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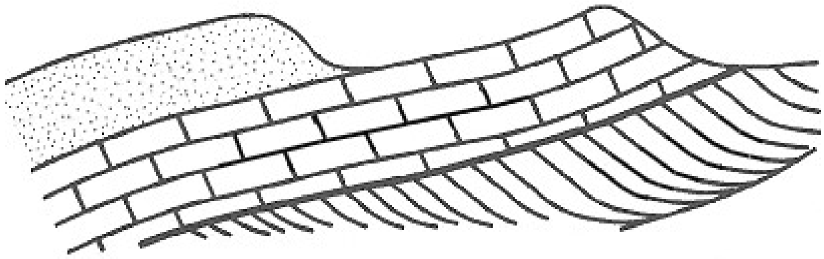

A local group within the GA

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Editorial

In this issue of the Magazine I have to report the extremely sudden, and totally unexpected, resignation of our esteemed Chairman, Graham Williams, who has been a stalwart of the Society for so many years.

I first met Graham over a cup of coffee at BP Research Centre Sunbury on Thames, when he was working on one side of the corridor (in the Micropalaeontology Section of the Palaeontology Department, i.e. the Palaeo Labs) and I was working on the other side of the corridor (in the Petroleum Geology Department, i.e. the rock labs). That was back in ?1968 (so long ago that I cannot actually remember the year) and our paths have crossed intermittently since and then we both ended up on the FGS Committee in the new millennium.

When I compiled the original index of all of the Society's newsletters from 1970 onwards, (*Index now maintained by John Stanley and is available on the FGS website)*, I was amazed by Graham's efforts. In 2005, he ran a series of field trips under the title "The Building of Southern England - Sunday Field Trips" with trips entitled: Albury Traverse; Lias, Dorset; Middle Jurassic limestones of the Cotswolds; Upper Jurassic - Dorset; Lower Cretaceous rocks of Sussex; Middle & Upper Cretaceous - W Weald; Tertiary - Kent. A truly good start to the geology of S England for all members to enjoy.

Then, from 2006-2019, his field trips have covered pretty much every region and every stratigraphic period of the UK. A summary of these field trip locations is included below:

- Scotland: NW Highlands, Hebrides, Caithness, Grampians, Dumfries & Galloway;
- 'N' England: Northumberland, N Yorks, Isle of Man, Derbyshire, Charnwood; Midlands;
- Wales, Ireland: Anglesey, Cardigan Bay, Gower Coast, Severn Bridge, Cork & Ring of Kerry;
- 'S' England: Shropshire, Gloucester, Marlborough, Cotswolds, Dorset, Kent, Sussex, SW Peninsula, Jersey;
- Europe/overseas: Normandy, Brittany, Languedoc, Majorca, Madeira;

An amazing feat; he had a lot of support from his wife Susan and of course from the ever faithful Jack!!

His hard work and dedication will be sorely missed by the Committee and all members of the Society. We are unaware of his reasons for leaving or his plans for the future, but we wish him the very best for a long and happy retirement from Farnham Geological Society.

Obituaries

Mary Darling sadly passed away in July, she and her husband Alan were active members of the FGS for many years during the 1980's and 1990's. She went to live with her elder son in Shropshire after the loss of her husband and from there moved up to Scotland. Over last year she was a resident in a care home in the Borders, where she died peacefully at the age of 93.

Tony Brown who was also a very active member, serving on the committee for many years but had been unable to attend field trips (which he loved) and meetings recently due to poor health.

Bill Houghton, another active member, from some years ago, also died this year following a fall in a nursing home.

Joan Prosser, a stalwart member of FGS since 1983 sadly lost her husband Tony at the end of August 2019. He had always supported Joan in her FGS activities.

We send our condolences to all their families and friends.

New horizons and the exploration of Pluto

Summary of September 2019 lecture given by Dr Kevin Pretorious

In 1929/30, Clive Tombaugh (employed at the Flagstaff Observatory, Arizona) was searching for Planet X – Percival Lowell's prediction of a large planet, perhaps 5 or 10 times the mass of the earth, orbiting beyond the orbit of Neptune. His job was to take photographs of the night sky every night, and to compare them with images taken a few weeks earlier, looking for anything which had moved in between the two exposures. On Feb 18th 1930 he found a likely candidate – a faint point of light that moved in just the right way to be a distant planet, which soon came to be named Pluto.

Whilst Tombaugh was looking for a planet – this was not it. Rather than being bigger than the Earth, Pluto is smaller than our Moon. The discovery of Pluto was therefore entirely serendipitous – it just happened to be passing through the part of the sky where Tombaugh was searching. Lowell's Planet X did not (and does not) exist.

Pluto's small size and great distance make it very difficult to study. At 5 billion km from the Earth, it appears as no more than a speck of light in any ground-based telescope. Its orbit was easy to determine, and its size was first estimated by stellar occultations – literally timing how long a star's light was blocked out as Pluto passed in front of it. Its mass could only be calculated once it was discovered (in 1978) that it had a moon (Charon), allowing calculations to be done on their mutual orbits.

Knowing the approximate size and mass provides its density which suggests its composition as a mixture of ice and rock. Spectroscopy indicated the surface was mostly comprised of nitrogen with some methane and carbon monoxide, and a puzzle existed over the thickness of Pluto's nitrogen atmosphere, which was thicker than expected.

And that's almost all of what was known for perhaps the 75 years following its discovery.

The New Horizons mission was launched in 2006 to obtain a close-up view (Figure 1). It carried a telephoto camera to obtain high resolution images, imaging spectrometers spanning the infrared, optical and ultraviolet ranges, and particle experiments to study the environment.

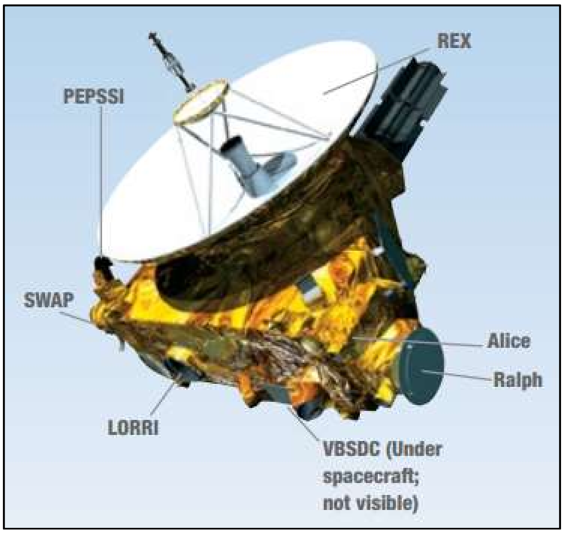


Fig. 1: The New Horizons probe illustrating the main instruments. (Image NASA/SWRI/JHUAPL)

Fig. 2: Hi Resolution image of encounter-facing side of Pluto (Image: NASA/SWRI/JHUAPL)

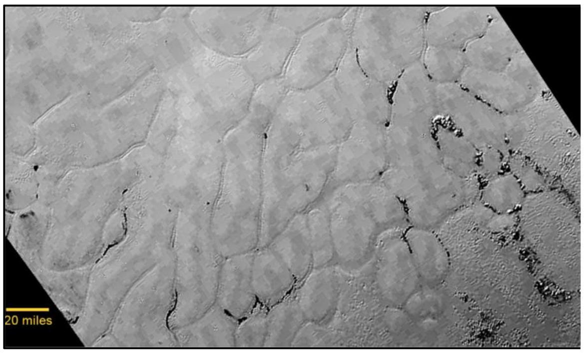
The first images of Pluto far exceeded expectations. Scientists were anticipating that Pluto would be a dull, ice-covered, dormant world, but observed a world with a rich and diverse topography, a vast nitrogen ice plain, mountains, a strange dark equatorial band stretching most of the way around this dwarf planet, and multiple signs of an active geology (Figure 2).

Perhaps most striking was the enormous heart-shaped feature (named Tombaugh Regio), whose western half (Sputnik Planitia) was a vast plain of Nitrogen ice devoid of impact craters (indicating a surface less than 1 Ma old).

Close-up examination of Sputnik Planitia (Figure 3) reveals it to be broken-up into polygonal or cellular regions several tens of kilometres across, with hills apparently piercing through the surface along a number of the cell boundaries. The nature and origin of these features was not initially apparent.

Higher resolution photos of the northernmost edge of the plain showed the presence of flow-lines around obstacles, which led the science team to conclude that the plain is actually a moving glacier.

The polygonal features are identified as *convection cells*, welling up slushy nitrogen ice in their centres, flowing outwards to the cell boundaries where they encounter flows in an opposing direction and are channelled downwards.



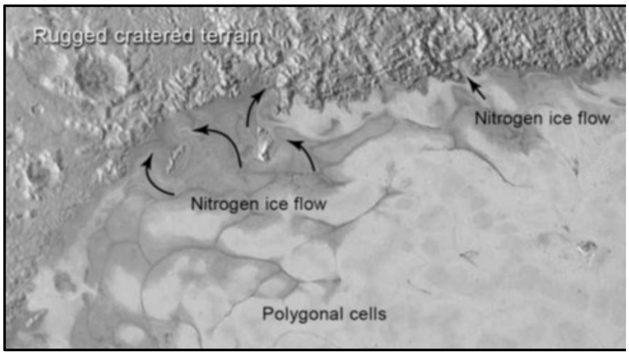
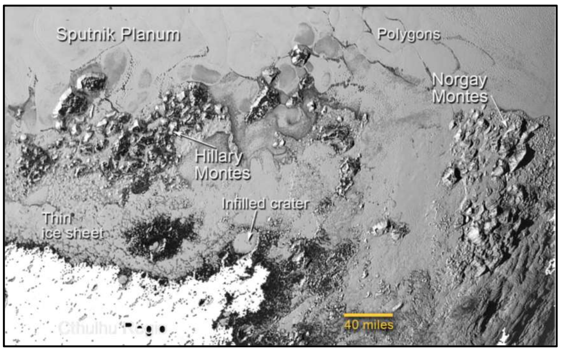


Fig. 3: Above: Close-up Image of Sputnik Planitia - a vast Nitrogen plain, criss-crossed with troughs, breaking up the plain into cellular regions, with small hills aligned with, and apparently piercing through the cell boundaries.

Upper Right: Moving glacier with flow-lines & polygonal convection cells.

Lower Right: Sputnik Planitia and its mountain ranges



As for the mysterious hills poking up through the boundaries – they're not hills at all. They're *icebergs* – large masses of water ice broken off from mountains east of the plain and carried to the cell boundaries by the slowly churning flows of the convection cells. When the icebergs reach the convection cell boundaries, they simply float there, unable to move further, except when jostled along the cell boundaries by the arrival of subsequent icebergs – a process that causes them to line-up along the boundary.

Down in the south-west corner of Sputnik Planitia (Figure 3b) are two mountain ranges which reach up to 3400m tall. Spectroscopy indicates the mountains are made of nitrogen, but this cannot be the whole story, as nitrogen is clearly able to flow at these temperatures (as it does in Sputnik Planitia) and cannot be used as a building block for mountains.

Other images however reveal traces of water ice visible in nearby canyons and craters which hint at the presence of an underlying water ice bedrock, from which these mountains are (surely) made. The nitrogen can only be a surface covering.

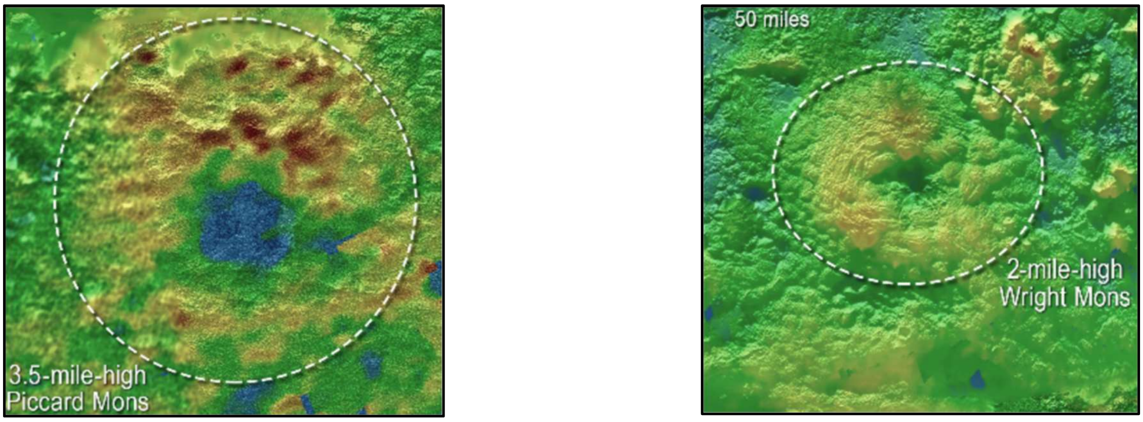


Fig. 4: Piccard and Wright Mons - candidate ice volcanoes (Image NASA/SWRI/JHUAPL)

The source of the fresh nitrogen – both in bright snow on Sputnik Planitia and indeed in the surprisingly thick atmosphere, may well be from *ice volcanoes*. Two topographic features were seen (*named Piccard Mons and Wright Mons – Figure 4*) which look remarkably like textbook volcanoes and may be spewing slushy ices down their sides or erupting nitrogen into the atmosphere (NB: no *direct* evidence of activity was seen).

Away from the plain (Figure 5) there is a dark, ruddy coloured band which otherwise encircles the equator of Pluto. It includes a variety of geological terrains, but it appears to be made of water ice, covered by a thick layer of what is presumed to be tholins - large, complex organic macro-molecules. Some of the highlands are additionally covered in a methane snow.

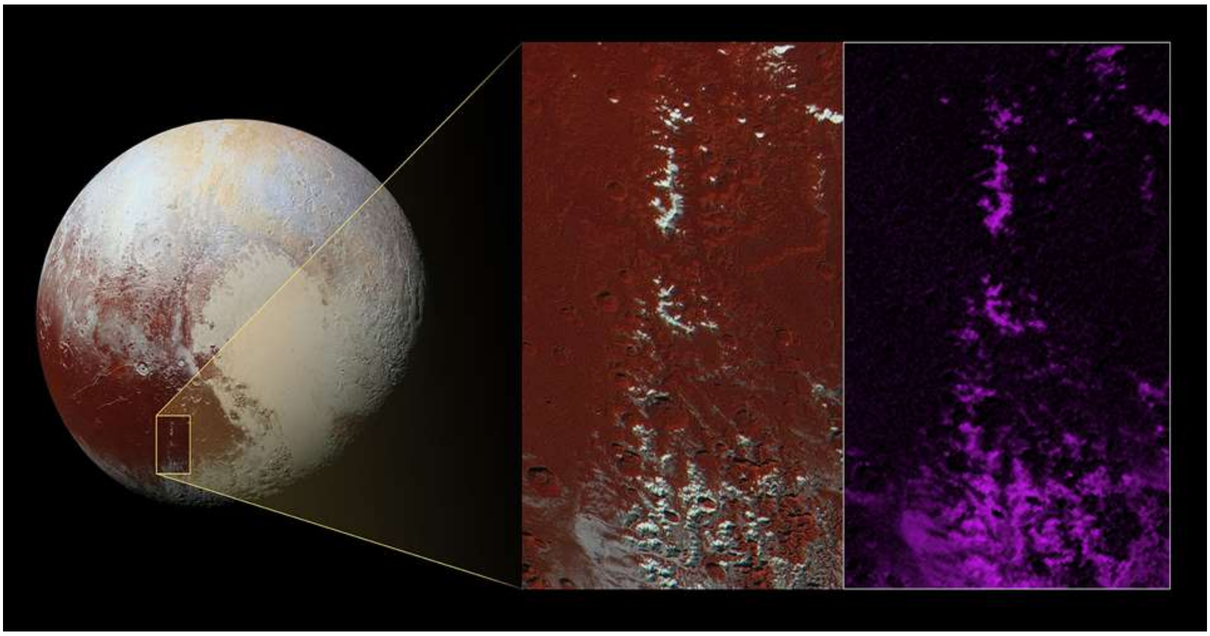


Fig. 5: Focussing on Cthulu Regio, the E end of a dark band of material which mostly circles the Pluto's equator. Spectroscopy reveals methane snow in highland regions. (Image: NASA/SWRI/JHUAPL)

Looking back on Pluto from its night-side (Figure 6) reveals an extensive, hazy and stratified atmosphere, which stretches out to about 130km from the surface. Intriguingly, the evening haze is noticeably thicker than the morning haze, providing evidence that the haze is created during the day, and depleted overnight. It's thought that Solar UV is processing the methane into simple organics such as ethylene and acetylene, and thereafter into more complex macro-molecules (tholins), which rain down onto Pluto's surface giving it its evident ruddy colour.

Pluto's moon Charon was also studied during the fly-by (Figure 7). This is a completely separate world with a very different geology. It is made entirely of water ice, with no significant quantities of nitrogen, methane or carbon monoxide ices as found on Pluto. Its surface is heavily cratered throughout, indicating a long-dead world with no active geology.

Around its equator it has a long system of canyons, and other pull-apart features. Scientists think this most likely indicates that Charon may initially have had an underground ocean, which froze and expanded, stretching and fracturing the surface.

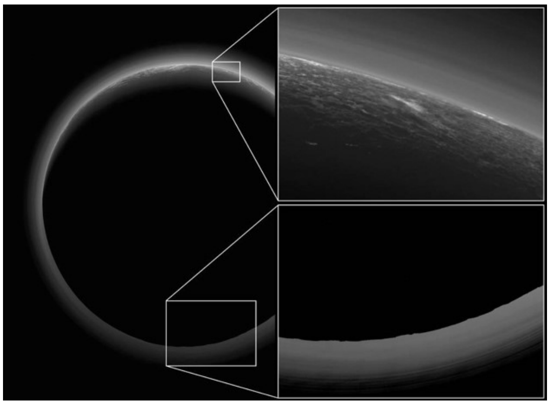


Fig. 6: Night-side view of Pluto, illustrating the layers of haze in the atmosphere, and the thicker evening haze (bottom right inset) versus morning haze (top left inset). (Image: NASA/SWRI/JHUAPL)

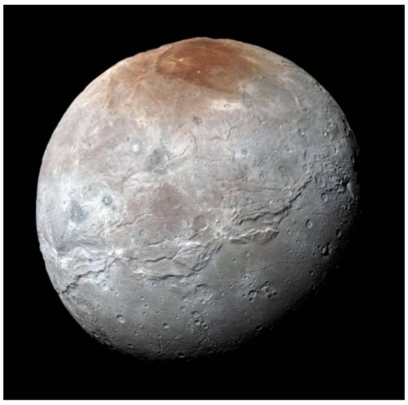


Fig. : Pluto's largest moon Charon - a water-ice world with canyons and cliffs around its equator and a dark ruddy macula at its North pole.

At its North Pole is a large and distinctive dark spot (Mordor Macula), which is very reminiscent of similar maculae on Pluto *(macula is term used for dark spots on planets or moons).* The problem is however that Charon has no native methane to process into tholins. The consensus view then, is that the pre-cursor molecules were lost from Pluto's atmosphere (potentially blown by the solar wind) which fell and froze onto Charon's pole during the Winter and were subsequently re-processed into these macro-molecules by the action of the Sun's UV during the Summer. Lighter components would have sublimated, leaving only the dark sticky residue of tholins remaining at the pole. In all probability, another macula exists at the South pole, but was merely not visible during this short fly-by.

Analysis of Charon and the other moons of Pluto establishes that they are all of a similar age, surface composition and orbital shape, which points to a common origin – most likely as the result of a major impact event some 4 Ga ago.

New Horizon's fly-by of Pluto was fast and brief, but in perhaps 6 hours, flying past Pluto at around 40x faster than a rifle bullet, this tiny probe added immeasurably to our understanding of this world. It took 15 months to download all the data from the encounter, but scientists will be studying this for a decade or more to come.

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Kevin Pretorius

An introduction to the economic geology of the Weald basin
Summary of April 2015 lecture given by Dr Richard Seaborne

Introduction

This summary starts by considering the general geology of the Weald Basin, its location, how it formed, what it contains and what its geometry is. This background then allows a discussion on various economic aspects of the Basin, including:

- Its oil and gas potential, both conventional and in terms of its fracking potential.
- The various rock formations that have uses in the building industry and beyond.
- How the geology is influencing the steadily growing wine industry in the area.

It also briefly introduces various moribund economic activities reliant on the geology, that were once important in the area.

The area covered is the 200km between the SE coast of Kent and the eastern parts of Hampshire in an east-west sense and the 45km between the south coast and the northern chalk outcrop in a north-south sense.

Basic Geology

Figure 1 is a map of the surface geology of the South East of England *(Map is Based upon BGS 1:625k surface geology of the Great Britain and Northern Ireland map, with the permission of the British Geological Survey).* At the surface the core of the Mesozoic Weald basin comprises the Early Cretaceous Weald Clay Group, shown in olive green. These are the oldest exposed rocks in South East England. Successively younger layers of strata form haloes around the edges of the Weald outcrop:

- The Lower and Upper Greensand are shown in beige and grey respectively.
- Overlying this is the outcrop of Chalk shown in light green.
- The youngest rocks in the area are shown in mauve and represent the Tertiary sediments of the adjacent London and Wessex Basins.

The Basin contains a succession of Cretaceous and Jurassic age sediments. Figure 2 is a schematic geological log of the rocks encountered in the Albury gas field, operated by IGS Energy just to the southeast of Guildford. This field is producing natural gas from early Cretaceous Purbeck Formation sands. This log will be used for each economic topic to demonstrate where the rocks associated with the economic aspect are located in the stratigraphic column.

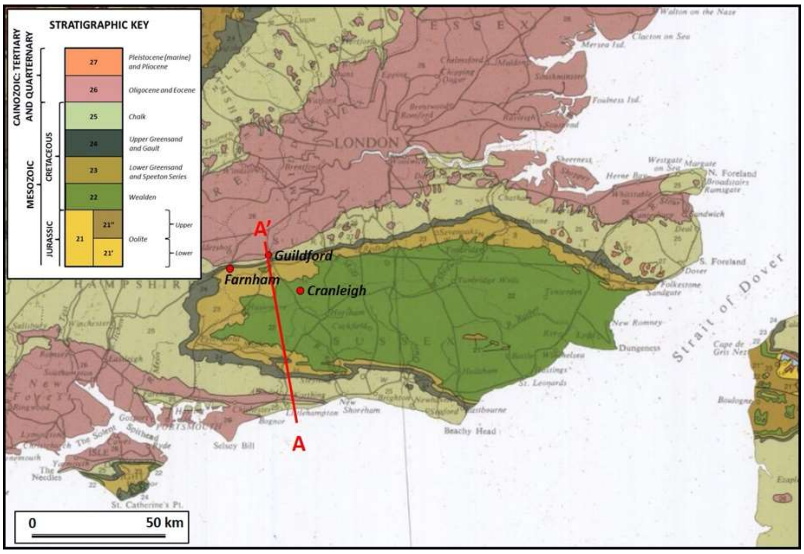

Fig. 1: Surface geology of southeast England.

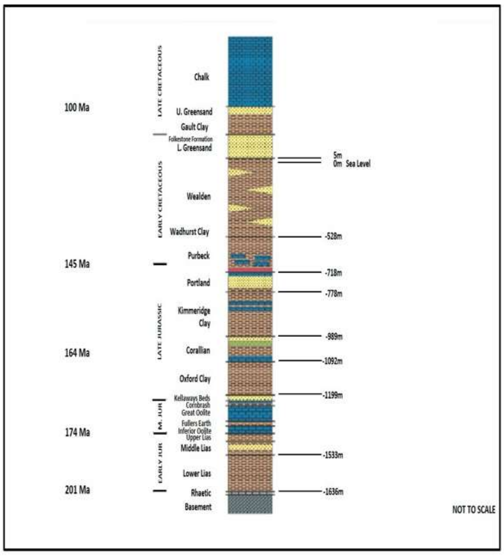

Fig. 2: Summary log for Albury gas Field.

On the left of the log in Figure 2, are the absolute ages of the rocks.. The youngest Chalk, at the top, is less than 100 Ma old. The oldest sediments at the bottom are just over 200 Ma old. Over a thickness of ~1700 m the rocks have been deposited over a time span of a little over 100 Ma. This equates to an approximate average rate of sedimentation of just under 2 mm per 100 years.

The next column shows the sub-divisions of the two geological periods of interest; the Jurassic at the bottom, overlain by the Cretaceous. The third column lists the names given to the rock formations. The next column describes the types of rock found in the well. The colours in the column represent. Blue is limestone, yellow is sandstone and brown represents the muddier shales and silts. The right hand column shows the depth at which the rocks were encountered, relative to sea level.

Figure 3 is a geological cross section along the line A-A' shown in Figure 1 and compiled by Buttler and Pullen (1990). With the north on the right, starting near Guildford, and the Channel coast on the left near Littlehampton, you can see that there are around 3,000 m of preserved Mesozoic sediments sitting on top of the much older Palaeozoic rocks, shown in grey.

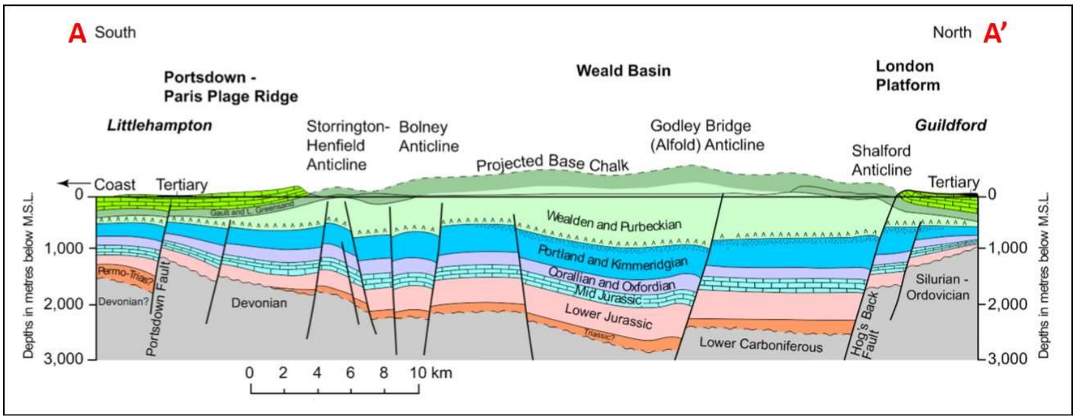

Fig. 3: S - N geological cross section through the Weald Basin, from Butler and Pullan, 1990.
In oil and gas terms the grey rocks constitute economic basement and, generally less important in today's story.

What the section in Figue3 doesn't show is the missing Chalk and Greensand that once overlay the Wealden clay in the centre of the basin and are now eroded. There is probably well over 1,000 m of rock missing in the centre of the Basin

Historical Economic Activities

Coal was produced in Kent for approximately 100 years, with the last colliery, at Betteshanger, closing in 1989. Local interest exists because the potential for the Carboniferous coal measures to underlay SE England was identified by Shalford geologist Robert Godwin-Austen in the mid-1800s. Coal was discovered in NE Kent in 1890 during trial digging for an early Channel Tunnel project. Apart from having ceased as an economic activity the former mining of coal does actually fall just outside of the true limits of the Weald Basin.

The remaining three aspects were key to Britain's historical naval activities. Gunpowder was an important product from several factories in the Weald until the early 20th century. Flowing water resulting from the geological form of the land, and the trees that grew along the water courses supported an industry that had a long history in the area. The major gunpowder works at Chilworth, just to the south of Guildford, operated for over 300 years, winding up only after the first World War.

300 years ago, the focus of this summary would have been on the production of iron from layers of the iron carbonate ($FeCo_3$) mineral, Siderite, interbedded with the Wealden clays. This industry started before the Romans arrived and persisted into the early 19th century. The resulting iron would have been widely used in the production of cannon and cannonballs.

Harvesting of the oak trees, which thrived in the Weald, through managed coppicing continued up to the second world war. These trees were a key component of the ships that provided Britain's naval strength for many years.

Oil and Gas Exploration and Production

Oil and gas have been known about and produced from the Weald Basin for well over 100 years. Serious exploration for it has been going on since the 1960s. The first commercial use of hydrocarbons dates back to 1889 when natural gas, encountered during the drilling of a water exploration well into the Early Cretaceous at Heathfield in Sussex, was used to power gas lamps at the local station. There have been around 250 wells drilled in the Basin and some 30 hydrocarbon bearing structures penetrated.

In the last couple of years there has been considerable interest around UK Oil and Gas's Horse Hill-1 discovery, known as the Gatwick Gusher, and the follow up well at Broadford Bridge near Billingshurst.

Three main elements are needed for a working hydrocarbon play system, namely:

- a mature source rock with a migration pathway for fluids to reach the second element;
- a reservoir capable of delivering hydrocarbons at a commercial flow rate; and
- a trapping mechanism for the hydrocarbons.

Figure 4 is the stratigraphic column from Albury with layers of rock in the Weald Basin that contribute to the source and reservoir elements of the hydrocarbon play system highlighted. On the right are symbols which indicate where potential source rocks and potential reservoirs occur in the column of rocks. The red diamonds are positioned adjacent to a variety of potential source rocks throughout the Jurassic interval. Most important are the mudstones of the Lower and Middle Lias and of the Kimmeridge Clay Formation. In terms of maturity for the generation of oil and gas, the Lias section is mature for oil generation over much of the basin and the Kimmeridge is locally mature for oil generation in the centre of the basin.

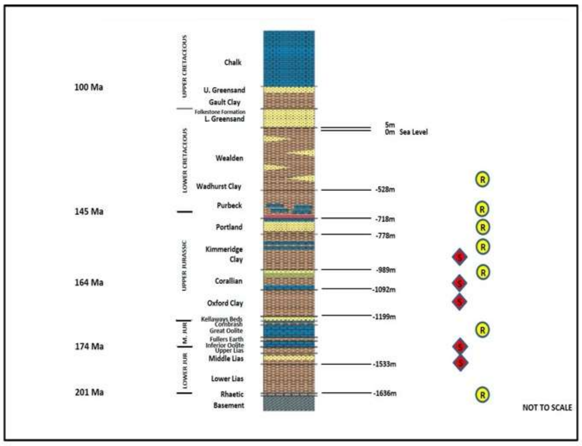

Fig. 4: Stratigraphic location of the source and reservoir elements of the Weald Basin hydrocarbon play systems

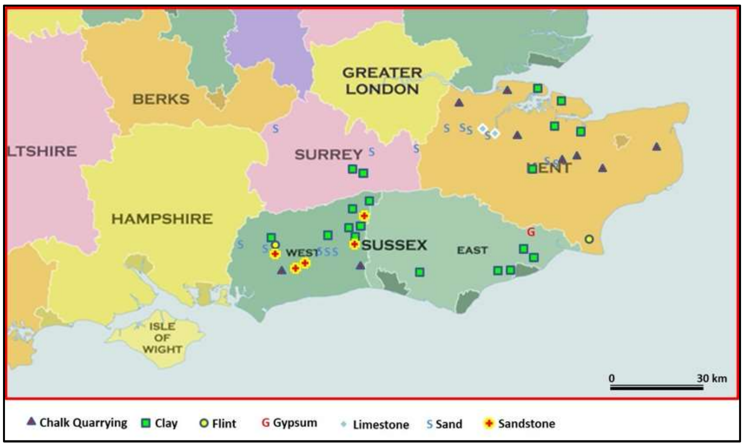

Fig. 5: Geographical distribution of sites where building materials are extracted from the Weald Basin.
Chalk is quarried for cement; most active workings, shown by red triangles, are in Kent on N margin of the basin, however there are a couple of workings in West Sussex.

Figure 4 is the stratigraphic column from Albury with layers of rock in the Weald Basin that contribute to the source and reservoir elements of the hydrocarbon play system highlighted. On the right are symbols which indicate where potential source rocks and potential reservoirs occur in the column of rocks. The red diamonds are positioned adjacent to a variety of potential source rocks throughout the Jurassic interval. Most important are the mudstones of the Lower and Middle Lias and of the Kimmeridge Clay Formation. In terms of maturity for the generation of oil and gas, the Lias section is mature for oil generation over much of the basin and the Kimmeridge is locally mature for oil generation in the centre of the basin.

In a new twist, in a paper published in 2018 (Pullan and Buttler), the authors make a case for the gas accumulations in the Basin to have been sourced, at least in part, from Palaeozoic rocks known to occur beneath the Mesozoic Basin fill. The paper fails to pin down exactly where the source is in the stratigraphic column but it concludes that the trapped gas cannot have come entirely from the Lias, which is the only Jurassic source section that is mature for gas generation.

The yellow circles on Figure 4 denote the various horizons where hydrocarbons have been encountered in exploration drilling. There are multiple sandstone and limestone layers that have the potential to act as reservoirs. Of these, the Great Oolite and the Portlandian sandstone are the most important.

Building Materials

Figure 5 shows the geographical distribution of the main quarrying and mining activities in the Weald and Figure 6 shows the stratigraphic distribution of extracted materials.

Clay workings are marked by green squares. Clay from the Weald Clay Formation has long been used for the manufacture of bricks and tiles. Examples of former working s are clustered around Cranleigh at the Cranleigh Brick and Tile works and the Swallowhurst works; a planning application has recently been submitted for expansion of the workings at the Old Ewhurst Brickworks.

Flint, which is reasonably pure silica dioxide, is locally worked from bands at a couple of locations within the chalk, marked with yellow circles. Being very hard it is a useful building material, particularly in walls. The exact mode of formation of flint is not clear, but it is believed to occur as a result of chemical changes in compressed sedimentary rock formations, during the process of diagenesis. One hypothesis is that a gelatinous material fills cavities in the sediment, such as holes bored by crustaceans or molluscs, and that this becomes silicified.

There is a single, but quite significant gypsum mine at Robertsbridge in East Sussex. Gypsum is hydrated calcium sulphate. It occurs in the Purbeck formation from around the base of the Cretaceous. The British Association for the Advancement of Science discovered Gypsum when searching for coal in Robertsbridge and in 1876 the Sub-Wealden Gypsum Company was formed to create plaster. The mineral is now used for creating plasterboard.

Limestone, which is used for roadstone, is quarried from the Hythe Formation in the Lower Greensand in a couple of locations in Kent. Production costs are quite high because the limestone occurs in thin beds and has to be separated from adjacent sands.

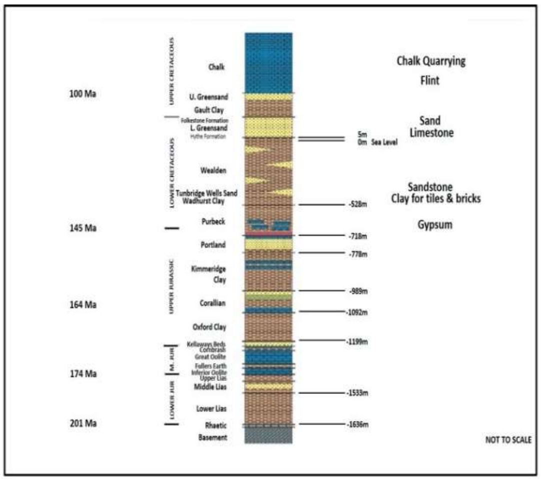

Fig. 6 : Stratigraphic distribution of building materials extracted from the Weald Basin.

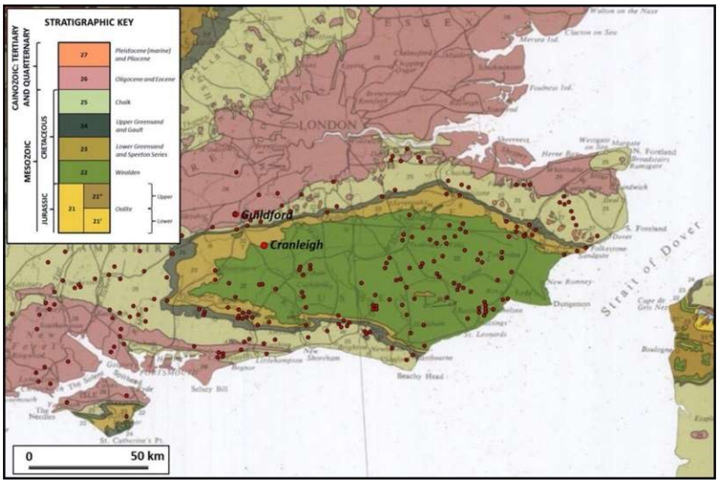

Fig. 7: Location of vineyards (red circles) imposed on the surface geology of southeast England.

Sand is quarried from the Folkestone Formation in the Lower Greensand, mainly for construction sand but also for glass and other industrial uses. Quarries exist in Kent, Surrey and West Sussex. There is some sand and gravel produced from recent deposits along the coast, and from dredging, but that is not really part of the Mesozoic Weald basin so is not discussed further.

The red and yellow markers showing the location of sandstone quarries. Sandstone was once extensively quarried for building stone but the amount of production has reduced considerably. Production is now focussed on the Ardingly Member of the Tunbridge Wells Sand Formation. This is a thick sandstone band within the Wealden Clay and is worked in several locations in West Sussex.

Wine

The popularity of grapes as an agricultural product in south east England has escalated over the past 25 years. Whereas connoisseurs of good wine used to joke about English wine, things have moved on and English sparkling wine has a growing reputation. It can now hold its own in comparison with many champagnes.

There are plenty of other agricultural products grown in the Weald but none is considered to have such a close dependence on the geology as the grape. Figure 7 shows the approximate location of vineyards in SE England, superimposed on the surface geology. *(Based upon BGS 1:625k surface geology of the Great Britain and Northern Ireland map, with the permission of the British Geological Survey.)*

For the purposes of discussion this section strays a little beyond the confines of the Weald because the northeast corner of Wessex Basin has some of the same rocks as grapes are grown on in the Weald so the wine industry is not respecting structural geological boundaries. The discussion covers Surrey, Kent, East Sussex, West Sussex and Hampshire and the analysis has more to do with county boundaries than geological constraints.

Although the growing of grapes in SE England has increased in popularity over the past 25 years the area under cultivation is still small compared with the main growing regions of France:

- 120,000 hectares in Bordeaux
- 34,000 hectares in Champagne
- 28,530 hectares in Burgundy
- 1,167 hectares in SE England

The southeast of England contains a little under half of the vineyards and a little under half of the acreage under grape for the whole UK. Kent has the most vineyards and the largest number of planted hectares. Although Surrey looks to be the least significant of the grape growing counties in the southeast it can lay claim to the largest single vineyard at Denbies near Dorking.

The sparkling wine trade in Southeast England is only a little over 25 years old. The same grape varieties of Chardonnay, Pinot Noir and Pinot Meunier that go to make Champagne were planted in the late 1980s at the Nyetimber vineyard in West Sussex. The question is now being asked, do the rocks on which the vines are planted matter? At this stage in the evolution of English sparkling wine the jury is out. The vineyards of the Weald basin are planted on Chalk, Greensand and Wealden Clay. Owners of chalk properties are defensive about the benefits of growing on chalk but owners of properties on other rock types will stress the importance of a southerly aspect and good drainage.

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Richard Seaborne

Women in geology

Summary of February 2019 lecture given by Dr Chris Duffin

In February Chris Duffin gave FGS a talk about significant women geologists. A list of these women was provided to me, so I decided to look into each of them and found wonderful details and a website called *Trowelblazers.com*.

If you read the comments about the early ladies – you will note that they all 'helped' their husbands, brothers or uncles - many of them iconic British geologists such as Roderick Murchison, William Buckland, Charles Lyell, William Smith, John Phillips, even in the 1960s, Janet Watson was regarded as the brains of the Sutton-Watson team although John Sutton got the glory. It is thrilling that Janet eventually achieved status as a truly iconic female & geologist in her own right.

- Hildegard von Bingen 1098-1179
  - A nun who suggested ailments could be cured by different minerals. Jasper as cure for deafness.
  - She was at St Anne's church in Annaberg Bucholtz Germany
- Martine Bertereau 1600-1642 I
  - Involved in silver ore extraction and mines in France. Also witchcraft and Cardinal Richelieu 1585-1642
- Ethelred Benett 1776-1845 in Wiltshire
  - Mentioned in History of Geology by HB Woodward in1911
  - Credited with being the 'First Female Geologist'
  - Devoted much of her life collecting and studying the fossils that she discovered in South West England
- Maria Graham 1785-1842
  - Recorded raising of coast by 50ft on west coast of S America, Quintero Bay in1822 due to Earthquakes.
- Barbara Rawdon Hastings 1810-1858
  - 20th Baroness Grey de Ruthyn, Marchioness of Hastings
  - A fossil collector and geological author
- Mary Anning 1799-1847
  - Collector of fossils in Lyme Regis Dorset
  - One of the greatest fossil hunters ever
  - She received no training but her technical illustrations were very detailed and accurate
  - Became world famous for important finds of Jurassic marine fossils
  - Her findings contributed to important changes in scientific thinking about prehistoric life and the history of the Earth.
  - Geologists from round the world purchased her specimens, visited her to collect fossils or discuss anatomy and classification.
  - Henry De la Beche and Anning became friends as teenagers and went fossil-hunting together. De la Beche and Anning kept in touch as he became one of Britain's leading geologists
  - William Buckland, geology lecturer at the University of Oxford, often visited Lyme on his Christmas vacations and was frequently seen hunting for fossils with Anning.
  - She made the important interpretation that the objects known as 'bezoar' stones, were really the fossilised faeces of ichthyosaurs or plesiosaurs. Buckland named them coprolites.
  - She also assisted Thomas Hawkins collect ichthyosaur fossils at Lyme in the 1830s.

- Elizabeth Philpot, 1780-1857, one of 3 sisters; died in Lyme Regis
  - An early 19th-century British fossil collector, amateur palaeontologist and artist
  - Collected fossils from the cliffs around Lyme Regis in Dorset
  - Friends with & collaborated with fellow fossil-hunter Mary Anning
- Mary Buckland 1797-1857,
  - A highly skilled scientific illustrator and fossil preparator
  - A great aid and important artist before meeting and marrying William Buckland.
- Mary Ann Mantell 1795-1869
  - Credited with the discovery of the first Iguanodon fossils with sketches of the fossils for her husband, Gideon Mantell's, scientific description of Iguanodon
- Mary Elizabeth Lyell 1808-1873
  - A conchologist and geologist, married to the notable British geologist Charles Lyell
  - Assisted him in his scientific work but never became widely known in her own right
  - However she probably made major contributions to her husband's work
- Charlotte Murchison 1788-1869 (see Figure below)
  - Born in Hampshire, England, wife of geologist Roderick Impey Murchison
  - Together they travelled to France, the Alps, and Italy
  - Charles Lyell called her timid; Benjamin Disraeli called her the silent wife of a stiff geological prig
  - She opened up lecture theatres of KCL to female geology students,
  - Is credited with the making of one the most lauded careers in 19th Century geology i.e. that of her husband, Roderick Impey Murchison.
- Anne Phillips 1803-1862
  - The niece and ward of William Smith, (of first geological map of Britain fame)
  - She was housekeeper, confidant and constant companion of her brother John Phillips, a fellow geologist
  - Working in Malverns with her brother, she discovered a fragment of conglomerate that helped clarify the history of the Malvern Hills, proving Sir Roderick Murchison wrong in the process!

'making her own reconnaissance, she found an outcrop in Lower Dingle Quarry, Malvern, that yielded a conglomerate containing fragments of the igneous hills at the base of the Silurian sediments. This proved the Malvern Ridge had formed first (in the Precambrian), and had time to be the weathered and deposited beneath the Silurian seas. This became known as Miss Phillips' Conglomerate, which became a must-have item on every self-respecting geological collectors' tick list'. See Trowelblazers.com

  - John acknowledged her immense help - *"Whatever I possess is as much yours as mine, for without you I should not have won it."* 1838 (quoted in Morgan 2007), see Trowelblazers.com
- Ethel Wood 1865–1939 Nee Ethel Gertrude Skeat
  - An English stratigrapher, invertebrate palaeontologist, and geologist
  - worked on Jurassic glacial deposits in Denmark and on Lower Palaeozoic rocks in Wales, Carmarthenshire
  - The first English woman to win the Murchison Fund offered by the Geological Society of London, as a mark of appreciation for her geological work in Denmark and Wales
- Nancy Hartshorne Kirk 1916-2005
  - A British geologist who developed original theories regarding the life habits of graptolites
  - A protegee of Welsh geologist & professor, O.T. Jones.
  - Publications include turning the world of graptolites upside down
- Marie Stopes 1880-1958
  - Got a first in geology & botany from UCL & a PhD from Munich
  - Became first female academic at Manchester University, as a palaeobotany lecturer
  - Worked on Coal Balls in Nova Scotia
- Dorothea Bates 1878-1951 (was at Royal Holloway)
  - A British palaeontologist and pioneer of archaeozoology
  - Her life's work was to find fossils of recently extinct mammals with a view to understanding how and why giant and dwarf forms evolved
  - Aged 19, she got a job at the Natural History Museum in London, sorting bird skins in the Department of Zoology's Bird Room and later preparing fossils
  - She was probably the first woman to be employed as a scientist by the museum
  - She remained there for 50 years and learned ornithology, palaeontology, geology and anatomy
  - She was a piece-worker, paid by the number of fossils she prepared
- Dorothy Garrod 1892-1968
  - An English archaeologist who specialised in the Palaeolithic period
  - Was Disney Professor of Archaeology at the University of Cambridge from 1939-1952,

- The first woman to hold an Oxbridge chair.

- Inge Lehman 1888-1993
    - A Danish seismologist and geophysicist
    - Worked on Earthquake theory and measurement using seismic waves
    - In 1936, she discovered that the Earth has a solid inner core inside a molten outer core
    - Seismologists tested and then accepted this explanation
- Janet Watson FRS 1923-1985
    - One of the most distinguished and best known geologists
    - She spent most of her academic career at Imperial College London
    - Known throughout the world for her exceptional gift of clear and persuasive exposition in lectures & committees
    - A major contributor to the advancement of the earth sciences
    - President of Geological Society in 1982–84
    - Awarded, jointly with husband, Prof. John Sutton, both the Lyell & Bigsby Medals
    - Edinburgh Geological Society awarded her the Clough Medal (1980)
    - Fellow of the Royal Society of London (1979), member of its Council and Vice-President (1983 until her death)
    - Worked on migmatites and specialised in Lewisian rocks with numerous publications
- Zofia Keilan Jaworovska 1925-2015
    - Polish palaeobiologist who worked in Mongolia
    - In 1960s, led a series of Polish-Mongolian paleontological expeditions to the Gobi Desert
    - First woman to serve on the executive committee of the International Union of Geological Sciences
- Modern day and currently working Geologists
    - Professor Emily Rayfield at Bristol
        - palaeobiologist researching functional anatomy of extinct vertebrates, especially dinosaurs, using computational methods such as finite element analysis
    - Jenny Clark at Cambridge
    - Dame Jane Frances British Antarctic Survey
        - Director of the British Antarctic Survey
        - previously Professor of Palaeoclimatology at the University of Leeds
        - Dean of the Faculty of Environment
        - interests are palaeoclimatology and palaeobotany
        - specialises in the study of fossil plants, especially woods, and their use as tools for climate interpretation and information about past biodiversity
        - focusing on understanding past climate change during both greenhouse and icehouse periods, particularly in the polar regions, the areas on Earth most sensitive to climate change

Cartoon of Charlotte Murchison, called 'timid' & 'the silent wife of a stiff geological prig' from [*https://trowelblazers.com/charlotte-murchison/*](https://trowelblazers.com/charlotte-murchison/)

Mary Anning – one of the first women to attain global recognition. Photo from Wikipedia

Janet Watson, FRS & President of Geol. Soc., 1982–84, a distinguished, well known geologist & major contributor to the advancement of earth sciences. Her love was all things metamorphic with complex histories of folding etc.
Photo @365women in STEM

It is gratifying to see that today women are allowed to be given the credit and recognition that they deserve. Hopefully they are, or will soon get, paid the same as the men too.

Liz Aston