Farnham Geological Society

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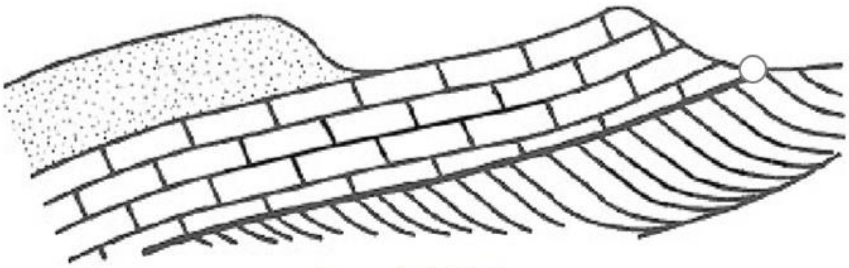

Founded 1970

A local group within the GA

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Contents

Editorial ………………………………………….... 1
Obituary: Ann Rosemary Sayer ………………. 2
Geological Snapshots of Argentina …………. 3
Something to amuse …………………. 11, 14, 19
But What Are Rocks? …………………………... 11
Geology From Your Sofa ……………………… 14
Volunteers Needed 14
Podcasts, Websites & the like ……………...... 15
Slow-Motion Earthquakes ……………………. 16
FGS Field Trip Programme 2020 …..………… 17
The Quartz Family Crossword ………………. 18
FGS Meetings Programme 2020 …..………… 19
FGS Committee 2020 …………..…………….. 19
And Finally, ……………………………………... 19

Editorial

This edition of the newsletter is different – due, of course, to COVID-19 and the "lockdown". Liz Aston, our Chairman, has asked me to put together a monthly, rather than the regular 4 monthly, online-only edition of the newsletter and this is the first. It is designed to provide you, the FGS members, with some geological news from the FGS Committee, but also from the wider geological community, in the absence, for the foreseeable future, of the Society being able to physically meet at our monthly gatherings or on our field trips.

With the help of the Committee I've tried to put together a varied newsletter which includes a summary of the talk given at our January meeting, a very interesting article by Mike Millar on how rocks are described by petrophysicists in the oil industry, some excellent and, I hope amusing, cartoons from Rennie Witt, together with news articles on a variety of topics including slow-motion earthquakes.

There is also a summary from the obituary notice published in The Guardian newspaper of one of our long serving members, Ann Sayer, who sadly passed away last month. RIP.

I hope you enjoy this newsletter. Stay safe.

Mick Caulfield

Obituary

Sadly, we have to inform you of the death of Ann Sayer, a member of FGS for many years.

This obituary is summarised from the Guardian: https://www.theguardian.com/sport/2020/apr/24/ann-sayer-obituary

Ann Rosemary Sayer, long-distance walker, born 16 October 1936; died 15 April 2020

One of Britain's finest long-distance walkers who was also a GB rowing international.

In 1977, Ann Sayer, who has died aged 83, was the first woman in Britain to qualify as a Centurion - someone who has walked 100 miles in under 24 hours. She tried to enter her first long-distance race walk in 1974 but was told by the male organisers that she could use the road, but that her name and time would not be recorded (!!). Had they been recorded, she would have received a medal, because she finished third.

She was a pioneer in women's athletics and in 1980 set the record (13 days, 17 hours, 42 minutes) for the fastest ever Land's End to John O'Groats walk by a woman - it is still unbroken. Others have beaten that time, but, by running some of the way, so they are running records. Ann walked every step of the 840 miles.

At six feet tall, with immensely long legs and flying blond curls, she had a relentless, unremitting stride that earned her the nickname "metronome".

She graduated from London University with a geology degree and worked for BP whilst rowing in an eight for what became the Thames Rowing Club. Women's rowing was not admitted to the Olympic programme until the 1970s, but she was selected for GB in the 1962 European Championships, in which they reached the final, finishing fifth. The crew were largely self-funding, buying their own boat and blades, and sewing Great Britain on the backs of their tracksuits. "Some of the sewing was rather uneven," Sayer said.

When she took up race walking in her late 30s, the longest event for women was 5km and when she achieved Centurion status in October 1977, resignations were offered rather than allow her to join that elite all-male club (!!). She was nevertheless admitted, but two years later was barred from competing at another Centurions event - the organisers claimed the facilities were unsuitable for women.

"I was not aggressively women's lib," she said of her battle for acceptance in this male-dominated world. "I was more bolshy than anything. If men were allowed to be daft and do 24-hour walks, why not us? Why shouldn't a woman do this?"

In 1994 she became the oldest woman to represent GB at a 200km race in France. In 2005 she was appointed MBE for services to sport and she became vice-president of the Long Distance Walkers Association, who supported her on her Land's End to John O'Groats challenge and for whom she completed several of their annual 100-mile cross-country challenge events.

After retirement she was heavily involved in her local community, leading Walking for Health events, acting as a volunteer guide at Strawberry Hill House and working in the visitor information centre in Bushy Park.

Ann was quiet, with a wry sense of humour and a reluctance to blow her own trumpet. She was very much a team player and a regular attendee of FGS Meetings and Field Trips over many years. She will be sorely missed by all those who knew her.

She died from long-term complications after a fall in 2018 and is survived by her brother, Victor.

We send our sincere condolences to all members of her family and circle of friends.

Liz Aston

Lecture Summary

10 January 2020

Geological Snapshots of Argentina

Messrs Aston, Pritchard & Catchpole, FGS Members

Report by Liz Aston, FGS Member

In March 2019, Professor Dick Moody invited a group of us to join him on a field trip to Argentina and I should like to provide you with a flavour of this outstanding trip. Five FGS members were on the trip and it is sad that we couldn't all be on it, as it was so good.

My daughter, a pilot with British Airways, flew us over, which was memorable for me because normally I am at her home babysitting, and we arrived in Buenos Aires full of excitement and to an unforgettable couple of days.

The planned series of visits, to museums, Rio Plata and, of course, a tango evening all had to change as there were no trains running (major repairs on the rail lines out of B.A.), and then International Women's Day, when it seemed the entire female population of Argentina descended on B.A. Traffic and the city stopped at 13:00 hours and didn't move but made up for that by honking a lot of horns for hours. The traffic only started to move again when everyone finally went home at 22:30. I don't think anyone would have been able to see the tango evening that day. Despite this we did see the museums, the pampas, La Bocca and the rest of B.A. including, the next day, the tango. It is always good to get the problems over before venturing forth, the rest of the trip was unimpeded.

First I think we need to put Argentina and Patagonia into their geological context. South America is an enormous continent with very large countries including Brazil, Bolivia, Argentina, Chile and Peru. Geologically it ranges from Earliest Precambrian to recent. The oldest rocks range from Archaean, ca. 3.85 to 2.5 billion years old to the Paleoproterozoic, 2.5 to 1.6 billion years old and the Neoproterozoic, ca. 1.0 billion to 550 million years old. During this long period of time there were many plate movements, orogenies, magmatic and metamorphic events which have left a rich history of ores and other precious minerals and these complexes form the cratons (Fig. 1) which make up two-thirds of the continental basement.

This mass of cratons is bound along the west side by a series of mountain systems trending north-south, the Andes, which formed as the continent drifted west when the South Atlantic Ocean opened, and South America separated from Africa

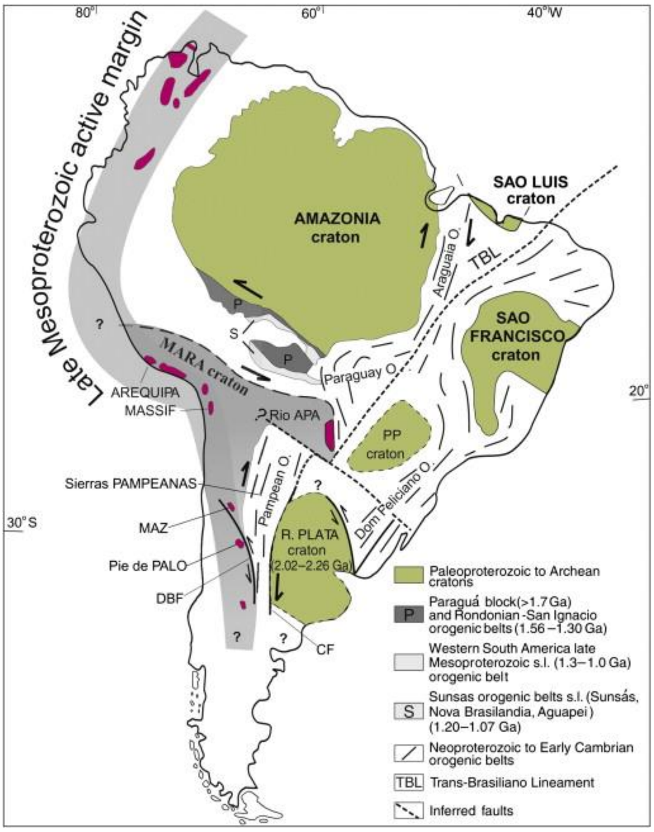


Fig. 1: Paleoproterozoic to Archean cratons and the Middle-to-Late Mesoproterozoic, and Neoproterozoic to Early Cambrian orogenic belts of South America (Ref. 2).

and the rest of Gondwana, ca. 180 million years ago (Jurassic) onwards. A link between the southern tip of South America and Antarctica remained until the Cretaceous. Country boundaries tend to follow geological boundaries as a comparison of Fig. 1 and Fig. 2 shows.

We covered all corners of Argentina – from the Iguazú Falls in the north, to the pre-Cordillera in the west; to Trelew, home of the giant dinosaurs on the east coast and then to the south – to the glaciers and high Andes, finishing up on the last evening with a safari trip through farmlands adjacent to, and ending up at, the Chilean border. It is impossible to do the trip justice; all I can give here is a glimpse of each area visited.

First, Iguazú Area and Paraná Basin - the iconic Iguazú falls form an exciting spectacle and an excellent place to start the geology of South America as it comprises a Late Proterozoic crystalline basement (the Rodinian Paranápanema gneissic-granitic crust); this is overlain by Ordovician sediments which accumulated in an embayment of the Panthalassa Ocean and were then trapped in Gondwana's interior forming the Paraná Basin (Fig. 3).

Fig. 2: Map of South America from Google Earth showing control of geology on major Political boundaries.

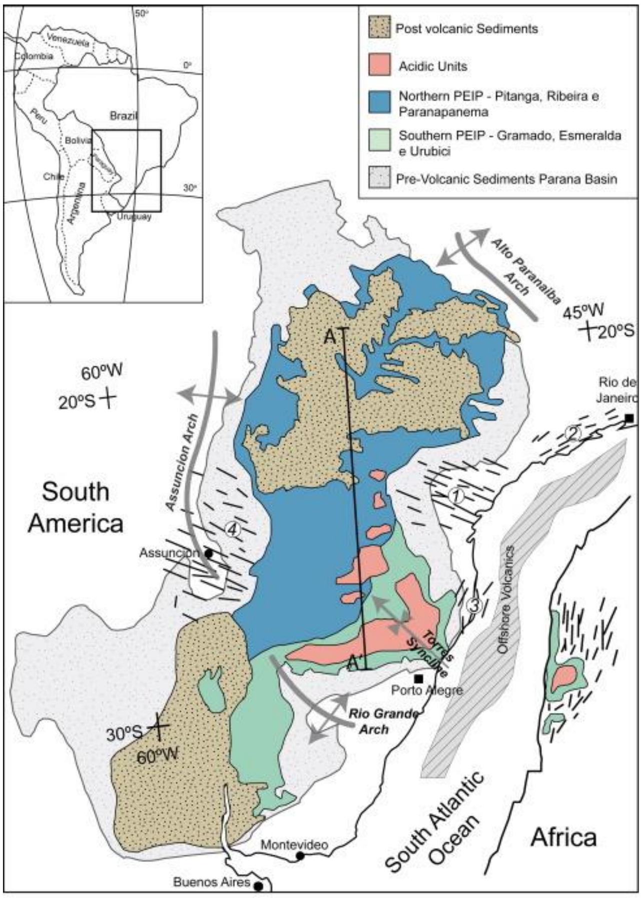


Fig. 3: Paraná-Etendeka Large Igneous Province, Argentina-Africa (Ref. 9 & Ref. 12).

As Pangea began to break up and the Atlantic to open, it did so in stages: Central, then South, then North. During the Early Cretaceous opening, the crust in this area thinned, fractured and magma poured up these faults and fractures (Fig. 4), creating the Early Cretaceous basalts of the Serra Geral Formation at the Iguazú Falls. These basalts are part of the Paraná-Etendeka Large Igneous Province outlined in Fig. 3. Coeval flood basalts occur in many varied but genetically related volcanic features on the Atlantic seafloor between Argentina and reappear in the Etendeka region of Namibia, W Africa.

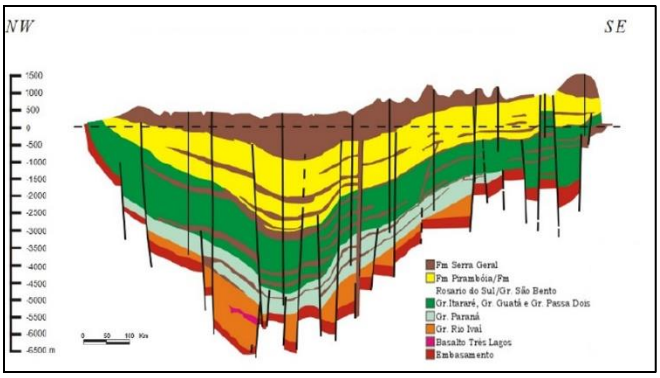


Fig. 4: Schematic geologic cross section across the Paraná basin from NW to SE (Ref. 12).

These Early Cretaceous basalt flows vary between <1m to >10m thick and the province covers >>1,500,000km^3 extruded between ca. 134 to 132 million years ago. From the limited amount of exposure I examined, the upper flows appeared to be more vesicular than the lower which is maybe why they have eroded back more quickly, as is obvious in Fig. 5 and Fig. 6.

The Rio Iguazú is one of five tributaries of the Paraná River and erosion, particularly in the Pleistocene, has created the waterfalls and their gorges. The falls can be seen from Argentina and from Brazil – both sides are dramatic: Argentina where one can get up close to huge volumes of water pouring over the edge (Fig. 5) with clouds of mist and Brazil, where wide areas of falls can be seen from a distance (Fig. 6).

Fig. 5 is adjacent to the River Iguazú as it flows over the edge in Argentina, while Fig. 6 is taken from the Brazilian side showing how the upper sequences of basalts have been eroded faster that the lower suite. The Paraná River System has an asymmetric drainage basin of ca. 1,500,000km^2. From October to March, the river is heavily laden with silt and clay and forms a large delta when it enters the Atlantic at Rio de la Plata; it was full of red silty water when we were there.

Fig. 5: River Iguazú as it flows over the edge in Argentina.

Fig. 6: River Iguazú as it flows over the edge from the Brazilian side.

On to Patagonia, part Argentina and Chile, the largest and least populated region of South America. It comprises the southerly section of the Andes, with deserts, pampas and grasslands to the east and a coastline on the Pacific, the Atlantic and the Southern oceans. The Tierra del Fuego Archipelago is sometimes included in Patagonia: Magellan called the tribes of this area 'Patagon', thought to mean 'giants'.

The Archaean to Mid-Cambrian geological history of the green/grey cratons in the northern part of South America (Fig. 1) is comparable with the Congo craton – they were all part of West Gondwana (Fig. 7).

Patagonia, however, is different – it is believed to have attached (agglutinated) onto Gondwana adjacent to these cratons along the southwestern edge, probably 270 to 250 million years ago (Permian).

The 'Patagonian Plate' has suffered several episodes of fragmentation/rifting from, and then convergence and re-accretion to, Gondwana in the Lower Permian. Two large depressions intersect

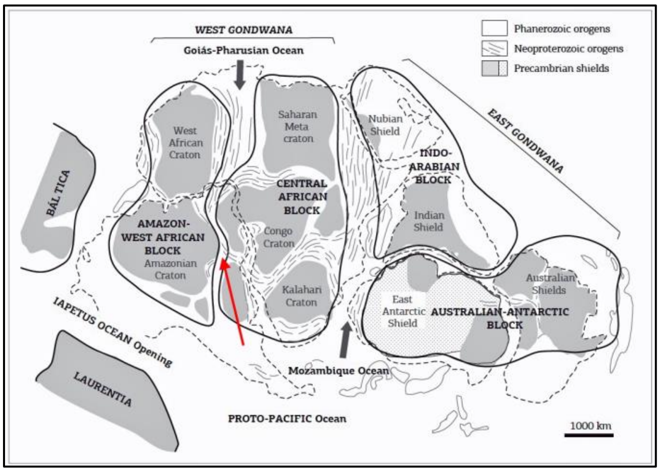


Fig. 7: Crustal building blocks of west and east Gondwana (Ref. 12, modified from Ref. 3).

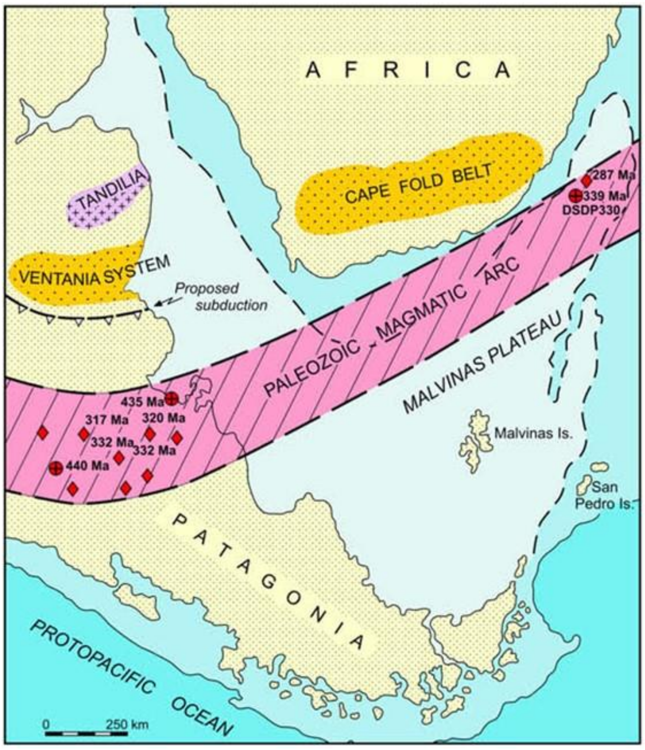


Fig. 8: Northern belt (Ref. 8).

transversely (probably ancient, tectonic, oceanic lines) as shown in Fig. 8, the northern belt and Fig. 9, the western belt.

The northern belt extends from Bariloche to the Atlantic coast and comprises a Cambrian to Early Ordovician marine facies associated with a magmatic arc, dated at ca. 470 million years old. Cambrian (with Neoproterozoic zircons) to Carboniferous sequences, suggest a para-autochthonous origin within Gondwana.

The westerly belt from Central Patagonia, south to Deseado Massif and beyond comprises a magmatic arc of Devonian to Permian age, ca. 380 to 320 million years old, running NNW-SSE, along the eastern side of the Andes (Cordillera). This

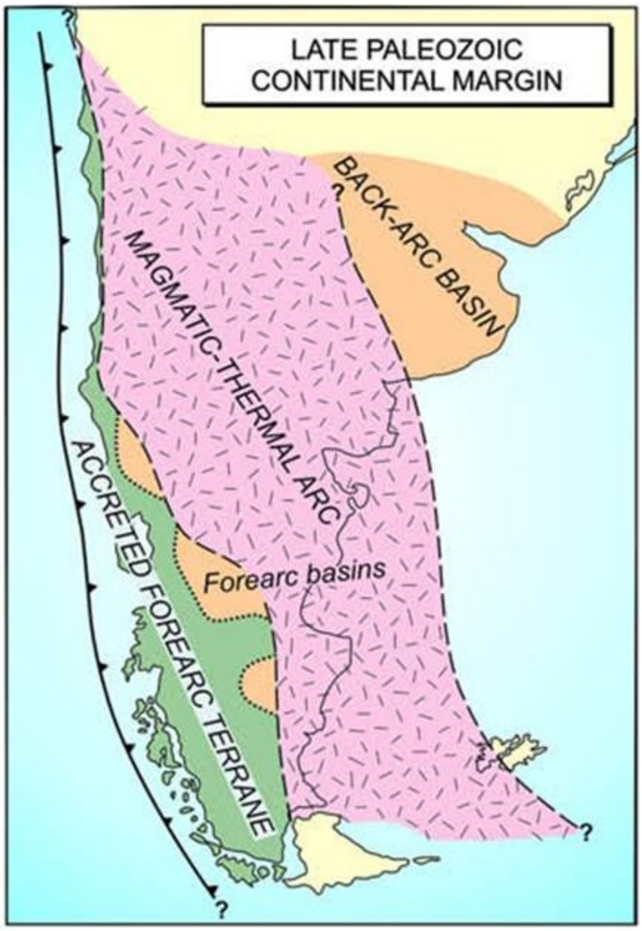


Fig. 9: Western belt (Ref. 8).

sequence is associated with Carboniferous zircons, 345 million years old. A magmatic arc from late Paleozoic subduction was followed by collision, resulting in igneous–metamorphic complexes and foliated granodiorites, emplaced deep in the crust and migmatites ca. 280 million years old; the episode ended with intense thrusting and faulting.

Argentine Patagonia has thirteen 100m (approx.) terraces, covered with shingle and almost bare of vegetation. In the west, near Chile, they include many porphyry, granite and basalt clasts. The high rainfall and low sea temperatures mean there are lots of ponds, lakes and the largest icefields in the Southern hemisphere, bar Antarctica.

Our first stop was in the pre-Cordillera and into the Andes where Darwin had made his historic journey across the Andes, and then to Mendoza of Malbec fame. Fortunately for us red wine drinkers there were numerous wines to taste, including one called Benjamin (also the name of one of our group) which like the others was very palatable.

Pre-Carboniferous sediments formed in distinct tectonic environments and were later tectonically juxtaposed with ophiolites, dolerite and gneiss.

These rocks form the structural base of the area. Initial folding was driven from the west (Paleo-Pacific) with shearing along minor zones early in Devonian times; folding continued and intensified, resulting in an ultramafic/gabbro complex being thrust over younger units.

Much later, in Tertiary times, there was thrusting from the east; this was part of the Andean Orogeny with open folds, thrusts and reactivation of earlier features forming terranes in the south western Precordillera. These terranes strike north-south (Fig. 10) and from west to east, they comprise: thick Carboniferous to Early Permian sedimentary sequences; an igneous–metamorphic belt; foreland basin deposits >5000m thick; and last, terrigenous sediments ca. 2500m thick deposited in a rift system of late Permian age. The thrusting of this area is well displayed in the cross section in Fig. 11 and can be seen in the Fig. 12 and 13.

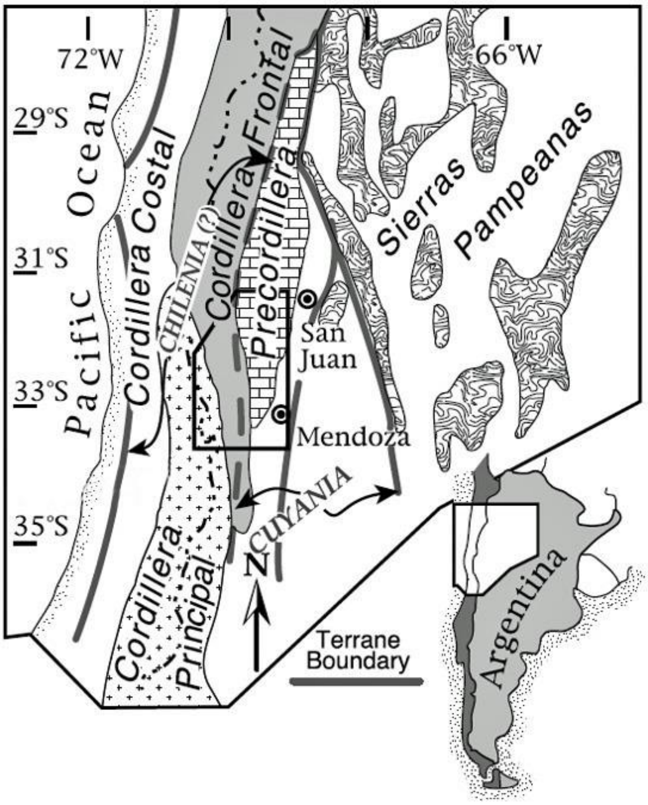


Fig. 10: Location of the Precordillera terrane in Western Argentina (Ref. 4).

Charles Darwin made an iconic excursion through the Andes, spending almost two years in South America, analysing the geology, people and animals and he considered it a crucial step in his understanding of The Origin of the Species.

Close to the Cross of Paramillo, site of Darwin's Plundered Fossil Forest, we found many samples of andesite (the intermediate lava from which most

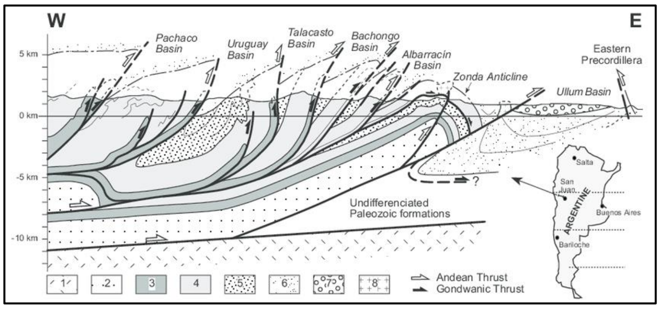


Fig. 11: Cross section through the Central Argentinian Precordillera (Ref. 1).

Fig. 12: Subvertical strata in the Precordillera

Fig. 13: Puente del Inca, a natural bridge.

terrestrial volcanoes are formed and named for their prevalence in the Andes) and a variety of iron, copper and other ore minerals. Later we passed the famous Inca Bridge, which Darwin considered 'uninspiring' (Fig. 13).

From Mendoza we flew east to Trelew and the Valdes Peninsula. Here we were treated to a wonderful day with the palaeontologists at The Egidio Feruglio Museum of Palaeontology, in this quiet 'Welsh' town. This is an excellent museum that focuses on Patagonian fossils but is also home to a research team that have collected and are now cleaning and classifying an amazing collection of bones from the largest dinosaur as yet discovered, namely Patagotitan majorem, an unknown group of titans (long-necked herbivores). They were discovered in 2013 by a local farmer who saw a bone protruding from desert rock near

Fig. 14: Patagotitan majorem, 40m long, 70 tonnes (Ben, 'holding him up', is 1.8 m+).

Fig. 15: Patagotitan majorem spine, ca. 2m long.

La Flecha, about 250 km west of Trelew. Six individuals of this species were found together, part of a diverse group that roamed Patagonia ca. 100 million years ago. Their neck is so long and heavy that they couldn't hold them up – they had to extend out in front of them, counterbalanced by their tails. This area has a lot of gigantic fossil species including ammonites and Glyptodonts, relatives of Armadillos. The gigantism is thought to be due to a warm climate, lush land, thick forest and an abundance of food.

The nearby coast, including the Valdes Peninsula, is home to an amazing collection of creatures including Southern Elephant Seals, Magallenic Penguins, Armadillo, Little Owls, Southern Crested Caracara, Guanaco and Rhea. We were blessed with sunshine, but the wind was very strong, akin to the Hebrides.

The area is part of a large Jurassic volcanic province which formed across this part of Patagonia during the breakup of Gondwana

Fig. 16: Patagotitan majorem individual vertebrae ca. 1.2m tall.

(a transtensional regime with large-scale half-grabens). The province contains alkaline and calc-alkaline trends (andesite to trachyte to rhyolite) with a gradual increase in silica, sodium and aluminium. The time span for the eruption of the various lavas is from ca. 180 to 165 million years, with migration of magmas from south to north.

The Mesozoic and Cenozoic deposits in this area have a good vertebrate fauna: a model of mid-Jurassic Piatnitzkysaurus is displayed at Trelew airport; the huge mid-Cretaceous dinosaur Argentinosaurus has been found in Patagonia; also gigantic wingless birds, larger than any others known; the very large mammal Pyrotherium and many cetaceans. An Upper Cretaceous turtle (Meiolania) is almost identical to a Pleistocene Meiolania in Queensland, indicating there was a connection between Australia and S America.

During Oligocene and Early Miocene times, large swathes of Patagonia experienced a marine transgression, which temporarily linked the Pacific and Atlantic oceans.

Finally, we travelled over to southwest (Andean) Patagonia, to El Calafate, west of the Precordillera. A land of glaciers, lakes, high mountains, beef farms and, like everywhere else in Argentina, friendly and helpful 'natives'. The area is often dominated by recent glacial features - lake basins along the Cordillera include Lake Argentino and Lake Fagnano. There are hand paintings in caves nearby – a very moving spectacle partly to think that people had been crouching down and living

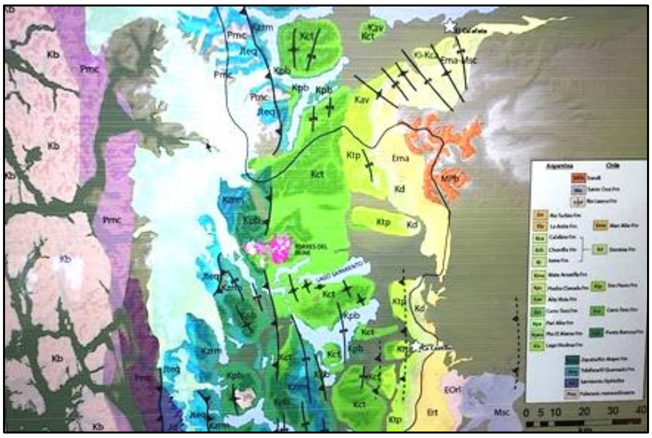


Fig. 17: Simplified tectono-stratigraphic map of southwest Patagonia (Ref. 4).

there thousands of years previously but also because sadly some previous visitors had hacked away and physically removed these paintings – vandalism at its worst.

A simplified tectono-stratigraphic map of southwest (Andean) Patagonia (Fig. 17) shows the South Patagonia batholith (pink) lying in a complex of Palaeozoic metasediments (grey).

The Patagonian fold-thrust belt consists of a) the Rocas Verdes, Jurassic-Early Cretaceous, back-arc rift basin (purple) with both basaltic and silicic volcanic rocks; then b) a foreland back-arc basin under compression with deep to marginal marine siliciclastic rocks of Late Cretaceous Magallanes-Austral (green); and then c) shallow to non-marine siliciclastic rocks associated with the Cenozoic foreland basin (not pictured).

The transition from back-arc extension to compression was associated with gentle folding and deepening the fore deep from 100-500m to 1,000-2,000m. The final phase was a transition from deep-marine facies into shallow and marginal-marine deposits of the Campanian-Maastrichtian. Jurassic rift-related and Cretaceous foreland basin strata are exposed along the South Andean fold-thrust belt (green areas in Fig. 17).

The last few journeys on our trip were into the high Andes mountains, glaciers and farming country. This is the area of the Southern Patagonia Ice Field which extends for ca. 350km over an area of 12,363km^2, most of it lying in Chile. There are many glaciers in the area, and we visited the Perito Moreno Glacier, 258m^2, which was continuously calving whilst we were there.

Whilst we had thoroughly enjoyed every bit of the trip, the best was in fact left for the last evening – a ‘safari’ into the ‘outback’. We piled into two jeeps

Fig. 18: View of Mt Fitzroy

Fig. 19: One side of the Perito Moreno Glacier

Fig. 20: River from Perito Moreno Glacier.

and off we went through the most beautiful farming area of Argentina past interesting outcrops of ?Miocene sedimentary rocks which had been ?thrust west and then into the wilds of the Andes foothills, ending at the Chilean boarder (Fig. 21).

On the way we had passed a lonely ‘croft’ a small farmhouse - but the best was to come - on the way back, in the dark, the guides settled us down in the farmhouse, in front a roaring log fire with canapés,

Fig. 13: Foothills of the Andes, at the border with Chile.

beer and wine and then a sumptuous supper with a local speciality of homemade beef stew in a bowl-shaped pastry case – delicious! Thank you Dick for a great trip.

Fig. 21: Argentina Odyssey Group including FGS Members Liz Aston, Janet Catchpole, Gay Hamilton-Williams, Roger Lloyd and Sally Pritchard.

References

1. Alonso, J.L., Rodríguez-Fernández, L.R., García-Sansegundo, J., Heredia, N., Farias, P., Gallastegui, J., 2005, Gondwanic and Andean structure in the Argentine Central Precordillera: the Rio San Juan section revisited, *6th Internacional Symposiumon Andean Geodynamics (ISAG 2005, Barcelona), Extended Abstracts: 36-39.*
2. Casquet, C., Rapela, C.W., Pankhurst, R.J., Baldo, E.G., Galindo, C., C.M. Fanning, C.M., Dahlquist, J.A., J. Saavedra, J., 2012, A history of Proterozoic terranes in southern South America: From Rodinia to Gondwana, *Geoscience Frontiers, 3 (2).*
3. Cordini, I.R., 1955, Contribución al conocimiento del sector Antártico Argentino. *Publicaciónes del Instituto Antártico Argentino, 1.*
4. Fosdick, J.C., A. Graham, S.A. Hilley, G.E., 2014, Influence of attenuated lithosphere and sediment loading on flexure of the deep-water Magallanes retroarc foreland basin, Southern Andes, *Tectonics, 33, 2505–2525, doi:10.1002/2014TC003684*
5. Gerbi, C., Roeske, S.M., Davis, J.S., 2002, Geology and Structural History of the SW Precordillera Margin, N Mendoza Province, Argentina, *Jour of South American Earth Sciences, 14.*
6. Gibson, S. A., Thompson, R.N., Day, J.A. 2006, Timescales and mechanisms of plume-lithosphere interactions: 40Ar/39Ar geochronology and geochemistry of alkaline igneous rocks from the Paraná-Etendeka large igneous province, *Earth & Planetary Science Letters, 251 (1-2).* http://www.largeigneousprovinces.org/06nov
7. Malkowski, M., Schwartz, T., Sickmann, Z., 2016, Jurassic–Cretaceous Stratigraphic Evolution of the Magallanes–Austral Deep-Water Foreland Basin, Argentine Patagonia.
8. Ramos, V.A., 2008, Patagonia: A paleozoic continent adrift?, *Jour of South American Earth Sciences, Volume 26, Issue 3.*
9. Rosetti, L., Lima, E.F., Waichel, B.L., Hole, M.J., Simões, M.S., Claiton, M.S.S., 2018, Lithostratigraphy and volcanology of the Serra Geral Group, Paraná-Etendeka Igneous Province in Southern Brazil: Towards a formal stratigraphical framework, *Jour of Volcanology and Geothermal Research, Volume 355.*
10. Schwartz, T.M., Fosdick, J.C., Graham, SA., 2017, Using detrital zircon U-Pb ages to calculate Late Cretaceous sedimentation rates in the Magallanes-Austral basin, Patagonia, *Basin Research, Volume 29, Issue 6.*
11. Stone, P, 2015, Geological exploration of South Atlantic islands and its contributions to the continental drift debate of the early 20th century, *Proceedings of the Geologists' Association, Volume 126.*
12. Blog: http://written-in-stone-seen-through-my-lens.blogspot.com/2017/11/the-geology-of-iguazu-falls-of-south.html

Photographs from the trip were provided by Sally Pritchard and Janet Catchpole.

A little something to amuse, from one of our FGS members, Rennie Witt.

“A little cartoon of an incident I saw while out in Godalming on my daily exercise! I think it catches the mood of today. The dog walkers explained they were practicing ‘social distancing’, but I don’t think the dogs were too pleased!”

Article

But What Are Rocks?

A biased view of rock descriptions and rock properties from the oil-patch

Mike Millar, FGS Member

Geologists usually describe rocks in terms of things like colour, mineralogy, grain size, sorting, and shape, bedding, fossil content, and cementation. These properties are based on the solid components of the rocks including their chemical composition.

Wikipedia defines a rock as "any naturally occurring solid mass or aggregate of minerals or mineraloid matter. It is categorized by the minerals included, its chemical composition and the way in which it is formed. Rocks are usually grouped into three main groups: igneous rocks, metamorphic rocks and sedimentary rocks. Rocks form the Earth's outer solid layer, the crust."

From the British Geological Survey **Lexicon of Named Rock Units** we see rocks described as "Camberley Sand Formation comprises a fairly uniform sequence of homogeneous, bioturbated, yellow-brown, sparsely to moderately glauconitic silty fine-grained sand, or sandy silt, with some ironstone concretions and masses of white sandstone." Or The Gault as "Pale to dark grey or blue-grey clay or mudstone, glauconitic in part, with a sandy base. Discrete bands of phosphatic nodules (commonly preserving fossils), some pyrite and calcareous nodules."

But rocks frequently have a fluid (liquid or gas) component, as well as their solid component, which is hardly surprising given that sedimentary rocks are deposited in the presence of water or air. And this is not limited to sedimentary rocks, extrusive igneous rocks frequently give off gases like water vapour, sulphur dioxide, hydrogen sulphide, carbon dioxide and carbon monoxide, with some igneous rocks defined by their vesicles.

So, we also need to think of rocks in terms of the interaction between the solid and fluid components. This is related to their grain structure including properties such as porosity, permeability and capillarity. It is especially relevant to earth scientists working in the oil patch, as these are the properties that help determine the potential quantities of oil and gas we have discovered and our ability to produce them safely and economically. And the same principals can be applied to earth scientists working on underground water supply projects, or carbon capture projects.

Porosity is the ratio between the void (empty) space and the total volume of the rock. It can be expressed either as a percentage or as a fraction. It is important because it defines how much space there is for fluids between the solid rock grains, i.e. the “carry capacity” of the rock unit.

In theory we can define maximum porosity based on packing arrangements of ball bearings or glass beads (Fig. 1). These theoretical views help us to understand some things about porosity. For example, that it can be affected by sorting and packing, but that it is not affected by grain size.

In practice, I have never come across a rock unit made of perfectly spherical and perfectly sorted grains. In the real-world porosity can be above those theoretical maxima. For example, the structure of the tests of coccoliths and diatoms means that Chalk and Diatomites often have porosity in excess of 50%, even though the pore size is very small (Fig. 2). Even in sandstones porosity can be enhanced by the dissolution of certain rock grains to above the theoretical values, for example the dissolution of feldspars within Eocene sands and the dissolution of sponge spicules within certain Jurassic sandstones (Fig. 3). The downside to these two processes is that elsewhere the chemicals released by the dissolution often results in the precipitation of minerals that reduce porosity, for example, kaolinite from feldspar and quartz from sponge spicules.

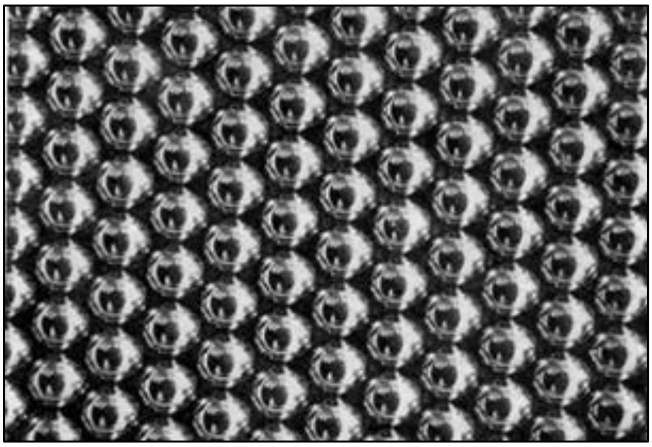


Fig. 1: Porosity in theory, spherical ball bearings, showing idealised rhombohedral packing and well sorted, which will give a maximum porosity of 26%.

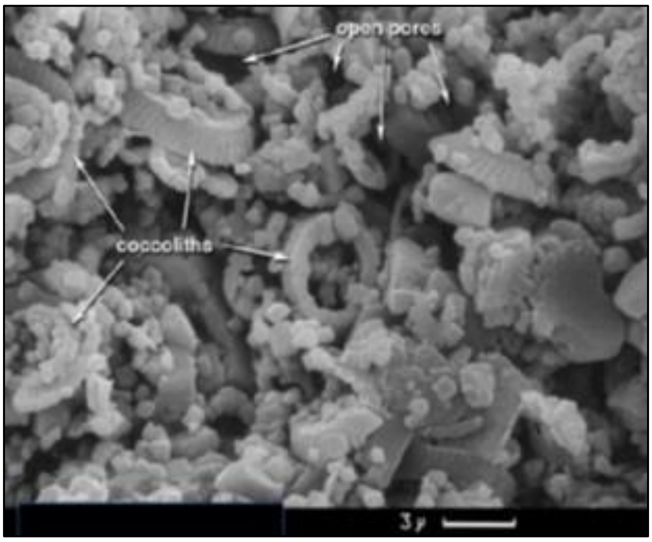


Fig. 2: Porosity in Chalk. SEM showing pore space between the tests of coccoliths. Scale bar is 3 μm.

So, porosity can form with primary deposition and can be enhanced or reduced by diagenetic processes. It can also be formed by fractures. It is reduced by compaction as the rocks are buried.

Pore space can form in a huge range of sizes, from the microscopic scale of coccolith tests up to vugs and fractures you can put your finger into. The magnitude of porosity is not affected by the size of the voids, and as a consequence the carrying capacity of our rock unit is not affected by this.

However, the void size does have a significant influence on the potential for reservoired hydrocarbons because of its effect on permeability and capillarity.

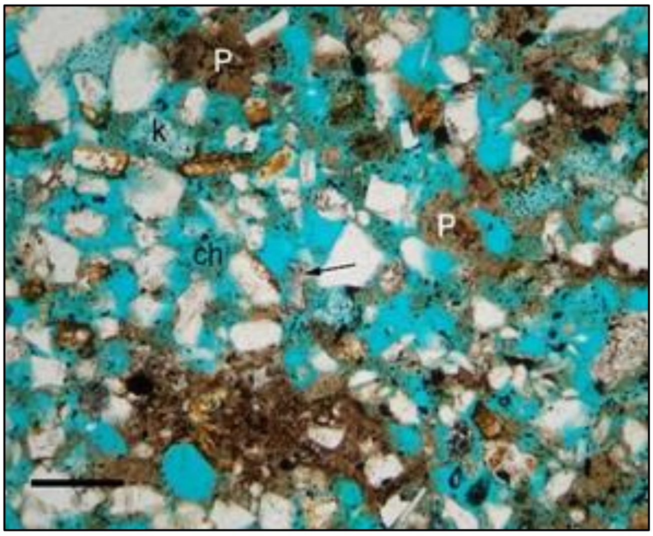


Fig. 3: Primary and secondary porosity in Jurassic sandstone. Thin section with pore space stained blue. Scale bar is 0.2mm, porosity is 30% and air permeability is 25mD.

Permeability is the ability of the rock to transmit or flow fluids, will any oil and gas get into the rock unit and will we subsequently be able to get it out at a commercial rate of flow? Henry Darcy first quantified permeability in a way that can be measured on rock samples. He was a civil engineer working on the public water supply for Dijon in the 1840s and 1850s, and in the oil patch we still use the Darcy (more often millidarcies) as the unit of measurement for permeability; note the SI units are square metres.

Although it is clear that if there is less void space, there is less possibility of fluid flow through a rock unit, there is not a simple relationship between porosity and permeability. As indicated above, pore size, or more specifically pore throat size has a big impact on permeability. It is much easier for fluid to flow through larger pore throats than smaller ones. So, for example, in a chalk unit the average porosity maybe 30% and the average permeability maybe 5mD (millidarcies), whereas in a sandstone unit the average porosity maybe lower at 25% but with a much higher permeability of 250mD.

So, permeability is influenced by pore and pore throat size, and these are affected by a number of factors including the depositional environment of the rock unit and then what happens to it after it is deposited. During burial, compaction will reduce porosity and pore throat and thus permeability.

Also, during burial, increases in temperature may cause a variety of diagenetic processes, as discussed above. Dissolution may improve porosity and thus permeability. And the precipitation of clays such as kaolinite and chlorite will reduce pore space, often at the pore throat and thus reduce permeability (Fig. 4). Precipitation of cements such as quartz, calcite or dolomite may completely fill the pore space reducing permeability to effectively zero (Fig. 5).

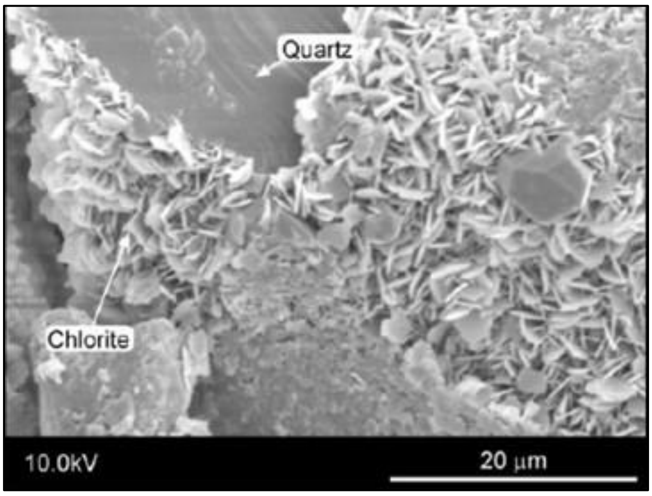


Fig. 4: SEM showing diagenetic Chlorite restricting pore throats and thus reducing permeability.

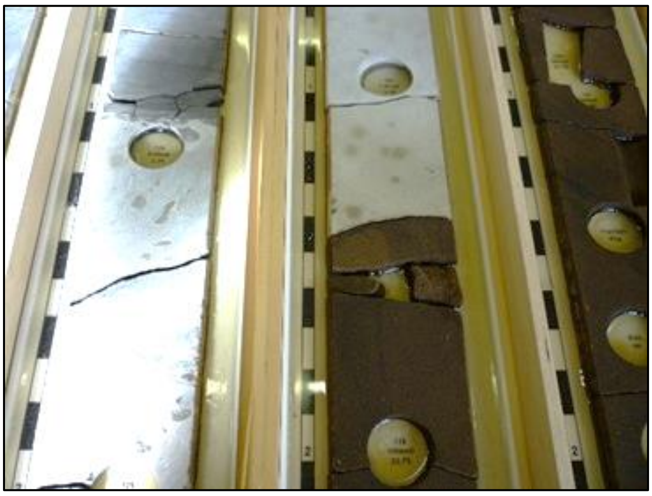


Fig. 5: Cemented Jurassic sandstone (white) in contrast to oil stained porous and permeable sandstone (brown) in slabbed core. The holes are where horizontal plugs are cut to perform analyses for porosity, permeability and grain density. Each slab is about 4 inches across and about 18 inches long.

This brings us onto another concept, that of wettability. In our example the glass is water-wet and the air is non-wetting (Fig. 6). If you polish your car, rainwater forms discrete droplets on the surface before it rolls off. If like me, you don't polish your car, the rain just smears all over the car (Fig. 7). The polish makes the water non-wetting on your car. Water is generally present throughout the subsurface, so sediments usually start out water bearing and water-wet, acting like our glass tubes and the water will fill all the pore space.

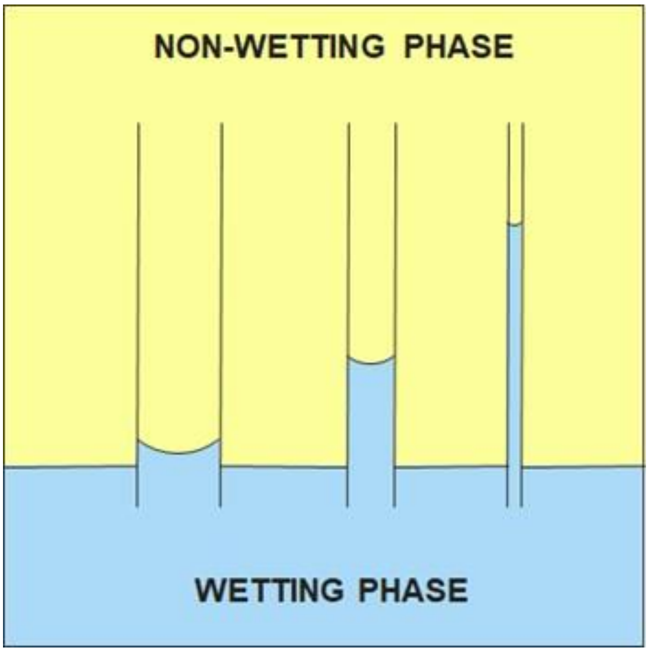


Fig. 6: Water (blue) as wetting phase, rising up capillary tubes displacing, in this case, non-wetting air (yellow).

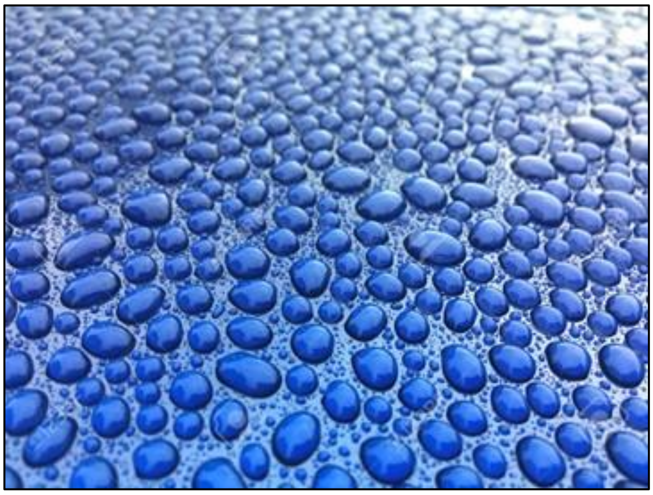


Fig. 7: Non-wetting droplets of water on the polished surface of a car, unlike most of the subsurface where the rocks are water-wet.

So, if our subsurface sediments are full of water, how does oil and gas get into the rock units of our oil and gas fields? Hydrocarbons are generated in organic rich source rocks over time. The hydrocarbons are less dense than water and they migrate upwards due to buoyancy until they are trapped within the field structure, displacing most of the formation water in the reservoir. Migrating hydrocarbons displace the water from the bigger capillaries first, so reservoir quality in terms of porosity and permeability has a major impact on the water and hydrocarbon saturation of the reservoir.

Wettability plays an important role here too, as discussed, the sediments generally start out water-wet. As the hydrocarbons displace the water, some water is left attached to the rock surfaces held by capillary pressure. So, it is usual for an oil or gas reservoir to have some water present, and this is known as the water saturation (Sw).

It has to be noted that in some cases, with the effects of mineralogy, water and/or oil chemistry, time and temperature, the wettability of the rock may change.

So where does this lead us in terms of describing our rocks?

A geologist may say that a rock unit is "a clean, well sorted, fine-grained sandstone. Bioturbation level is probably no greater than moderate. The mottled fabric reflects a combination of local cementation adjacent to bivalve shells, plus Palaeophycus burrows"

Whereas in an oil company a petrophysicist would say "the sandstone has 30% porosity and 800mD air permeability, with a water saturation of 10%".

And both are right of course, and both are of equal importance for understanding the subsurface. The petrophysicist's numbers can be used to help determine how much oil is present and whether it can be produced safely and economically. And the geologist's description will help us to understand the bigger picture: will the whole reservoir be like this? how big might it be? is there likely to be another one like this nearby?

News

Geology From Your Sofa

16 April 2020

“Whilst the Geologists’ Association may not be able to invite you to attend lectures and field trips at the moment we are looking at ways for you to still enjoy geology, virtually through online courses and virtual field trips.

Here at “Geology From Your Sofa (GFYS)” we’ve added more content for you to explore and enjoy. From free geology lectures and podcasts to a wealth of online courses, some free and some available for a small fee.

We have had some positive feedback on one of Nick Zentner’s virtual field trip. So, if you have particularly enjoyed something GFYS have signposted please let us know by emailing Sarah Stafford - geol.assoc@btconnect.com.

Also, if you find something you think visitors to the GA website would enjoy please share that with Sarah too.

From the GFYS team”

https://geologistsassociation.org.uk/sofageology/

A little bit more something to amuse, from Rennie Witt.

“Out on a run I suddenly, over the crest of a hill, found myself running down a wooded lane with a family coming up! Not good, but they took evasive action and we kept our social distance!”

Geologists’ Association

Volunteers Needed….

30 April 2020

"We've just added a number of new volumes to the GA Carreck Archive online resource. This is part of the ongoing digitisation being undertaken by the British Geological Survey. The digitised archive has also been transferred to the BGS Earthwise platform, which is very similar to Wikipedia. With this move we can now start to create an index for the albums. This is where you come in – **we need volunteers to help with this project**.

The task is simple: once registered on Earthwise you'll be able to start helping transcribe the information from the albums into an index which will be there for everyone to use. This can be done in your own time, at your own pace, and from home (or wherever you may be). All you need is access to a web browser and you'll receive help and guidance to get you started.

This really is a great opportunity to have a deeper delve into the archives and see what you can find and help grow the archive resource as you do so.

If you're interested to get involved please contact me at archive@geologistsassociation.org.uk

Jonathan Larwood

GA Archivist"

Podcasts, Websites and the like

Open Country

The Music of the Surrey Hills

16 April 2020

Judith Wilson, FGS Member: "Some of us visited St Barnabas Church last summer, after the tour of the Denbies Vineyard. The Open Country programme on Radio 4, talks about the church and mentions the vineyard and it's geology, saying it is like the Champagne district in France."

https://www.bbc.co.uk/programmes/m000h7s3

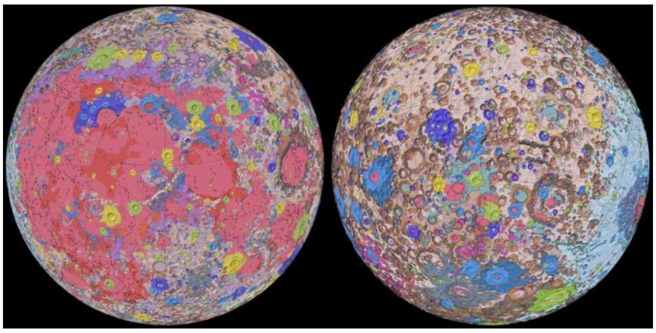
Websites

USGS Releases First-Ever Comprehensive Geologic Map of the Moon

New Comprehensive Geologic Map of the Moon Released

The United States Geological Survey (USGS) has just released a new authoritative geological map to help explain the 4.5-billion-year-old history of our nearest neighbour in space.

For the first time, the entire lunar surface has been completely mapped and uniformly classified by scientists from the USGS Astrogeology Science Center, in collaboration with NASA and the Lunar Planetary Institute.



The lunar map, called the "Unified Geologic Map of the Moon," will serve as the definitive blueprint of the moon's surface geology for future human missions. The digital map is available online now and shows the moon's geology in incredible detail.

https://www.usgs.gov/news/usgs-releases-first-ever-comprehensive-geologic-map-moon?fbclid=IwAR2azos0tQt23b0_5nYQSQ3Qu5b696iXtKD5nOvRYOT5OCHaEWY8hfFh1c8

The Infinite Monkey Cage

Dinosaurs

Brian Cox and Robin Ince are joined by Rufus Hound and palaeontologists **Susannah Maidment** and **Steve Brusatte** who reveal the big new discoveries in the world of dinosaur hunting.

https://www.bbc.co.uk/programmes/m0008hkl

A YouTube link for a bit of **astronomy** (courtesy of Farnham Astronomical Society):

https://www.youtube.com/channel/UC5npZmbA_Ntb0aj14Mm8VlQ

Liz Aston

A little bit more amusement, from Rennie Witt.

The weekly shopping scene

"What I found most amusing, when I went down on my bike to the supermarket, the upturned trolleys were in service as a fence. I am sure Heath Robinson would have approved."

News

Getting to the bottom of Slow-Motion Earthquakes

https://eos.org/articles/getting-to-the-bottom-of-slow-motion-earthquakes

Summary of an article by Adityarup Chakravorty (chakravo@gmail.com, Science Writer)

A new study published in **Science Advances** indicates that geological heterogeneity may be the reason for some slow-slip seismic events.

Most earthquakes last for a few seconds or minutes at most, releasing a great deal of energy usually both quickly and violently. Slow-motion quakes (slow-slip events) can last for days or months and release small amounts of energy, usually only detectable by GPS networks, over a long period of time. Although they were first recognized ca. 20 years ago, little is still known.

Fig. 1: Drilling in IODP Expedition 372.

Fig. 2: Core Samples from Hikurangi subduction zone.

Both photos - Philip Barnes (NIWA)

Philip Barnes, lead author of this study, is a geologist at New Zealand's (*NZs*) National Institute of Water and Atmospheric Research and noted that slow-slip events at the Cascadia subduction zone in North America occur at depths of ca. 40km (out of reach). However, the NZ researchers have observed slow-slip events at depths of <15km in the Hikurangi subduction zone, along the coast of North Island, NZ. By drilling into this zone, his team was able to collect samples from the Pacific plate before it moves under the Australian plate.

These core samples have provided compositional and physical properties of the plate which they have combined with seismic reflection data. The rock sections comprised volcaniclastic rocks from the top of a seamount at the margin of the Hikurangi subduction zone; the same rocks are considered to form part of the slow-slipping subduction fault zone.

The rocks are extremely heterogeneous, with highly variable properties, such as strength, porosity, and texture. "*Some rocks were mushy and weak, whilst others were hard, cemented and strong*," Barnes said in a press release. '*In some areas, properties such as porosity varied almost twofold within tens of cm. Not only was the Pacific plate made up of heterogeneous rock types, its geology was variable as well, including seamounts rising more than a kilometre above the seafloor.'* This geological and physical heterogeneity could explain the slow-slip events observed in the area, according to Barnes. "*Many people think faults with slow-slip events are in a transitional frictional state*," he said. "*They are very close to failing (causing a typical earthquake), but something is holding back that failure*."

This variation of rock types and geological features entering the Hikurangi subduction zone could mean that "*some parts of the fault get periodically stuck and unstuck ('stick slip'), whereas other parts are sliding along without much ado (aseismic or fault creep), ultimately yielding an overall area with slow-slip events*".

Roland Bürgmann, a geologist at the University of California, Berkley, who was not connected with the study commented: "*This study provides new, directly sampled, and beautifully imaged information about the stuff that is being subducted into a slow-slip zone*."

Jean-Philippe Avouac, a geologist at the California Institute of Technology not connected with the study said: *"While this study is an impressive effort to characterize the incoming seafloor [at the Hikurangi subduction zone], how it plays out in explaining slow-slip events is yet to be fully determined."*

Other comments note "*factors, such as fluid pressure changes, probably influence slow-slip events, both at Hikurangi and at other locations. Also, the degree of heterogeneity that the authors found may make interpretations more challenging*".

Barnes agrees that more work needs to be done. "*This paper is one of the first outputs of a very large research project*. *We are at the beginning stages of what I hope will be a much fuller exploration of slow-slip events*."

Summary by Liz Aston

Farnham Geological Society Field Trip Programme 2020

Update 31 March 2020

Cornwall: Sunday 24 to Wednesday 28 May
Cancelled

Canary Wharf: Saturday 20 June
To be confirmed by end May

Cathedral to Cathedral: St Paul's - Southwark
Thursday 9 July
Led by John Williams
To be confirmed by end June

Thames Foreshore: Sunday 9 August
Led by Adrian Rundle
To be confirmed by end July

Folkestone: Saturday 12 September
Led by Adrian Rundle
To be confirmed by end July

50th Anniversary Field Trip to NW England:
Monday 5 to Friday 9 October

Monday 5: Visit Brymbo Forest en-route

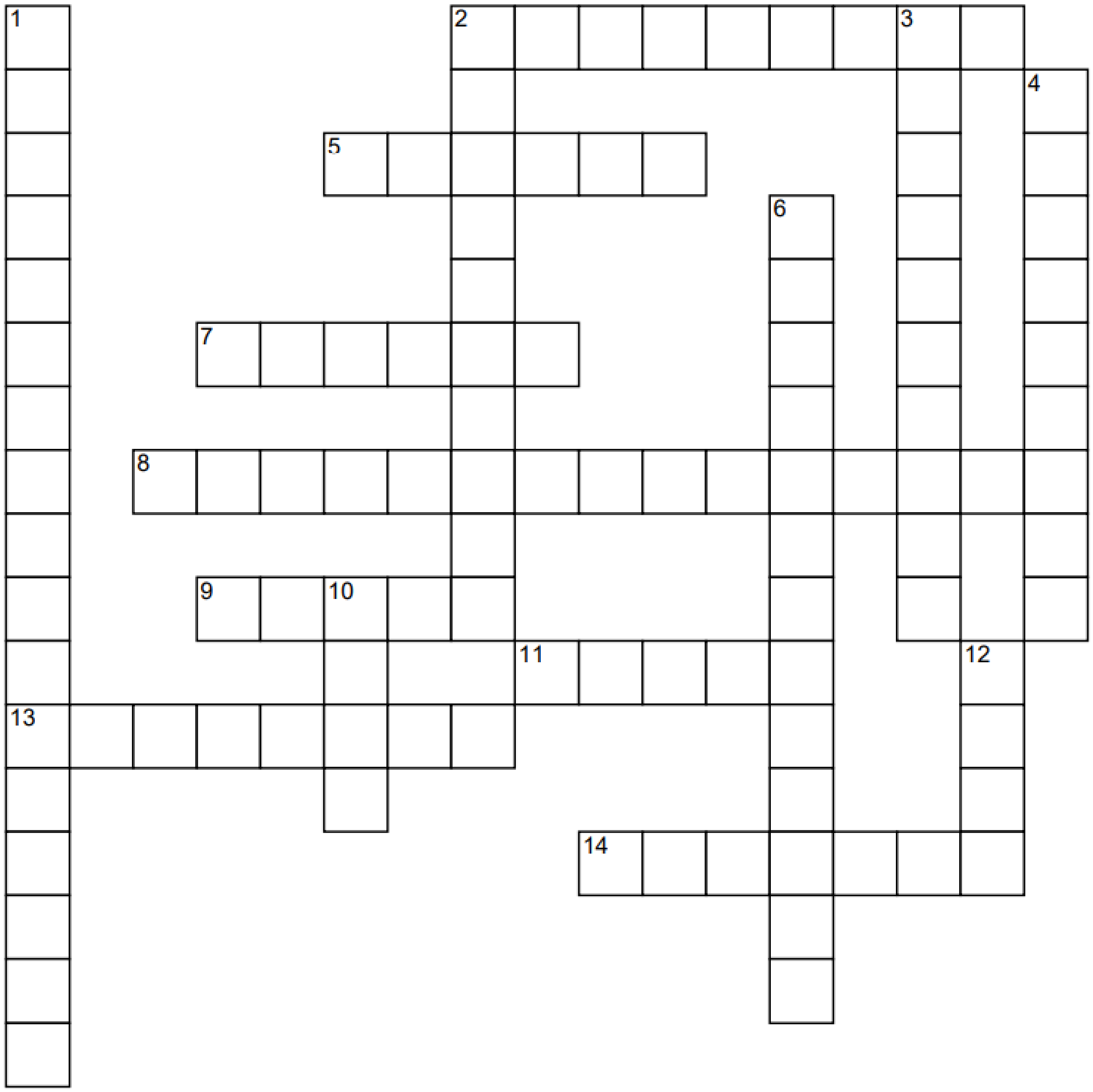
Tuesday 6: Building Stone Walk and Manchester Geology Museum

Wednesday 7: Area north of Manchester

Thursday 8: Liverpool Williamson Tunnel and Thurstaston Hill and shore

Friday 9: Return to London via Satnall Hill Quarry Geotrail

The Quartz Family Crossword



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ACROSS

2. A clear red chalcedony.
5. One of the most common of minerals in the continental crust.
7. An opaque red variety of cryptocrystalline quartz.
8. The chemical formula for quartz.
9. _______ quartz is a brown type of quartz.
11. The name of a group of silicates made of chalcedony.
13. A purple variety of quartz.
14. A yellow variety of quartz.

DOWN

1. Crystals are only visible with magnification.
2. One of the cryptocrystalline varieties of quartz, the mineral in agates.
3. A green variety of cryptocrystalline quartz.
4. A chatoyant gemstone containing asbestos.
6. Mechanical pressure generates electrical charge.
10. A black and white banded variety of cryptocrystalline quartz.
12. _______ quartz is a pink type of quartz.

Answers in the June Monthly Newsletter.

Farnham Geological Society Meeting Programme 2020

Update 4 May 2020

Argentina Odyssey 10 Jan
Messrs Aston, Pritchard & Catchpole
FGS Members

A Volcano Valentine's Day 14 Feb
Dr Matthew Genge
Dept. Earth Science and Engineering, Royal School of Mines, Imperial College

Last Patagonian ice sheet 13 Mar
Dr Bethan Davies
Centre for Quaternary Research, Dept. of Geography, RHUL
Cancelled

Brymbo Forest: its discovery & conservation 17 Apr
Dr Tim Astrop
The Brymbo Fossil Forest Project, N Wales
https://bff.news.blog/discovery/
Cancelled

Cambrian Arthropods & their subsequent evolution 15 May
Dr Greg Edgecombe
Dept. of Earth Sciences, Natural History Museum
Cancelled

Climate archives of caves & stalagmites 19 Jun
Prof Dave Mattey
Dept. of Earth Sciences, RHUL
To be confirmed by end May

FGS 50th Anniversary Meeting 10 Jul
To be confirmed by end June

Extremophiles: The search for extra-terrestrial life 18 Sep
Dr Marina Barcenilla
University of Westminster

Mass accumulations of Chalk Ophiuroids in Lewes 9 Oct
Dr Tim Ewin
Dept. of Earth Sciences, Natural History Museum

The smallest things can make a difference 20 Nov
Dr Liam Gallagher
Consultant

Tongan pumice raft 11 Dec
Dr Isobel Yeo
National Oceanography Centre, Southampton

Farnham Geological Society Committee 2020

Chairman	**Liz Aston**
Treasurer	**Peter Luckham**
Secretary	**Judith Wilson**
Programme Secretary	**Janet Catchpole**
Membership Secretary	**Sally Pritchard**
Field Trip Secretary	**John Williams**
Newsletter Editor	**Mick Caulfield**
Web Manager	**Michael Hollington**
Advertising	**Peter Crow**
IT/Sound	**Mike Millar**

And Finally, …

As I mentioned in the last Newsletter I would like to ask for your help in providing ideas for improving the Newsletter … for example, have you read a geological book recently and would like to submit a review? Or have you discovered an interesting geological website or Facebook page that you would like members to know about? Or read an article or taken a photograph that you feel your fellow FGS Members would be interested in?

I would also be very interested in hearing your thoughts on the Newsletter. Or if you wanted to write a comment on any other aspect of the FGS I would be interested in publishing them on a Members "Letters" page. If the latter then please let me know whether or not you would be happy for me to include your comments in a "Letters" page.

If you do have any ideas please feel free to forward them to me at caulfm@hotmail.com.

Mick Caulfield