exposure of Dalradian pillow lavas, which are steeply dipping and 'younging' down stream to the east. Some show chilled margins.

Drumadoon Sill

View of the Tertiary Drumadoon Sill, a 30 metre high quartz feldspar porphyry intrusion with well developed columnar jointing, intruded into red marls and siltstones of the Triassic Auchenhew Beds. We also saw feeder dykes exposed on the shore. View looking north-east from Drumadoon Point, near Blackwaterfoot, in south-west Arran.

Hutton's Unconformity

This unconformity, discovered in 1787 by James Hutton, was the first of three he found. This view, looking roughly south, shows Dalradian schists at the base, which dip steeply to the SE. (Here he first realised that these sediments represent the products of erosion, transport, deposition, burial, heating and folding) They are stained red, probably due to weathering in the late Palaeozoic. Above the unconformity, the fluviatile lower Carboniferous sediments dip gently to the NW.

Dalradian Schists

On the west coast in this shore section at Imachar Point are highly deformed Dalradian schists.

Dyke in Permian at Fairy Dell, Lochranza

Tertiary, basalt dyke cutting through red Permian sediments at Fairy Dell, 1.25 km north-east of Loch Ranza on northern-most tip of Arran.

Many of the dykes seen along this coastline are associated with the opening of the Atlantic Ocean

Brittany - a recent invasion

The media had major national and international news items on which to report at the end of March 2005 but one item appeared to escape their notice - namely that a group of hammer-wielding British, (not one of them in the first flush of youth), crossed the channel by night and infiltrated the province of Brittany. On a more serious note, this was in fact a "Brittany Study Tour", organised and led by Dr Paul Olver, with participants being mainly members of the Woolhope Naturalists' Field Club (Herefordshire) or of Farnham Geological Society, plus some individuals hailing from Dorset, Essex and Oxford.

Our daytime "mobile home" for the ten days was provided by Farnham Coaches, whose good-natured driver took in his stride seemingly impossible sharp turns into narrow roads and reversing through gaps only centimetres wider than the coach. He was heard to remark (on being asked if he had driven a group like ours before) that "Yes", he had - but they were usually a lot younger! He also wondered why we (these "elderly hooligans" ?), having had a "good rock-bashing experience" in one spot, wanted to get out and do it all over again at the next location. Sadly we failed to turn him into a geo-enthusiast !

Rocks were not our only interest during the trip. There was also ample opportunity for archaeology, history, botany, architecture and art, not to mention crepe/galette sampling and supermarket shopping for picnic lunches! With Brittany being home to so many ancient megoliths, as well as the famous "Calvaries" in churchyards, it was good to have the chance to gaze in awe at sights like the far-ranging Carnac stone alignments, at giant menhirs (single standing stones) towering above us, at soaring spires, decorated churches, inspired sculpture and brightly coloured stained glass.

We were also able to explore (albeit briefly) the towns chosen for our overnight stays. The maze of cobbled streets and the picturesque old buildings in Vannes were tempting (as long as one didn't get lost!). Quimper too had a character all its own, with its medieval quarter, its cathedral (currently undergoing major repairs) and its attractive boulevards along either side of the broad river. Here, as elsewhere, the well-maintained flower beds were a delightful informal mixture of Spring flowers – a kind of relaxed carpet bedding with no set patterns.

One of the highlights of the trip for me was the visit to Mont St Michel – mainly because we went there on our first morning, straight from the ferry terminal, and we arrived early – before the crowds arrived, before the causeway became a long river of metal on wheels, before the car parks became flooded with parked vehicles and before the streets filled with jostling people. We could gaze down with ease from the abbey, perched high on its granite outcrop, at the land below us that was once water or primeval slime and imagine how life used to be before the silt built up and before the tourist trade discovered the area.

Despite all the man-made delights, what can compare with the pleasure of exploring the beaches and cliffs for "treasure"? Brittany's interesting geology was awaiting us and the sound of the hammer would be heard in the land! We learnt that Brittany consists of three roughly east/west bands – a central basin, largely of metamorphosed and un-metamorphosed sediments of late Pre-Cambrian and Palaeozoic age, bounded to the north by a Pre-Cambrian terrain of granite and metamorphic rocks and to the south by the South Armorican shear zone.

We began by exploring parts of the northern coastline – first the Emerald Coast with its granites and gneisses and the St Malo migmatite belt. At Pointe de la Heussaye, the more sure-footed amongst us picked a way over the rocks to find pillow lavas. Further West is the Cote de Granit Rose, so called because of the large pink orthoclases within the granite. At Kerleo disused quarry, (largely thanks to a very agile member of the group), we were able to see examples of both (older) fine-grained and (younger) coarse grained granites, the latter containing large crystals of pink feldspar.

A day or two later, crossing the Central Brittany Basin, we detoured to Etang des Salles by Lac Guerledan, an area of Palaeozoic sediments where the slate contains crystals of andalusite, a result of late-stage, low pressure metamorphism. Its characteristic square-shaped cross-section and cross-shaped carbonaceous inclusions were intriguing and the hunt for better and better specimens only came to an end at the thought of lunch ! Having travelled south, we stopped for a time at Port Navalo on the Golfe de Morbihan, discovering a migmatite belt, intruded by granite (lovely crystals of phlogopite – copper coloured mica) Here also could be found metatexite containing sillimanite, a white mineral growing in fibrous clumps, named after the US mineralogist Dr. Silliman.

Then we turned westwards towards the Crozon peninsula. My book on Brittany calls this "an attractive slice of countryside....and a dramatic one too if you climb up Menez Hom for an overview." We did just that, on a wonderfully clear day that allowed 360^o views, since Menez Hom, at 1082 ft, is the highest point in the area. Later, on the beach near Pointe de Lanveoc, we searched for brachiopods and trilobites amongst the limestones. (All I managed to find were live boring piddocks – marine bivalves that bore into rocks by means of saw-like shell valves.) However, fossils were more easily found in the shales of La Morte Anglais cliffs.

Paul had arranged for us to visit the Geological Museum at St Hernod, a privately owned concern, whose dedicated owner gave us a talk on the local area and explained the excellent exhibition. A gasp went up at the end when the lights went out and the specially laid out minerals fluoresced under ultra-violet lights. What a beautiful, artistic and amazing sight ! We then flocked to his shop, euro's at the ready, and carried off precious treasures that we would never be likely to find for ourselves.

As we headed away from Crozon, nearing the end of our trip, we detoured via Huelgoat to see the chaotic landscape of giant granite boulders (plutons), lying tumbled in a river bed. These were probably washed down by glacier melt floods but one could imagine the folklore attached to the site (angry giants hurling boulders etc)
The granite there contains crystals of cordierite – a mineral rarely found. (Our easiest finds were amongst the granite chippings on the pathway !).

All too soon we had reached Roscoff, back on the north facing coast, with the raucous cries of seagulls much in evidence. This was where our driver performed his greatest miracle - squeezing the coach through a narrow street with cars parked on either side to reach our hotel; otherwise we would have had to carry our own luggage through the street. We heard that if we had been there the previous week, we might have had to paddle to our hotel, which backed onto the waterfront – the wind and high tide had sent water surging up the alleyways into the street at the front. That night we had our last meal together, ending, appropriately, with "Brittany Cake" for dessert.

But – we still had one last day before catching the homeward bound night ferry and we were back with migmatites at the L'Aber Wrach estuary. (This was where I had my best find of the trip – a metatexite rock, showing the layers of its first metamorphism and the crenellations of its second – my "much traumatised specimen" !) Later, on Porspoder beach on the west coast, there were wonderful examples of granite pebbles showing shear lines and at the Ile de Melon, more granite, with sparkling tourmalite and pink orthoclase.

By this time, the coach was a great deal fuller and heavier than when we had set out (the driver's comments can no doubt be imagined!) and there was some surreptitious dumping of surplus rocks as the moment of departure from our "mobile home" loomed. However would we carry them all ? It was said that the ferry operators were going on strike the day after we were booked to return home – we only just escaped with our plunder ! The bagfuls and boxfuls of rocks that we eventually staggered home with were all too good to leave behind and will be a lasting memento of a very enjoyable and informative trip – thanks to Paul.

Ann Bower

Newspaper snippet - First picture of a planet outside our solar system

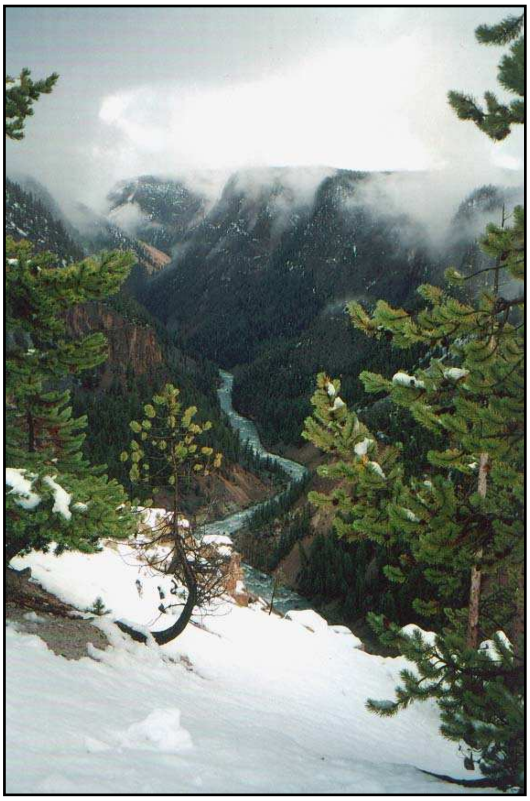
Astronomers have captured the first picture of a planet orbiting a star beyond our own solar system with a technique that could soon open the way to seeing into other worlds with extra-terrestrial life. The scientists say the planet is five times the size of Jupiter - previously the biggest known planet - but is far too cold to offer much hope of harbouring life. However, the sophisticated imaging technology used by the European Southern Observatory's mountain-top telescope in Chile could be refined to see Earth-sized planets where life may have evolved, said Gael Chauvin, the leader of the research team.

Last September, the European Southern Observatory first reported the presence of a red object close to a brown dwarf star. The object was about 100 times fainter than the star, which was itself an extremely faint speck of light in the southern constellation of Hydra about 200 light years away. Dr Chauvin said "The body is what we can call a giant planet of about five Jupiter masses. We cannot expect life on it, but it is the first detection of a planetary mass companion and we can hope in the future, perhaps 10 years or 20 years, we might be able to detect planets around other stars similar to Earth "

Steve Connor, Science Editor, The Independent, Saturday 20 April, 2005

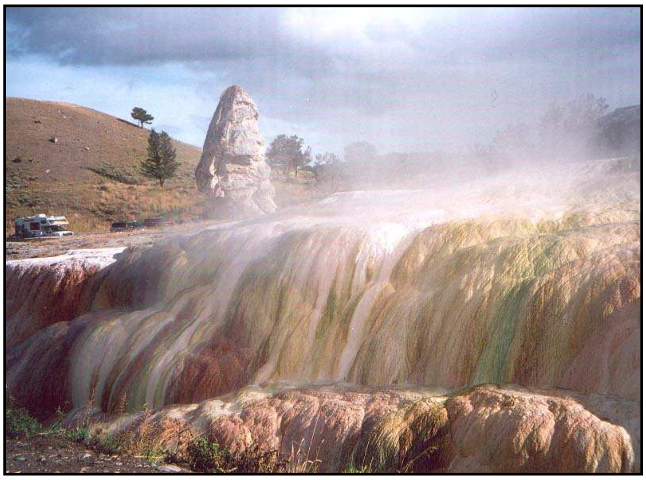
Yellowstone National Park and its volcanic history

Farnham Geological Society last visited the Yellowstone National Park in 1996 when we travelled with Ivan Dering and his Teachers (See Cath Clemesha's article in FGS Newsletter, Summer 1997). Early on the first morning of our recent visit to Yellowstone in September 2004, we drove to the West Entrance and found a queue of cars waiting, because there had been fall of snow in the Park (3 inches in some areas) and we had to wait for the snowploughs to begin clearing the roads before we could enter.



After visiting Fountain Paint Pots to see the mud pots, hot springs and eysers, the cold weather emphasising the outpourings of steam (see above photo), we moved on to Old Faithful. On our last trip we had good weather and blue skies, but this time it was cloudy and when the Geyser erupted, it was against a grey sky and not so dramatic. However, the 12.15pm eruption was still brilliant! Next we drove via West Thumb and Bridge Bay to Inspiration Point, (see above photo) above the Grand Canyon of the Yellowstone River (1200 feet deep in parts), where the snow still lay.

Finally we travelled via Norris Basin to Mammoth Springs. Here we again saw the tremendous outpouring of travertine which form the terraces (see photo above), while in the North East corner were some new terraces in the act of being formed (see photo alongside), probably due to changes to the geothermal springs by local earth movements. Travertine here can be deposited by the springs at a rate of three feet per year.

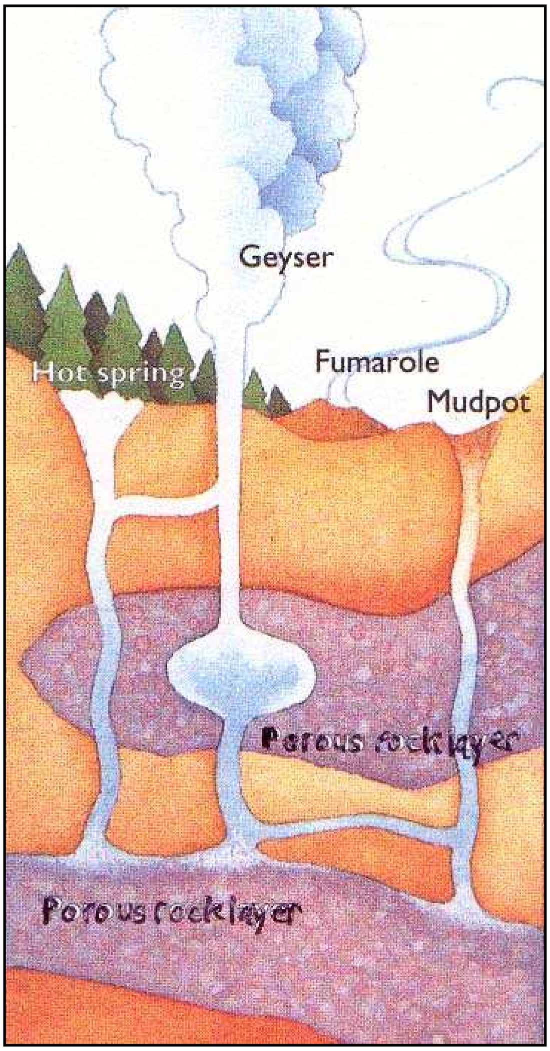


Early Geological History of Yellowstone

Yellowstone National Park, the first ever created in the U.S.A., in1872, is located in the North West corner of the State of Wyoming on the continental divide between the North and Central Rocky Mountains, averaging 7,200 feet above sea level. It is the centre of one of the earth's largest volcanic fields where activity has continued at least over the last 2 ½ Million years.

It has long been known that Yellowstone was volcanic in nature but it was not until the 1960's that the source was revealed. Bob Christianson (of the US Geological Service) had been studying the Park and could not locate the caldera responsible for the volcanism. At this time NASA were testing some new high altitude cameras and decided to photograph Yellowstone while doing so. They passed copies of the resulting photo's to the Park authorities. When Christianson saw the photo's he realised why he had not been able to spot the caldera before because virtually the whole Park (9,000 sq. km.) was the caldera, nearly 65 km across. It is a supervolcano over a hot spot, with a magma chamber about 72 km in diameter and up to 13 km in depth lying between 200 km deep and near the surface. The hot spot remains static and the surface volcanicity moves North East as the underlying continental plate moves South West.

The Yellowstone Caldera, the youngest of three overlapping, aged about 2 Ma, 1.3 Ma and 0.6 Ma respectively, is filled with rhyolitic and highly potassic (acid) lavas. The three eruptions produced ashfall, which being windborne, reached as far east as the Mississippi River, a thousand miles away. Later major magmatic activity has occurred at 150,000, 110,000 7 70,000 years BP, during which time the central caldera dome in Yellowstone has had periods of renewed uplift & depression. Between 1924, when this activity was first measured, and 1984 the dome was raised by 3 feet, falling back in 1985 by 8 inches. Geologists have worked out the cycle of Yellowstone's major eruptions is on average 600,000 years, the last one 630,000 years ago!!!



Modern Geothermal and Seismic Activity

Minor eruptions and earthquakes continue to be evident in the area, such as a huge landslide at Hegben Lake in 1959 caused by a quake of magnitude 7.5 which sent 80 million tonnes of rock down into the valley below, then 120 metres up the other side of the valley, killing 28 campers in its path. In 1999 there was a big rockfall in Gardiner Canyon, where no one was hurt. These events do not seem to put off visitors who pour into the Park each year attracted by the wonderful thermal activity of Mudpots, Fumaroles, Geysers and Hot Springs (see diagram) together with the scenery and wildlife. These include Bison, Elk, Moose, Black Bear, Grizzly Bear, Wolf, Coyote, Deer, Chipmunk as well as a great variety of birds. Beside many varieties of shrubs, grass and wildflowers the main tree types are Spruce Fir, Lodgepole Pine and Douglas Fir all adding to the differing ecosystems within the Park.

(*With grateful acknowledgement to John Williams for his excellent tour and Guide 'Geology in the Rockies'; to Bill Bryson's chapter 'Dangerous Beauty' from 'A Short History of nearly Everything'; and the Yellowstone Association's 'The Official Guide to Yellowstone'*)

Colin Brash

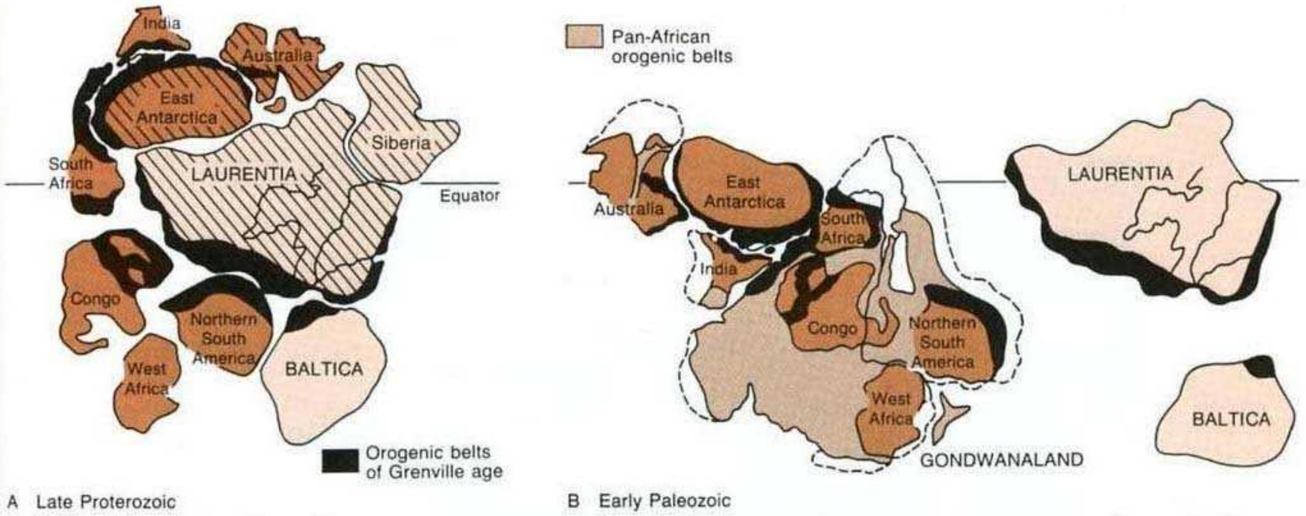
Planet Earth - First 4 billion years - Part 2: The Proterozoic

Part 1 of this article, *The Archean*, appeared in the previous newsletter

What happened in the Proterozoic ?

The development of large cratons ("continents") resulted in extensive deposition of sediments in broad shallow seas, in contrast with the predominantly deep water deposition of the Archean. From about 2000 my these cratons exhibit rifting, an plate tectonic processes formed mountain belts with characteristics similar to modern subduction and collision systems.

By the end of the Proterozoic a supercontinent had formed (fig 3); massive rifting at the end of the Proterozoic fragmented this supercontinent; Laurentia and Baltica drifted away from the remaining fragments (fig 3); these fragments subsequently coalesced to form Gondwanaland.



Changing paleogeographic patterns between late Proterozoic and early Paleozoic time. *A.* The likely configuration of the late Proterozoic supercontinent, in which North America occupied the central position. The lined portion of the supercontinent represents the smaller craton thought to have included North America earlier in the Proterozoic. Continental areas shown in dark brown represent future elements of Gondwanaland. The supercontinent was assembled by suturing along orogenic belts of Grenville age. *B.* The assembly of Gondwanaland along Pan-African orogenic belts after Laurentia and Baltica broke away. *(After P. F. Hoffman, Science 252:1409–1412, 1991.)*

By the early Proterozoic the earth's crust was markedly cooler, particularly evidenced by extensive glacial deposits at around 2500-2300 my, whilst tillite (glacial sediments) show evidence of several glaciations between 2300-1000 m) Australia suffered extensive glaciation even though it was situated within 30^{o} of the equator. Ironically, tillites have been found in all the major continents except Antarctica. The final and most extensive glaciation of the Proterozoic took place, shortly after the rifting of the Proterozoic supercontinent. This was the only ice age to put glaciers at sea level in equatorial latitudes.

As we saw above, the Archean atmosphere contained negligible free oxygen. Free atmospheric oxygen appeared late in the Archean and became abundant through the Proterozoic. How do we know? Uranium and iron oxides and iron sulphide weather rapidly in the presence of oxygen; they are rare in sediments younger than 2000 my but are relatively abundant in buried sediments older than 2000 my. Red beds are not found in terrains older than 2300 my, but become increasing common through the Proterozoic; hematite, a highly oxidised iron mineral, give the colour and often forms secondarily by oxidation of other iron minerals in the sediments, generally within a few million years of deposition. Proterozoic soils, though thin and rare, have been found; they show the chemical nature of weathering when the soil formed and show that atmospheric oxygen had reached at least 15% of it's present level by 2000 my.

How did these changes affect life ?

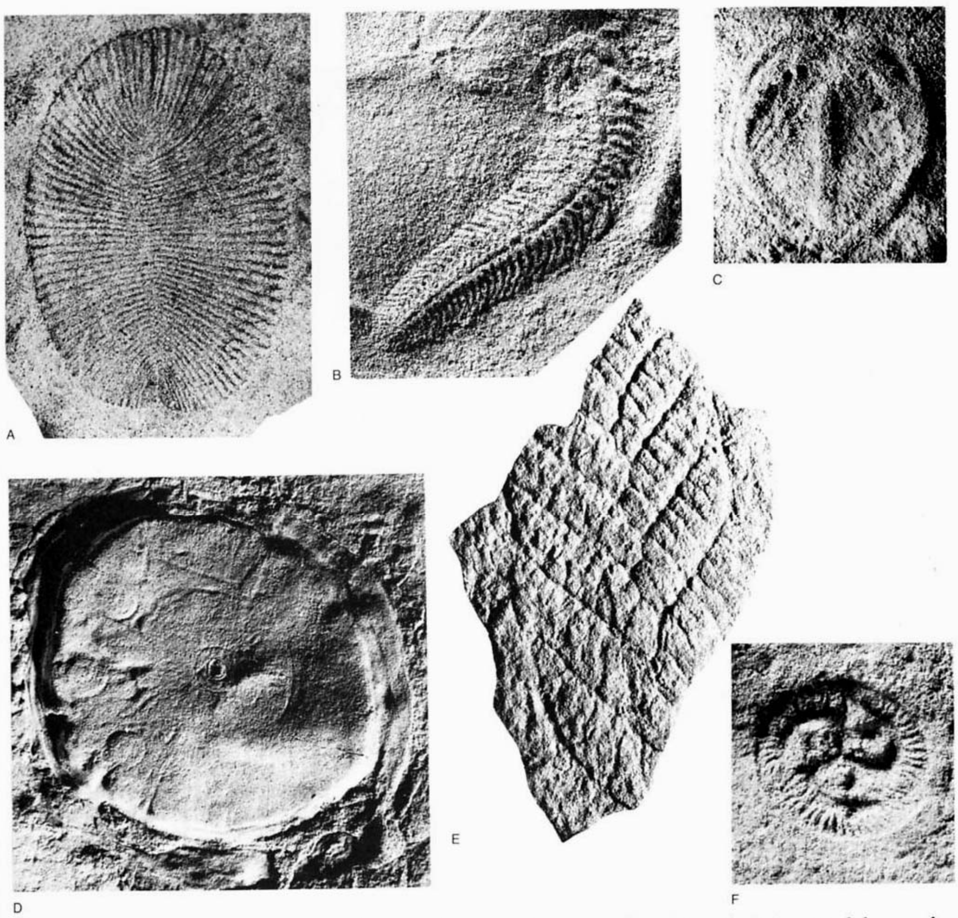
By the end of the Archean the earth was populated exclusively by single-celled prokaryotic (cells with no nucleus or chromosomes) life forms; a great expansion of life developed from these simple forms during the Proterozoic

Prokaryotic organisms, particularly cyanobacteria, have survived almost unchanged to the present - **NO** evolution!! Why? - two main reasons. Firstly, reproduction is asexual, and therefore no change in genetic material can be provided. Secondly, they can live anywhere - desert and water; hot springs and under the Antarctic ice (they have survived immersion in liquid helium at -269^{O}C in the light and in the dark 3000 feet down in the ocean; they are resistant to x-rays, ultra violet, gamma irradiation (they have survived atomic bomb blasts!) - the don't need to evolve to survive!!

With the expansion of continental shelves, after about 2300 my, stromatolites became abundant, even formed extensive reefs and remained abundant until the Phanerozoic.

All forms of life, except bacteria and cyanobacteria, are eukaryotes (their cells have a nucleus and chromosomes). They appeared around 2000 my and became abundant about 1700 my; they need a stable aerobic global environment, and this first became established about 2000 my. Eukaryotes seem to have derived from assemblies of different prokaryotes to form large simple cells.

Planktonic acritarchs appeared after about 1400 my, and became common after 1250 my; cyst like bodies suggest these forms probably developed the capacity for sexual reproduction around 1100 my. Some acritarchs may have been the cysts or resting stages of Dinoflagellates, one of to-day's most important groups of planktonic algae. Acritarchs were up to l cm in size; they diversified after about1100 my to reach a peak of development about 900 my.



Representatives of the late Precambrian Ediacara fauna of Australia. *A.* A problematic flat, segmented form (× 1). *B.* An animal that appears to be intermediate in form between a segmented worm and an arthropod (× 1.7). *C.* A strange form of uncertain biological relationships (× 1.35). *D.* An animal that may be a jellyfish (× 0.7). *E.* An animal that may be a sea pen (× 0.6). *F.* A form that may be related to the echinoderms (× 1.2). *(M. F. Glaessner.)*

About 1200 my multicellular oxygen producing algal forms and predatory animal-like forms called protozoa (like amoeba) appeared. Around 800 my some protozoans developed a rigid skeleton (the ancestors of the immensely successful foraminifera). Life became complicated; in the Archean the proliferation of the photosynthetic prokaryotes in seas and lakes was limited only by the supply of nutrients; now they became prey of the protozoans

The Earth's algal population experienced a major collapse at the time of the Proterozoic's last glaciation (-650 my). There was a decrease in carbon dioxide and an increase in oxygen - generally inimical to photosynthetic activity. This reverse greenhouse effect was associated with mega-glaciation.

The earliest mineral skeletons appear near the base of the Cambrian when there was an "explosion" of marine life. This fauna is extremely diversified and included many large multicellular organisms. There should be evidence of their soft bodied predecessors in the form of burrows and trails in the Precambrian. Such trace fossils have been found, but only in sediments younger than about 600 my ie post glacial. At the same time the Ediacaran fauna appeared (fig 4) - these soft-bodied organisms have been preserved as imprints, represent a variety of forms and are quite large, up to 20cm. The principal assemblage has been record from the Ediacara Hills in Australia; specimens also have been found in late pre-Cambrian rocks of Charnwood Forest and Carmarthen.

In conclusion

By the end of the Archean, after 2 billion years, there were substantial continental cratons, with lakes and rivers. These continents were surrounded by shallow seas in which there were huge colonies of bacteria and cyanobacteria which could or live and thrive in an anaerobic environment. Cyanobacteria gave off oxygen (a corrosive poisonous gas) as waste. Most of this oxygen was used up in "oxygen sinks" such as the banded iron stones; but eventually, by the Proterozoic, large volumes began to escape to, and poison, the atmosphere and create the ozone layer which protects Earth from harmful extra-terrestrial radiation. During the Proterozoic (the next 2 billion years) more advanced eukaryotic life forms developed which required an oxygenated atmosphere to live and thrive. By the end of the Proterozoic, animals were evolving which could cope with oxygen, and this enabled the evolution of the animal world.

It's not so long ago that scientists thought that life began in the Cambrian (5 my). But now the evidence suggests that life has been around for 4 billion years, since shortly after the formation of the planet. Then it took about 2 billion years for prokaryotic bacteria to form the first simple eukaryotic cells and another two billion years to evolve into a diverse animal and plant community - but then evolution really took off!

Graham Williams

Deposition and distribution of Eocene carbonates in NE Libya

Summary of May 2005 lecture given by Professor Richard Moody, Kingston University

Professor Moody described how his mapping of the rock deposits in the Soluq Basin and Jabal Al Akhadar regions of NE Libya was helping oil companies define the most profitable areas in which to look for oil reserves. The majority of deposits in the area described were limestones/sandy limestones, either Cretaceous or Eocene in age, the former often exhibiting "slump" structures. Rocks were laid down in either shallow water conditions, on shelf locations or in deep water. The rocks deposited on the shelf locations were, because of their coarseness and porosity, the likely reservoirs for the collection of oil.

The area had been affected by two major orogenies; the Syrian Orogeny in late Cretaceous and the Cyrenaican in Eocene times. When analysing drill-cores taken in the area, manganese content was an indication of sea-level at the time, and the nature of the rocks, fossils therein and chemistry defined the particular rock structures. Most of the coastline from Egypt to Tunisia has now been mapped by Professor Moody and others, and Professor Moody's estimate for as yet unfound reservoirs in the region of Northeast Libya with which he is most familiar amounts to 100 million barrels.

Michael Weaver

Early mining and extractive metallurgy

Summary of June 2005 lecture given by Dr Paul Craddock, British Museum, London

Mining for metallic bearing minerals began, firstly with the mining and smelting of native copper and then, following the realisation that copper could also be produced by smelting certain specific minerals, by the mining and smelting of copper-based minerals occurring in the earth's crust. The minerals were mainly the oxides and sulphides of copper, as these are readily reduced by a charcoal smelting process; not that miners then would have had any knowledge of the chemical compositions of the desired minerals or of the precise chemical reactions occurring during the smelting process.

Initially mining would have been restricted to surface breaking mineral veins, but as techniques improved, miners began to follow the veins underground. Even so, early mines were at no great depth as the miners had no way to deal with water ingress and poor ventilation. Early tools were made from antlers or stone, and these would have been used to mine the ore after its initial fragmentation by fire. Then, with the onset of the Iron-age, tools made from iron were widely used.

Dr Craddock pointed out that often it is difficult for archaeologists to know precisely which minerals were actually being mined at many ancient locations, as the rich mineral veins were removed in their entirety and more often than not there are no indications of the associated smelting areas. Many mines, originally thought to be predominately lead mines, were in all likelihood being worked for their copper content, as often large amounts of galena can still be found on their spoil tips. A big upsurge in mining occurred throughout the Mediterranean countries and in Asia once silver coinage was introduced as a widely accepted monetary system; lead then became the widely sought material as it is often associated with a high silver content.

Michael Weaver