GEOSCIENTIST

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The Fellowship Magazine of the Geological Society of London

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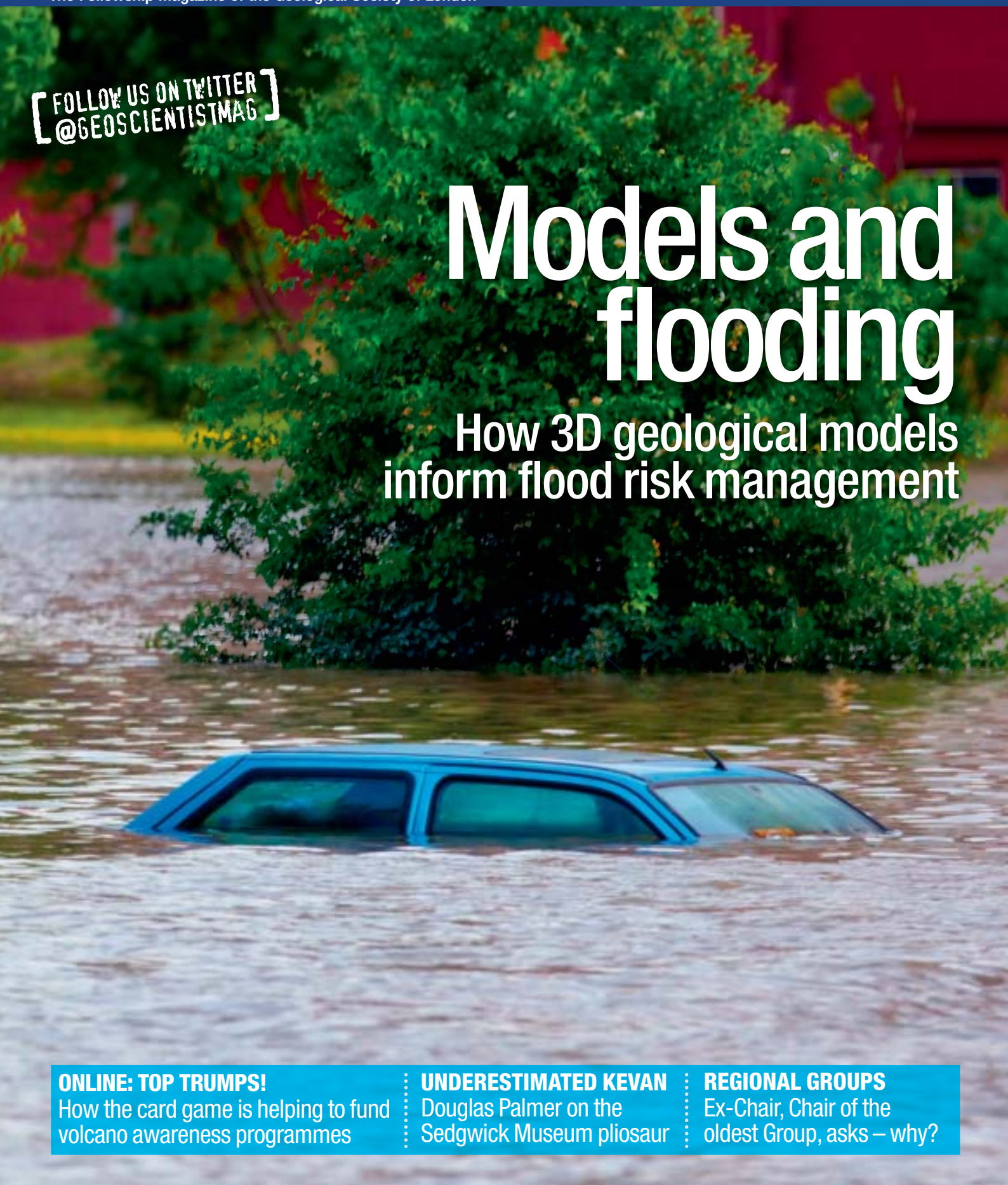

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Models and flooding

How 3D geological models inform flood risk management

ONLINE: TOP TRUMPS!
How the card game is helping to fund volcano awareness programmes

UNDERESTIMATED KEVAN
Douglas Palmer on the Sedgwick Museum pliosaur

REGIONAL GROUPS
Ex-Chair, Chair of the oldest Group, asks – why?

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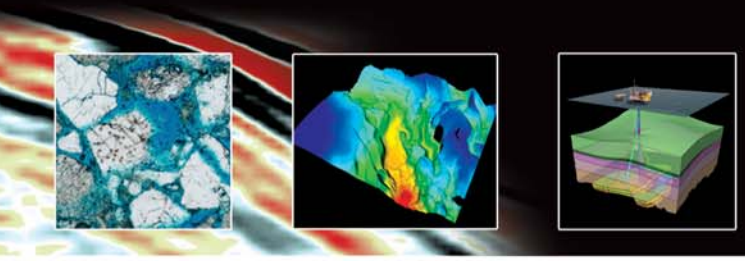
Petroleum Group

At the forefront of petroleum geoscience…



The Petroleum Group is the Geological Society's specialist group dedicated to petroleum exploration and production. Our purpose is to advance the study and understanding of petroleum geoscience and to represent the Society with respect to petroleum exploration matters.

This is achieved through supporting and leading a series of conferences, workshops and publications at the cutting edge of the science; bringing together industry and academia.

To view a list of our upcoming conferences or past meeting resources please visit: www.geolsoc.org.uk/petroleum

A Message from the Chair

Kitty Hall, Chairman

I became Chairman of the Petroleum Group at the start of 2016 and am looking forward to a great programme of events during my two years in office – the Committee has a great breadth of skill and experience and the conferences are at the absolute leading edge of geoscience. These are tough times for the exploration sector but the quality of our events remains at the highest level. The Petroleum Group is the most active of all the Specialist Groups of the Geological Society and we make an important contribution to the Society's finances.

Getting involved

Any Fellow of the Geological Society can join the Petroleum Group and subscribe to the PG E-Newsletter by emailing Sarah Woodcock (sarah.woodcock@geolsoc.org.uk). You can also keep up to date with conferences and other PG activities by clicking "like" on our Facebook page or by following us on Twitter.

Any Petroleum Group member can take a more active role by applying to join the Committee – applications to join the 2017 Committee are accepted until 9 September 2016 and the form is available on the webpage. The Committee is formed of around 20 members who will be expected to convene a cutting edge petroleum geoscience conference during their three year term of service.

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For further information please contact:

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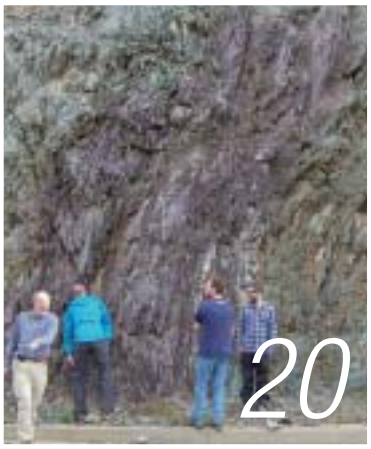

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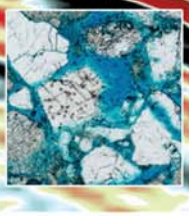
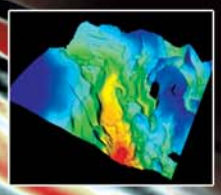
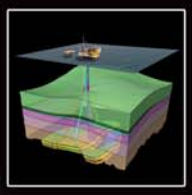

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Call for Abstracts – Deadline: Friday 30 June 2017

Fold and Thrust Belts: Structural style, evolution and exploration

31 October – 2 November 2017

The Geological Society, Burlington House, Piccadilly, London

Convenors:

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Fold and thrust belts have formed in all eras of geological time and, represent some of the planet's most complex geological environments. Deformation styles may evolve spatially and temporally according to the type of sedimentary sequence involved, the presence of main detachment zones, and the orientation and evolution of the stress field with respect to the plate boundaries. At the same time, fold and thrust belts contain many substantial producing fields and some of the world's largest remaining hydrocarbon reserves. The complex interaction of fold and thrust processes, and their effects on potential reservoir quality and deliverability makes accurate characterization of such fields and reserves extremely difficult. New technologies and approaches developed in the last 10 years are helping to advance understanding of fold and thrust belts, opening new exploration opportunities in these systems.

This three-day meeting aims to bring together leading academic and industry geoscientists to discuss new techniques and case studies, and to capture an up to date assessment of our understanding of fold and thrust belts globally.

Themes / Thematic sessions:

- Case studies documenting the temporal and spatial evolution of structural style
- New techniques and approaches to understanding fold and thrust belts
- New Exploration discoveries in fold and thrust belts, and their impact on understanding and prospectivity
- Understanding and predicting fold and thrust belt geometries
- Evolving stress fields and their impact on fault and fracture networks
- Hydrocarbon modelling in fold and thrust belts

Call for Abstracts:

Please email paper and poster contributions to abstracts@geolsoc.org.uk and copy to raffaele.dicuia@geplan.it by Friday 30 June 2017.

For further information please contact:

Sarah Woodcock, The Geological Society, Burlington House, Piccadilly, London W1J 0BG.
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> THE NOBLE JUDGE STARED AT ME BLANKLY. HE HAD SOMEHOW MANAGED TO GET THROUGH LIFE WITHOUT EVER HEARING THE TERM 'FRACKING' UNTIL THAT VERY MOMENT

Front cover image: © Dariush M/shutterstock.com

FROM THE EDITOR'S DESK:

Trumps Triumph

It comes as a shock when people with minds like steel traps turn out to be ill-informed - as though 'intelligence' and 'knowledge' always go hand-in-hand. Lunch at the Old Bailey the other day provided just such a moment, as life imitated a well-worn newspaper cliché. Over the grilled coley and fennel coleslaw, my bewigged companion asked: 'So, what's 'hot news' in geology just now?'. I answered: 'Well, just now it has to be fracking, obviously'. The noble judge stared at me blankly. He had somehow managed to get through life without ever hearing the term until that very moment.

No doubt, he would probably have been shocked by my ignorance of blood stains, or the Statute of Mortmain - most of us rarely notice how sheltered our lives are. It took me well over half a century, for example, to hear about a card-game called Top Trumps - my only excuses being that a) I grew out of such things long before it first appeared in 1968, and b) I subsequently followed Philip Larkin's advice about children. So, if you too have never heard of it, before you read thos month's Online Special (about how the game is helping to fund education campaigns in areas threatened by active volcanoes) here are some basics.

Each Top Trumps pack has a theme - cars, aircraft, dinosaurs, volcanoes – it could be anything. Each card displays various bits of numerical data. The aim of the game is to compare these values to try to trump your opponents' cards - and thereby win them.

All cards are dealt among the players. The first player selects a category from the top card and reads out its value. Other players then read out the corresponding value from their top cards. The 'best' value wins; the winner takes all the cards of that trick, placing them at the bottom of their hand. The winner then chooses a category for the next round from their new topmost card, and so on. Players drop out when they lose their last card. The winner obtains the whole pack.

So, it's not exactly Contract Bridge, a game requiring considerable brain-power and which my learned lunch-friend professed greatly to enjoy. But its potential as an educational tool is obvious. All credit, therefore, to Volcano Top Trumps's authors for the way in which they have been able to plough back royalties into the sort of learning of which one can, for once, truthfully say: 'it could save your life someday'.

DR TED NIELD, EDITOR - ted.nield@geolsoc.org.uk @TedNield @geoscientistmag

SOCIETY *NEWS*

What your society is doing at home and abroad, in London and the regions

Society Awards 2017

Make your nominations now, writes Stephanie Jones

Fellows of the Society are invited to submit nominations to the Awards Committee for the Society Awards 2017. Full details of how to make nominations can be found on the website at **www.geolsoc.org.uk/About/Awards-Grants-and-Bursaries.**

➤ Nominations must be received at the Society no later than **30 September 2016.**

FUTURE MEETINGS

Dates for meetings of Council and Ordinary General Meetings until April 2017 shall be as follows:

Ordinary General Meetings:
- **2016:** 20 September; 24 November;
- **2017:** 1 February; 4 April

Meetings of Council:
- **2016:** 20 & 21 September (residential); 24 November;
- **2017:** 1 February; 4 & 5 April (residential)

Geological Society Club

The Geological Society Club, successor to the body that gave birth to the Society in 1807, meets monthly (except over the field season!) at 18.30 for 19.00 in the Athenaeum Club, Pall Mall, or at another venue, to be confirmed nearer the date. Once a year there is also a buffet dinner at Burlington House. New diners are always welcome, especially from among younger Fellows. Dinner costs £57 for a four-course meal, including coffee and port. There is a cash bar for the purchase of aperitifs and wine. Burlington House dinners include wine.

➤ **2016 meetings:** Fellows wishing to dine or requesting further information about the Geological Society Club, please email Caroline Seymour on **carolineseymour554@hotmail.com**

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Subscribe to our bi-monthly newsletter to keep up-to-date with important Library news, electronic journal updates, online exhibitions, events and more: **http://www.geolsoc.org.uk/newslettersignup**

New acquisitions
A month-by-month list of new books and serial special issues which have been added to the catalogue can be viewed on our website at **www.geolsoc.org.uk/library_collections**

E-Journals
Fellows of the Society can access over 90 journals online using Athens authentication. There is no charge to Fellows for this service. Visit **http://www.geolsoc.org.uk/ejournals to register.**

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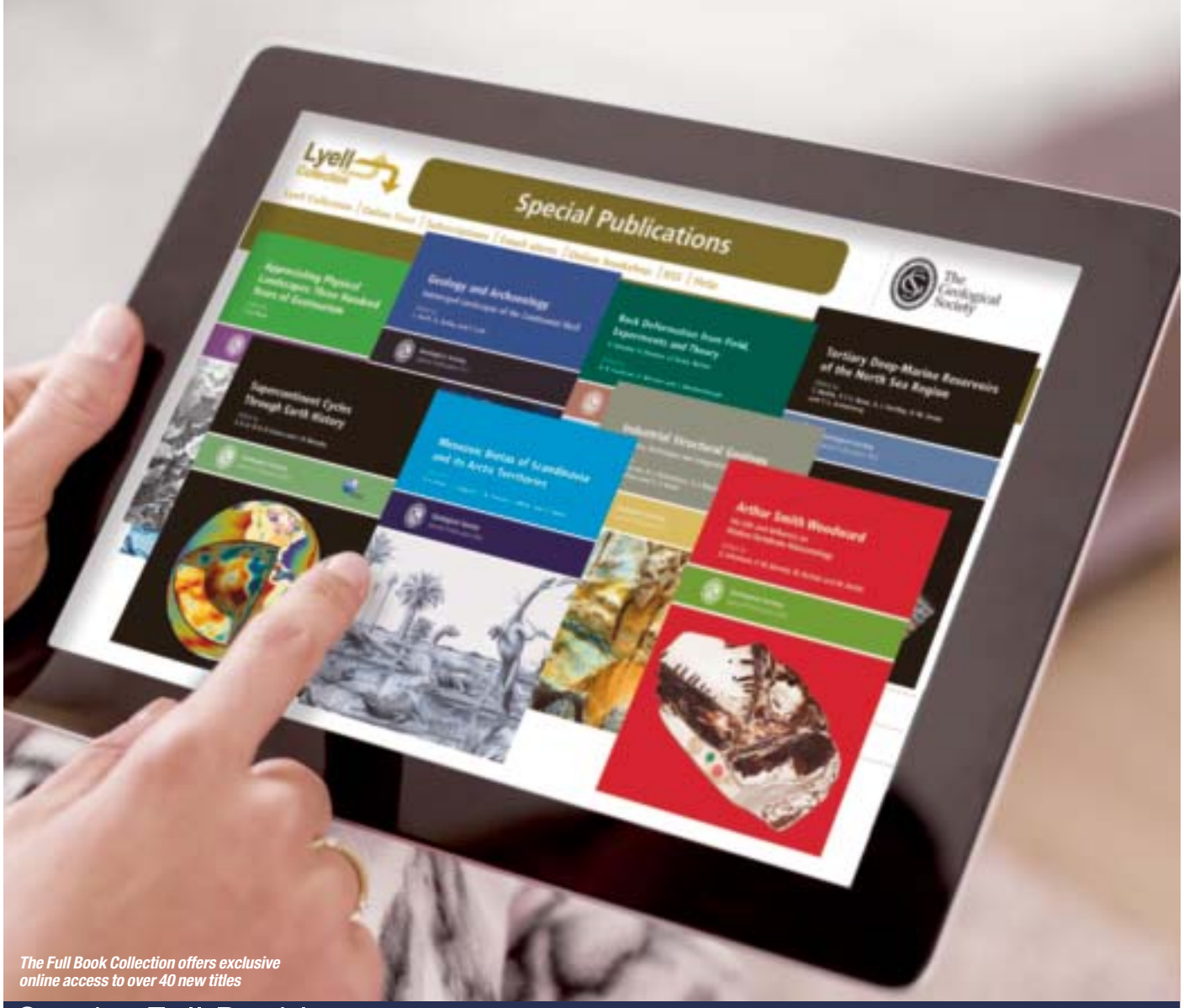
➤ The library is open to visitors Monday-Friday 0930-1730. For a list of new acquisitions click the appropriate link from **http://www.geolsoc.org.uk/library**



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Upgrade your fellowship to include the Full Book Collection, says Jenny Davey

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Was £83 Now £41 (for access until 31 December 2016)

Find out more:
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or T: **0207 434 9944.**

From The Publishing House

Anne Davenport and Jenny Davey bring you the latest news from the Society's Publishing House.

Recent Journal Highlights

Geochemistry: Exploration, Environment, Analysis

A continental-scale geochemical atlas for resource exploration and environmental management: the National Geochemical Survey of Australia, by P de Caritat and M Cooper
http://geea.lyellcollection.org/content/16/1/3.abstract

The Journal of the Geological Society

Gold in Devono-Carboniferous red beds of northern Britain, by John Parnell, John Still, Samuel Spinks, and David Bellis
http://jgs.lyellcollection.org/content/173/2/245.abstract

Petroleum Geoscience

Thematic Set: Geomodel Uncertainty
http://pg.lyellcollection.org/content/current

Recent Publishing Highlights

A revised correlation of Tertiary rocks in the British Isles and adjacent areas of NW Europe by C King, Edited by A S Gale & T L Barry

This Special Report comprehensively describes the stratigraphy and correlation of the Tertiary (Paleogene–Neogene) rocks of NW Europe and the adjacent Atlantic Ocean and is the summation of 50 years of research on Tertiary sediments by Chris King. His book is essential reading for all geologists who deal with Tertiary rocks across NW Europe, including those in the petroleum industry and geotechnical services as well as academic stratigraphers and palaeontologists.

ExCeL, London
PETEX
15-17 November 2016

Registration NOW OPEN at www.petex.info

Special features include:

- Career Development Area
- Consultants' Corridor
- Future Working Zone
- International Pavilion
- Onshore Zone
- University Forum

..and more

Conference to include:

- Enabling Technologies stream
- Exploration stream
- North Sea stream
- PETEX Forum
- Petroleum Geoscience Collaboration Showcase

Keynote Speakers:

Luca Bertelli
Chief Exploration Officer, Eni

Andrew Latham
VP Global Exploration Research, Wood Mackenzie

Jean Georges Malcor
Chief Executive Officer, CGG

Gunther Newcombe
Director, Exploration and Production, Oil & Gas Authority

We are pleased to announce the Oil & Gas Authority will be present in a big way at PETEX this year, featuring:

- Exploration Workshop
- Asset Stewardship Workshop
- Poster Session
- OGA booth

PETEX is the largest subsurface-focused E&P conference and exhibition in the UK, attracting thousands of delegates from across the world and across a spectrum of industry sectors, from supermajors to consultancies. The conference is also attended by a large contingent of geoscience Masters and PhD students.

Conveniently based at ExCeL, London, PETEX is a biennial event featuring a technical programme highlighting the latest developments in exploration, development, production and subsurface technology.

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Exhibition as a Marketing Tool

- During a recession or a downturn, you need to double your efforts to market your company
- Cost effective – reach more prospects in a 3-day exhibition than your sales force can in 3 months!
- Demonstrate your products and services hands on and have face-to-face meetings with all your potential customers during the show

The Right Kind of Show

- All delegate and exhibitor feedback rates PETEX as the best place for socialising, networking, maintaining contacts and building new relationships
- Very friendly atmosphere
- Compared to many other trade shows, we are one of the most cost-effective
- Enables smaller firms the opportunity to exhibit right alongside larger companies. No separate rooms!

The Right Audience

- First-class Technical Conference with high profile keynotes, attracting the right audience
- Extremely receptive to new ideas, knowledgeable and innovative
- Broad, quality international group and includes a large section of Exploration Managers from EMEA marketplaces

For more information on the conference, sponsorship opportunities, or to book an exhibition booth please contact **events@pesgb.org.uk** or visit **petex.info**

www.petex.info

RGs – what's the point?

John Black* ponders the role of regional groups from the perspective of an ex-Chairman once desperately seeking a successor

I used to be Chairman of the East Midlands Regional Group of the Geological Society of London. A role I attempted to lose at more than one AGM. As I strove to convince a fellow committee member (or a Fellow attending an evening talk) of the joys of office, I was rebuffed with: 'What's the point of a regional group?'

This question has occurred to me regularly as I enjoy hearing a good lecturer addressing our small band of (usually) about 20 regulars. Sometimes, with help from students (most of whom are not members), we might get 80; but it's a poor turn-out from the c. 650 Fellows who abide in our region. I am pretty sure these figures are fairly typical, so I wondered what structural or historical reasons might underlie such apparent apathy.

APIPG

Regional groups formed in the late 70s (East Midlands being the first!) under the 'Association for the Promotion of an Institution of Professional Geologists'. In due course, regional groups were incorporated into GSL when it merged with the Institution of Geologists in 1990.

There are now 15 regional groups in the UK, all attempting to coexist with a growing number of 'specialist' groups. Have they eroded some of our *raison d'etre*? It's pretty unreasonable to pitch a highly technical talk at our mixed audience. And then, what is the effect of 'streaming' lectures from Burlington House? Why travel perhaps 30 miles to your local regional group meeting when you can enjoy a 'celebrity' from Burlington House on your desktop?

Council has declared an ambition to grow membership by 25% in five years and foresees 'national and regional welcome events for new fellows'. Furthermore, a Society webpage cites 'Free membership of regional … groups to enable networking' as a benefit of membership. I can confidently claim that we very seldom attract enough professional geologists to enable worthwhile networking.

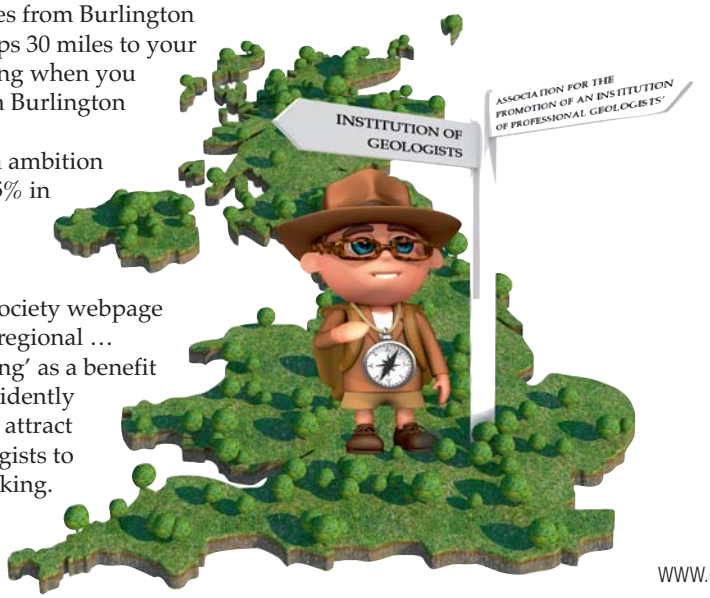
Accentuate the positive

Let us rather recognise ourselves for what we are and enhance our positive attributes. Our meetings are attended by a group of enthusiastic professionals. We are more informal than Burlington House and therefore should be less intimidating to younger Fellows. I believe we should focus on engaging local talent by:

- Using mainly local speakers, particularly younger professionals, possibly with multiple short talks
- Putting on 'debate style' evenings to encourage audience participation, based on current local and national geologically related controversies
- Marketing our meetings through social media with better access to our younger members
- Making our meetings more 'social' occasions

If we do this, I foresee perhaps 50 -100 joining in a stimulating, even rowdy event. If we can't manage that (and I'm not sure we can) then perhaps we should call it a day and join one of the many alternative local groups of 'enthusiasts'.

***John Black,** Director of **Insite Hydro Ltd.,** is a hydrogeologist specialising in low permeability rocks for nuclear waste disposal. E: **johnblack@insitehydro.com**



SOAPBOX CALLING!

Soapbox is open to contributions from all Fellows. You can always write a letter to the Editor, of course: but perhaps you feel you need more space?

If you can write it entertainingly in **500 words**, the Editor would like to hear from you. Email your piece, and a self-portrait, to **ted.nield@geolsoc. org.uk**. Copy can only be accepted electronically. No diagrams, tables or other illustrations please.

Pictures should be of print quality – please take photographs on the largest setting on your camera, with a plain background.

Precedence will always be given to more topical contributions. Any one contributor may not appear more often than once per volume (once every 12 months).

> "AS I STROVE TO CONVINCE A FELLOW ATTENDING AN EVENING TALK OF THE JOYS OF OFFICE, I WAS REBUFFED WITH: 'WHAT IS THE POINT OF A REGIONAL GROUP'?"
> JOHN BLACK

MODELS AND FLOODING

Helen Burke*, Rolf Farrell§ & David Morgan*

on how 3D geological models help flood risk management in E Yorkshire

Above: ***If you go down in a flood today, you're sure of a big surprise***

Flooding hit the headlines throughout the winter of 2013-14, with significant lowland areas of the UK (the Somerset Levels, Thames Valley and parts of southwest England) affected by coastal or inland (river or groundwater) flooding. The flooding was caused by a succession of Atlantic depressions and storm tracks that raced towards northern Europe, bringing high winds and above-average rainfall.

In early December 2013 these combined with high tides to create a tidal surge that affected low-lying coastal areas adjacent to the Irish and North Seas. Throughout the winter, flood damage to property, businesses and infrastructure was extensive and the overall cost to the UK economy was at least £1.1bn, taking into account insurance claims, uninsured losses, costs to Government and businesses[1]. The impact of these storms and floods highlights the vulnerability of certain parts of the UK to the forces of nature, with flooding likely to become more commonplace in the future if climate predictions for increased storminess and intensity prove correct[2].

Eastern England

Low-lying areas of eastern England, including the Humber Estuary and adjacent areas around Beverley, have historically been particularly susceptible to flooding. Kingston-upon-Hull lies in the south of the River Hull catchment, which covers an area of around 980km^2, including the Yorkshire Wolds and the Humber Estuary. The River Hull catchment area is very low-lying and carries the second greatest flood risk in England, exceeded only by the River Thames. Approximately 100,000 properties and over 5000 hectares of agricultural land within the catchment are at risk from river flooding. Within the Kingston-upon-Hull city boundary alone,

> THE IMPACT OF THESE STORMS AND FLOODS HIGHLIGHTS THE VULNERABILITY OF CERTAIN PARTS OF THE UK TO THE FORCES OF NATURE, WITH FLOODING LIKELY TO BECOME MORE COMMON

Flooding hits York

Right top & bottom: Flooding on the River Ouse

more than 130,000 properties are at risk from all sources of flooding.

Historical records dating back to the 17th Century document flooding in Kingston-upon-Hull, including the catastrophic tidal surge of 1657, which inundated the area with over one and a half metres of water. Prolonged rainfall in November 2000 caused severe surface flooding when the River Hull burst its banks and drains were unable to cope with the additional volume. Another severe flood event occurred in December 2013, when Kingston-upon-Hull was inundated by sea water. The highest ever tide was recorded at the River Hull Tidal Surge Barrier that day, and coastal defences were overtopped. This event was caused by a tidal surge that coincided with a spring tide.[3]

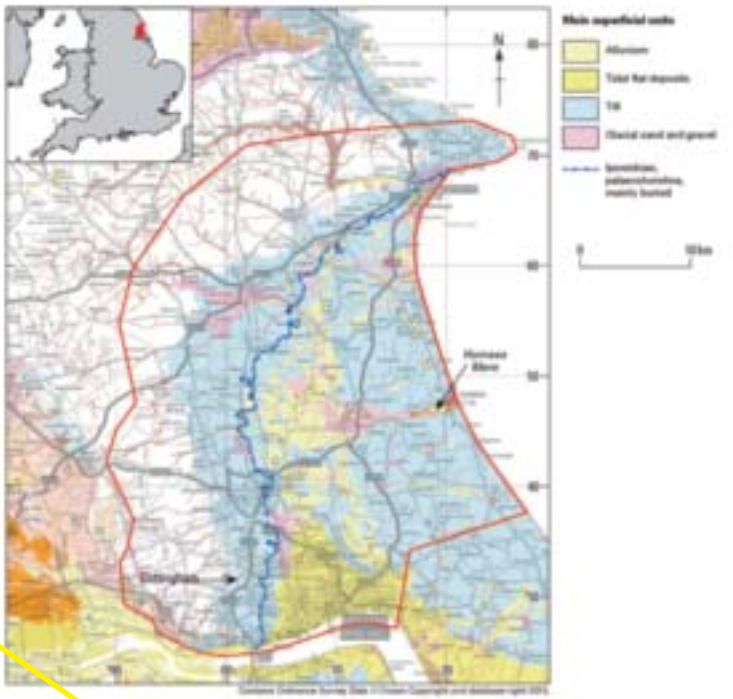
Among the Environment Agency's responsibilities is the management of water quality and resources and the management of flood risk from major rivers, estuaries and the sea. Its responsibilities include installing and maintaining flood defences, monitoring river levels and managing the Chalk Group groundwater aquifer - a principal water source for much of eastern England, but also a potential source of groundwater flooding. In partnership with the Environment Agency, local authorities are currently drafting plans to reduce flood risk and limit its impact over the next 50-100 years.

3D needs

The Environment Agency requires a three-dimensional (3D) understanding of the geology of the area and its influence on the movement of groundwater through the shallow subsurface. To meet this requirement, the British Geological Survey (BGS), working with the Environment Agency, constructed a detailed 3D geological model of the Holderness area. The model establishes the subsurface geometry of the Quaternary succession and identifies permeable groundwater pathways connecting the Chalk aquifer to parts of the superficial sequence and, potentially, the ground surface. This helps the Environment Agency to manage water resources effectively and advise on locating flood defences.

So how did we build the model? The Holderness 3D geological model was created using a specialist 3D modelling package called 'Geological Surveying and Investigation in 3D' (GSI3D). This considers a variety of geological data types[4]. The ingredients included 1245 borehole records from archives at the BGS and the Environment Agency, surface geological map data (BGS DiGMAPGB-505), a Digital Elevation Model (DEM) which accurately depicts the ground surface, published literature, and a small team of enthusiastic geologists[6].

The 3D model shows that most of the ▶



1:50,000 scale superficial geology map of the Holderness 3D geological model area (red), which covers 1280km2, from Kingston-upon-Hull to Flamborough Head and from Market Weighton to the east Yorkshire coast. Area underlain by thick glacial deposits, including till (pale blue) and glacial sand and gravel (pink). Holocene sediments: tidal flat deposits along the Humber Estuary, beneath Kingston-upon-Hull, and alluvium along river courses (yellow). Ipswichian palaeo-shoreline (blue)

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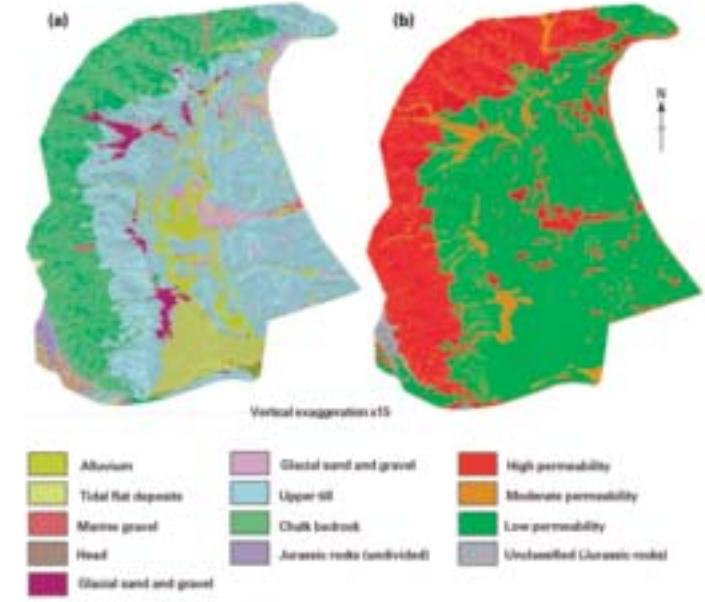
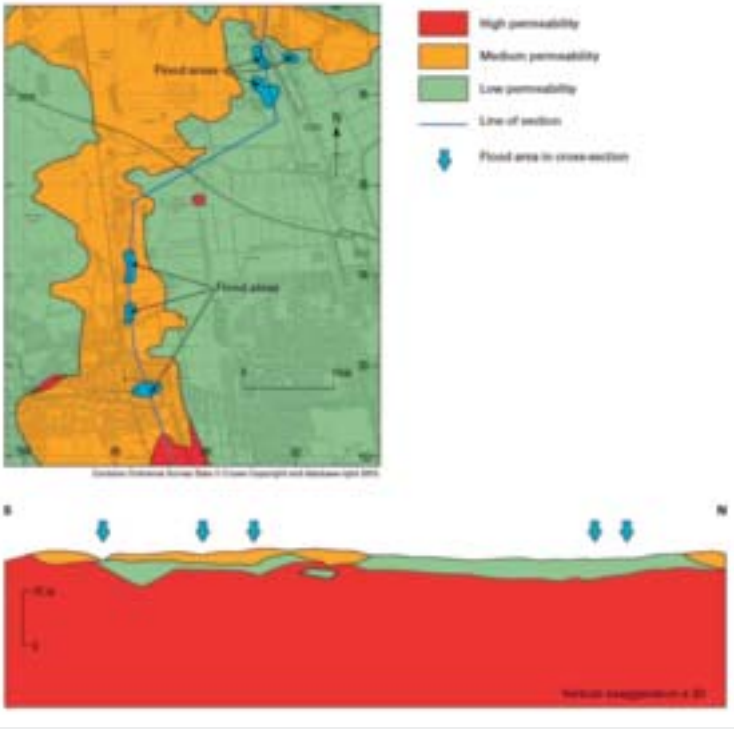
Lewes, E Sussex, – marker showing the maximum height of the water during the October floods of 2000



The Holderness 3D model is attributed with stratigraphy or permeability. (a) 3D view of the Holderness model coloured by stratigraphy; (b) 3D view of the model attributed by the bulk permeability value assigned to each unit. Chalk and sand and gravel have been attributed as high permeability; units with high proportions of clay, e.g. till, classed as low permeability. Purple glacial sand and gravel unit contains clay and has been attributed as moderate permeability



Location map of groundwater flooding recorded in Cottingham, 2001 (flooded areas shown) and a cross-section from the Holderness model. By colouring with the permeability attribute, the EA could distinguish between areas affected by surface flooding and areas of groundwater flooding. Flooding in the northern limb of the cross-section was caused by an abstraction borehole. Contains Ordnance Survey data © Crown Copyright and database rights 2015

▶ Holderness model area is covered by superficial deposits, underlain by Chalk bedrock with its top surface (rockhead) forming a slope that dips gently eastwards at 1-2°. This slope is not smooth, but undulates in places with several buried valleys incised into it. In addition, an ancient Ipswichian shoreline, aged approximately 121ka[7], forms a small step-feature in the Chalk surface. This palaeo-shoreline is mostly buried beneath superficial deposits, but crops out on the coast at Sewerby and Hessle.

Glacial

The overlying Quaternary succession is dominated by glacial sediments, including tills, sands and gravels, silts and clays, which reach c. 50m thickness in some areas. These glacial sediments were laid down during the latter part of the Late Devensian (c.27 to 15ka[8]), the last major glaciation to affect the British Isles during the Quaternary. At this time much of northern Britain was covered by up to 1.6km of ice of the British-Irish Ice Sheet[9].

The North Sea Ice Lobe of the British-Irish Ice Sheet extended down the North Sea coast of Britain as far south as northern Norfolk. The North Sea Ice Lobe was one of several fast-flowing rivers of ice, called ice streams, that rapidly drained ice from the interior of the ice sheet outwards towards its margins. This overtopped Flamborough Head, occupying the lowland area of East Yorkshire inland as far west as the Chalk escarpment.

Several major oscillations of the ice margin produced the classic till sequences of the region[10,11,12] that include distinctive erratics derived from northern Britain and Scandinavia [13,14]. At this time a second, small ice-stream occupied the Vale of York to the west of the Chalk escarpment.

Floodplain alluvium and tidal flat deposits, mainly composed of silts and clays, overlie the glacial sequence. These are locally incised into the glacial sequence and make up most of the Holocene sediments in the region. The extent of the glacial sediments and Holocene deposits can be seen in the Quaternary geological map of the region.

The wide range of lithologies in the Quaternary sediments gives rise to highly variable porosity and permeability properties, which in turn affect the storage and flow of groundwater, including, where connected, transmissivity into the underlying Chalk aquifer.

Model applications

As highlighted earlier, East Yorkshire has a history of flooding from several different sources. Low-lying coastal areas are susceptible to tidal flooding, particularly when high tides coincide with strong winds to produce storm surges, raising the level of the sea and enabling sea water to inundate the land.

River flooding occurs when the volume of water being carried by a river exceeds the channel capacity. This commonly occurs after prolonged heavy rain, whereby the river bursts its banks to flood adjacent low-lying areas.

Groundwater flooding occurs when the water table rises and intersects the ground surface in response to heavy rain. Kingston-upon-Hull is particularly susceptible to all of these types of flooding because of its location in a floodplain area, its proximity to a low lying coastal region and the presence of relatively shallow groundwater aquifers.

The Holderness 3D geological model helps the Environment Agency determine whether there is a geological control on groundwater flooding in the region, such as aquifers within the superficial deposits and hydraulic pathways from the Chalk aquifer to the ground surface. The Agency's initial understanding of the regional geology was based mainly on traditional published geological maps of the area, which indicate that the Chalk is overlain by a fairly substantial thickness (up to 50m) of mostly low-permeability glacial till with highly permeable bodies of sand and gravel occurring locally. However, prior to our 3D modelling, their geometries, extents and connectivity remained poorly understood. With the Holderness 3D geological model, the distribution of highly permeable rocks and sediments at depth and in the shallow sub-surface can easily be visualised and analysed.

Lithology

Each geological unit in the Holderness model is attributed with lithology and a bulk permeability value (high, moderate and low), as shown in the figure. The Environment Agency uses the permeability information to identify areas where permeable sediments are present throughout the sequence of superficial deposits, from the ground surface to the top of the Chalk. These areas are of particular interest because they may indicate where groundwater flooding is most likely.

One test location is Cottingham, a low-lying town just outside Kingston-upon-Hull. Back in 2001, flooded excavations were reported in the area, although the cause, source and potential for groundwater flooding at the time were unknown. Cottingham is located in an area that was once marshland and is drained by an artificial drainage network that pumps water into the River Hull. The land in this area is situated below mean high tide level and was prone to river flooding.

To reduce this risk, the River Hull has been artificially raised above the land surrounding it. The water table in the Cottingham area has a very shallow slope angle, or low hydraulic gradient, which inhibits drainage at the ground surface. It is therefore difficult to tell whether flood events are caused by groundwater or surface flooding because surface floodwater can take a long time to dissipate.

To investigate the cause of flooding at Cottingham the Environment Agency constructed a cross-section in the Holderness model through the areas where flooding had occurred in 2001 and coloured the model according to the permeability attribute – see diagram. This revealed that flooded areas underlain by low permeability superficial deposits are most likely to have been affected by surface water flooding, and groundwater flooding is likely to have occurred where permeable or moderately permeable superficial deposits connect the Chalk aquifer to the ground surface.

However, not all flooding in the area is natural. The northern limb of the cross-section passes through a cluster of flooded areas to the north of Cottingham, where the Chalk aquifer is overlain by approximately 10m of low permeability Quaternary sediments. After further investigation the Environment Agency discovered that the cause of this flooding is most likely to be an abstraction borehole and historic site-investigation boreholes, which have created artificial hydraulic pathways through the relatively ▶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Above: Victims of flooding deserve higher-tech help than the humble sandbag

> THE HOLDERNESS 3D GEOLOGICAL MODEL HELPS THE ENVIRONMENT AGENCY DETERMINE WHETHER THERE IS A GEOLOGICAL CONTROL ON GROUNDWATER FLOODING IN THE REGION

impermeable superficial deposits into the underlying Chalk aquifer, enabling groundwater within the Chalk to rise up and flood several fields.

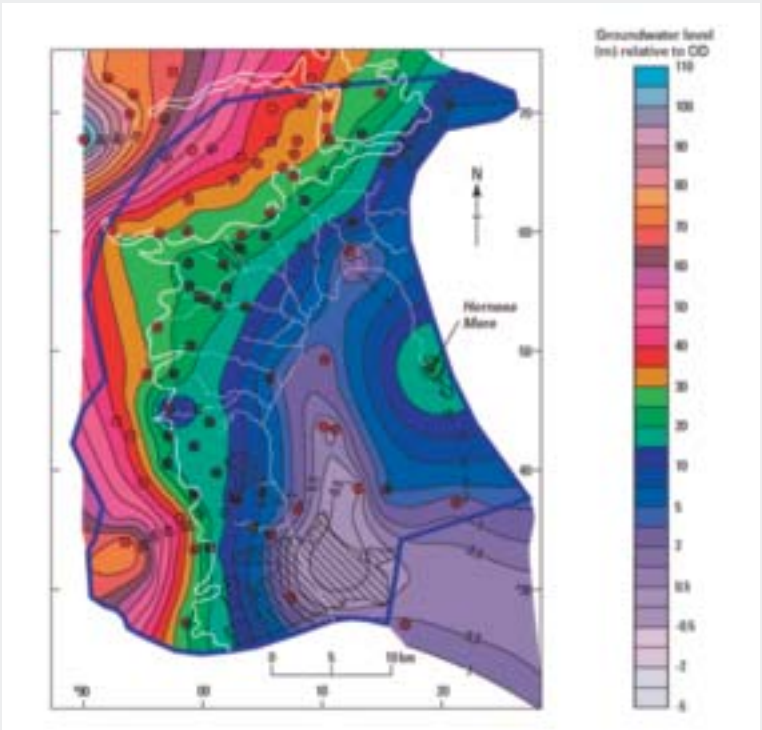
Vulnerable

Using the Holderness model, the Environment Agency discovered where the Chalk aquifer is most vulnerable to pollution from contaminants derived from historic land use. To manage water resources in the Cottingham area more effectively, the Environment Agency needed to understand the complexity of the superficial deposits. The Chalk aquifer is particularly vulnerable to pollution in areas where superficial deposits are very thin or completely absent and where permeable superficial deposits form a hydraulic pathway through the Quaternary to the surface. Disused gravel pits in the Cottingham area that were long ago used as waste-disposal sites are of particular concern to the Environment Agency because the landfill material is permeable and could contain contaminants, which might leak into the Chalk aquifer. This is especially important at Cottingham because two public water-supply boreholes are located in the area.

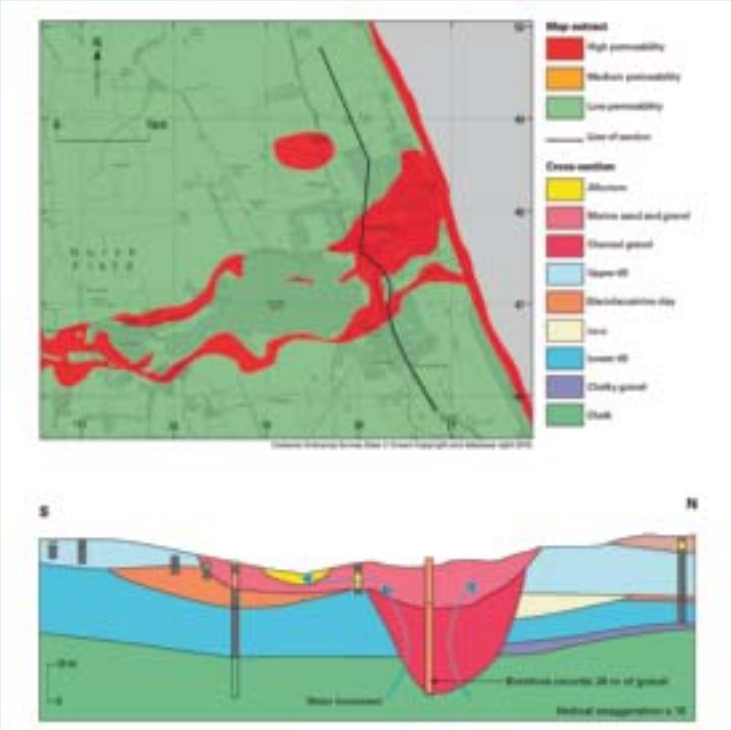
The Environment Agency used the geological detail in the Holderness 3D model to control development within the Source Protection Zone at Cottingham, which directly affected local planning applications. This is one of over 2000 Source Protection Zones in England and Wales established by the Agency to protect groundwater sources of public drinking water. Strict planning controls ensure that new developments posing a contamination risk are not located close to Source Protection Zones. One such development type is the installation of new petrol stations and associated underground fuel storage tanks. The Cottingham Source Protection Zone is centred on public water supply boreholes and was originally established using a numerical model of groundwater movement. However, this numerical model did not take into account the Quaternary sediments that overlie the Chalk aquifer. Using the geological detail in the Holderness model the Environment Agency have recently updated the Cottingham Source Protection Zone. This has directly influenced local planning policy, with land previously allocated for housing developments now falling within the most sensitive part of the Groundwater Protection Zone, where housing developments are not normally permitted. The Holderness model enabled the Agency to consider the local geology when making decisions on planning applications within the Cottingham Source Protection Zone. Only areas where the Chalk is overlain by a thick layer of clay were considered suitable for housing developments because the risk of contaminating the Chalk aquifer there is relatively low.

The Holderness geological model has also enabled the Agency to revise its hydrological understanding of the Chalk in East Yorkshire and validate their groundwater levels data. One location of particular interest is Hornsea Mere, where groundwater level is unusually high in one monitoring borehole - c. 10m higher than the surrounding area12. There was an obvious need to find out if this local anomaly was geologically controlled. Superficial deposits are at their thickest along the East coast, and are typically of till, with a high proportion of clay and should, in theory, act as a seal, trapping groundwater within the Chalk.

The 3D model revealed that the groundwater monitoring borehole is located in a deep gravel-filled channel that cuts through the glacial sediments directly into the Chalk aquifer. This provides a direct pathway from the aquifer through the superficial deposits, enabling groundwater-fed recharge of Hornsea Mere. The area where connectivity between the channel and the Chalk aquifer occurs is actually relatively small, and would have been difficult to predict



Contour plot of groundwater levels in the Chalk aquifer in East Yorkshire[14]. Note the 'bullseye' of much higher readings at Hornsea Mere, approximately half way up the east coast



Location map of Hornsea Mere cross-section, showing permeability values (high, moderate, low). The cross-section through Hornsea shows a gravel-filled channel cutting the surrounding clay-rich glacial deposits and into the Chalk. This permeable gravel unit enables the water table to rise through the superficial deposits and supply Hornsea Mere

without the Holderness 3D model. However, further investigation will be needed to find out exactly why the groundwater level within the Chalk is higher in this area.

Conclusion

Flooding is a major economic and societal issue, and is expected to become more frequent. One area with a long history of flood events is Kingston-upon-Hull because of its low lying coastal location within a floodplain. Groundwater flooding is difficult to predict and model, making groundwater flood mitigation especially difficult. The Holderness model provides a means for Agency to distinguish between groundwater and surface flooding, which helps them determine which mitigation measures are most suitable.

The Holderness geological model has been used by the Environment Agency to revise the Source Protection Zone located at Cottingham, where strict development controls protect supplies of public drinking water. This revision has directly influenced local planning policy, with the Agency ensuring that the Chalk aquifer is covered by a thick layer of clay beneath land allocated for housing developments in the area.

Three-dimensional geological models are useful tool for visualising the geology and can be used to identify areas of connectivity between permeable and non-permeable units and the underlying bedrock. The Environment Agency have used the 3D geological model of Holderness to increase their understanding of the geology and hydrogeology, which helps them to manage water resources more effectively and mitigate the risks associated with flooding.

The Holderness model has contributed to BGS's National Geological Model15, which comprises over 150 geological models of various scales and levels of detail. Models such as these will continue to add to the BGS's understanding of the 3D geology of the UK. The Holderness model is attributed with permeability values to meet the Environment Agency's needs, but any number of additional attributes could be assigned to the modelled geological units, including engineering properties, such as strength and porosity. ◆

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Somerset Levels 10 February 2016. Council workers close barriers to prevent drivers from accessing flooded roads ahead

ACKNOWLEDGEMENT

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AN UNDERESTIMATED KEVAN

> AT AN ESTIMATED LENGTH OF 10-20 METRES, THE EXTINCT PREDATOR WAS DESCRIBED IN THE LOCAL PRESS AS ONE OF THE BIGGEST AND MOST COMPLETE PLIOSAURS KNOWN

Senile? Arthritic? Scavenged? Abandoned? **Douglas Palmer*** on the Sedgwick Museum's giant Pliosaurus cf. kevani

Just over 60 years ago, in June 1952, the remains of a giant marine reptile known as a pliosaur were uncovered by a dragline excavator at Stretham, near Cambridge. At an estimated length of between 10 and 20 metres, the extinct predator was described in the local press as one of the biggest and most complete pliosaurs known. However, a more realistic estimate cuts it down to around 12 m long – the length of a standard bus.

Pliosaurs actively hunted fish and the squid-like cephalopods known as belemnites in the 100m-deep seas, which in Late Jurassic times (c.155 mya) flooded over the region represented by the British Isles today. A history of the find, its rather botched recovery and the complicated story of various attempts at interpretation and classification, has been published by a local geologist Dr Peter Hoare in the Proceedings of the Geologists' Association 126 (2015) 381–389.

Found but not (fully) recovered

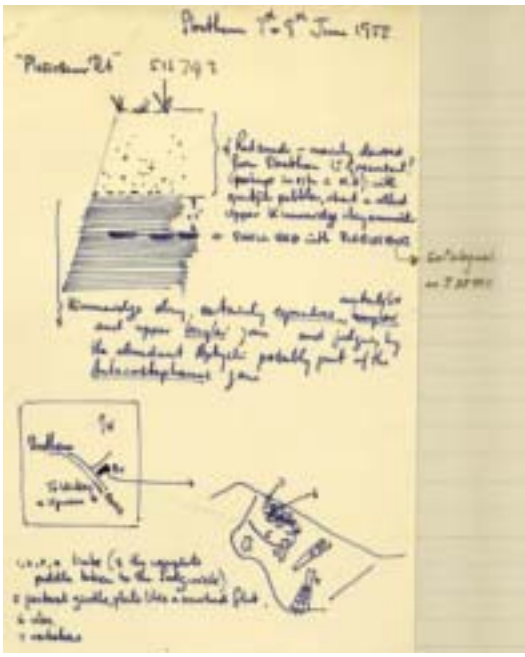
Such was the significance of the fossil and the popular interest it generated that the find spot was fenced off and the remains given police protection in the form of local Bobby PC Bill Lythell. The exact details of who first spotted the remains, and where, have not been firmly established; but the partly scattered bones of the huge skeleton were uncovered at Stretham where Kimmeridge Clay was being excavated for use in flood protection work by the Great Ouse River Board. And then, some of the bones were spotted when a load of excavated clay was dumped at Godmanchester (or so the story goes).

Dr O M B Bulman (1902–74), a Reader in Palaeozoology in Cambridge at the time (and subsequently Woodwardian Professor from 1955), was told of the find by a local dairy farmer Mr S R Hopkin and steps were taken to recover it. Other members of the Department of Earth Sciences and Sedgwick Museum who examined the remains included Maurice Black (1904–73, Reader in Sedimentary Petrology); Albert (Bertie) G Brighton (1901–88, Curator of the Sedgwick Museum); Brian Harland (1917–2003, Reader in Geology), Colin Forbes (1922–2014, Assistant Curator, 1954–67, and subsequently Curator the Museum 1967–83,) Michael House (1930–2002, then an undergraduate in Cambridge and latterly Professor and head of the Department of Geology at the University of Hull), along with Henry Brand, who was a Museum assistant from 1933 until 1980, and Stan Misson, who was a lab assistant in the 1950s.

Despite local press claims about the amazing size and remarkable preservation, Forbes left notes indicating that the fossil was 'so much broken as not to be worth the labour of collection'. Even so, Bulman supervised recovery of one of the huge paddle-like hind limbs, which was relatively complete despite being made up of many small bones, along with vertebrae, breast bones, ribs and part of the pelvis. Unfortunately, the skull seems to have been smashed by the excavator and it is likely that had it been preserved more effort would have been made to recover other remains.

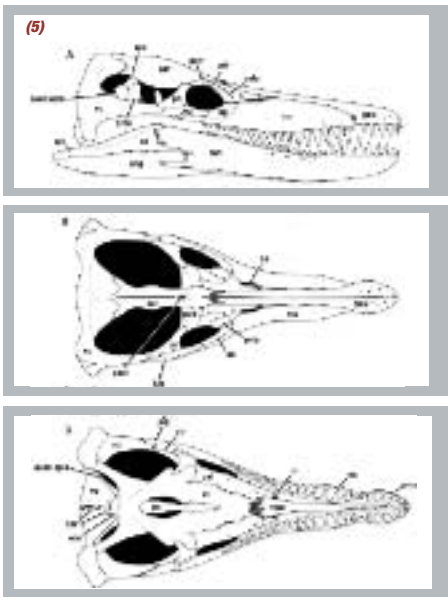
As it was, once the Museum staff had taken all they wanted there was still quite a lot of bone material left, and River Board personnel gave them to local schools (and more or less anyone who wanted them). Apparently, scores of people visited the site and carried away bits of fossil bone including a number of the dinner-plate-sized central portion of the vertebrae, which were subsequently used as doorstops. The Museum had collected just 69 bones, of which about half belonged to the really impressive two-metre-long hind paddle that is still on display in the Museum. The animal used the huge flat but flexible, paddle-shaped, limbs to propel itself through the water as if it were 'flying'.

Initial work on the fossil material by L B H Tarlo (1933–91, later known as Bev Halstead, Reader in Geology at the University of Reading) in the mid 1950s highlighted the potential importance of the find and led to the first of several attempts to recover the fossil material which had been given away. Then, in 1960, more bones were collected close to the original site in Stretham, so that the Museum now has around 165 bones, ▶



Above top: *The Stretham pliosaur's police guard in the person of PC Bill Lythell, the local 'bobby' along with some of the Great Ouse River Board staff (Cambridgeshire Collection, Central Library, Cambridge)*
Above middle: *Some of the pliosaur's local admirers (Cambridgeshire Collection, Central Library, Cambridge)*
Above lower: *Sketch map of the Stretham locality and section of the Kimmeridge Clay in which the pliosaur remains were found in 1952. (Sedgwick Museum archives)*

Left: *Pliosaurs hunted fish and belemnites in Late Jurassic seas*



***Above: (5)** Drawing of P.kevani skull n reconstruction of the skull journal.pone.0065989.g003.TIF*
***Above: (4)** Plaster cast of a 2m long pliosaur paddle (P. macromerus) found at Kimmeridge, Dorset in 1839 (Sedgwick Museum photo by Matt Riley)*

***Left: (1)** Professor O M B Bulman (back to camera) directing the excavation of the Stretham pliosaur on site in the Great Ouse River Board borrow pit within the Kimmeridge Clay at Fordham Road, Stretham, Cambridgeshire. In the background is the dragline excavator and just out of sight its bucket in which Brian Harland was lifted to take an 'aerial' view of the fossil – different health and safety rules applied in those days, no helmets, hi-vis jackets etc. but only the pliosaur fossil was damaged during the excavation*
***Left: (2)** The near complete hind paddle of the 'giant' Stretham pliosaur with individual bones numbered prior to removal from the Kimmeridge Clay. The 2m long fossil is now on display in the Sedgwick museum*
***Left: (3)** A little gentle brushing of more pliosaur backbones for the benefit of some local Stretham schoolchildren by Dr Colin Forbes (1922-2014), Curator in the Sedgwick Museum. Over 20 backbones and several rib fragments were found near the original findspot in 1960 and may have belonged to the same animal*

including 38 backbones, which altogether represent about 25% of the skeleton; although it is just possible that not all of the bones are from one individual.

By 1964 Tarlo's detailed examination revealed signs of osteoarthritis in some of the bones from the neck and left hind limb, which was the only one to be recovered in any degree of completeness. The osteoarthritic 'lipping' of the edges of the bones can be clearly seen on the fossil displayed in the Sedgwick Museum. Tooth-marks were also spotted on some of the backbones and a rib-bone showing that there had been post-mortem scavenging of the carcass by some large predator, possibly another pliosaur.

Misnamed

The first formal description and naming of the fossil (by Tarlo, 1958) called it *Pliosaurus* ; but he soon claimed that it was sufficiently distinct to be given a new name – Stretosaurus. However, he then realised that he had mistakenly identified one of the bones, which made the new name redundant, and suggested that it should revert to the name *Liopleurodon*, first established in 1873 for other fossil material. In recent decades even this identification has been questioned because of the incompleteness of the fossil remains and especially the lack of a skull.

In 2013, Roger Benson, who was a research fellow in the Department and is now an associate professor in the Department of Earth Sciences in Oxford, referred the Stretham pliosaur back to the original genus name *Pliosaurus*. This was the name that Tarlo used in 1958, and dates back to the 1840s when these kind of extinct marine reptiles were first found. The Museum also has a cast of a similarly large and even more complete *Pliosaurus* paddle found in 1839 within the Kimmeridge Clay at Kimmeridge, Dorset by John Mansel-Pleydell (1817-1902, St John's College 1836-9), one of the founders of the Dorset County Museum, where the original is on display.

Undervalued Kevan?

More recently, a large (2m-long) pliosaur skull, also found in the Kimmeridge Clay of Dorset, is well enough preserved to allow Benson and his colleagues to describe a new species, which they call *Pliosaurus kevani* and dedicate to all "…the underestimated and undervalued Kevans of this world" after Kevan Sheehan, the collector who discovered it in June 2013. These authors also feel that the Stretham pliosaur might fit this particular 'bill' and tentatively named it *Pliosaurus cf. kevani*. It certainly has been 'underestimated and undervalued'. ◆

***Douglas Palmer,** author, is Public Programmes Coordinator for the Sedgwick Museum, Cambridge.

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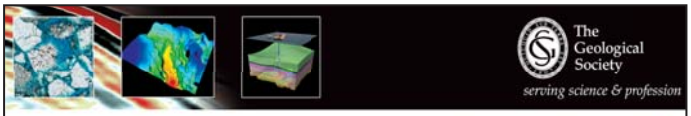

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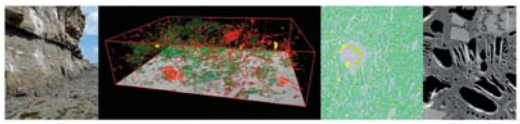

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Field work for subsurface geologists

Oil geologists studying ophiolites in N. Albania. From left C Ottesen, C Vahle, Z Veselovsky, M Carter and B Hansen (Eriksfiord)

Sir, Inspired by Mr Carruthers (*Geoscientist* 26.04, p 09), I would like to describe the role of fieldwork in my company. We consult for the oil industry and all our studies are based on numerical data such as borehole images, petrophysical logs and pressure measurements.

Our geologists work all day in the sterile environment of an office. They create various displays on a screen and try to imagine what real geology is going on down there at 5km, more inaccessible to humans than Mars. Their results are maps and sections that look as if they were surface geological maps and mountainsides or road-cuts. They use stereographic techniques the same way a field geologist does - with the difference that all data are acquired along a continuous curve, the well trace.

They constantly compare computed data with real rocks and real structures. Despite our modest budget, we require each colleague to participate in at least one conference fieldtrip per year, and in an annual field trip we organise ourselves. When recruiting, we select geology PhDs based on fieldwork. Techniques peculiar to industry the candidates learn on the job.

We do not sell fieldtrips to clients – we have no commercial axe to grind here. The conference field trips usually present field analogues directly relating to our work on clients' oil fields, whereas the annual field trip focuses on wider topics including obduction, volcanism, rifting, fold/thrust belts. All processes are connected; e.g. structures in outcrop are the work of stress we observe in wellbores.

Yes, we seriously enjoy our field trips, and we could not do our work properly without it. It is not a sin to enjoy one's job!

BIRGER HANSEN

Blessed are the data handlers

Sir, I will never dispute that 'the best geologist is the one who has seen the most rocks', but am finding the repeated emphasis on field geology '*über alles*' increasingly shrill. Data gathered in the field only becomes valuable once we have analysed and understood it, and produced a predictive model.

This interpretation relies heavily on data being 'clean', organised, and in a usable format. In order to meet reporting standards it is necessary to track any interpretive changes that deviate from the original field logging. From beginning to end, data must be handled so as to preserve user trust.

As a consultant I have seen dozens of datasets of different kinds, from clients all across the world, from major players to minor operators. In most instances, I would class their data storage and handling as 'poor to middling'. And neither size nor reputation of company, nor geographic location, have any bearing on the quality of their datasets.

Long gone are the days when an entire mineral deposit could be mapped or interpreted on paper. Nowadays that work is done on computers, running specialist software, needing solid databases to work from. Field studies and drilling programs cost money, and the value of the data won is very quickly lost if it is stored incorrectly. Poor data storage costs more in the long run than it saves in the short term.

We may not like the fact that a large portion of a geologist's life these days consists of moving columns of data around rather than licking rocks. But it is here to stay, and we should show more appreciation of the value added to our work by the 'dull' task of maintaining good quality databases!

FINDLAY CRAIG

Nepal – not all its seisms

Sir, In the aftermath of the earthquake tragedy in Nepal, scientists are rightly studying the seismic factors that can give rise to further landslides (*Nature 532, 428 - 431; 2016*). Such studies are of inestimable value for many earthquake-prone regions around the world.

However, the situation in Nepal is exacerbated by two additional factors. One is that the foreland zone of the Himalayas, home to most of the population, consists primarily of clastic sediments produced by the uplift and erosion of the Himalayas and deposited by rivers (R B Sorkhabi & A Macfarlane, Himalaya and Tibet: Mountain Roots to Mountain Tops, *Geol. Survey of America Spec. Pap. 328, 1-8; 1999*).

It is relatively easy to bulldoze a basic road through this material, but such roads are subject to slow settlement, and the steep water-saturated slopes through which they are driven are liable to slippage at any time and at any scale when the steepness or saturation reach critical values (P. Bak et al., *Phys. Rev. A 38, 364-374; 1987*). This means that better seismological understanding and measurement can contribute only partly to a solution.

The other factor is the presence at high altitude of 1466 glacial lakes, the banks of any one of which may collapse to release its contents and produce a devastating flood that destroys roads and villages further down the mountain. Seismic events can precipitate such collapse, but so can heavy rain, snow, or the attainment of critical conditions.

Monitoring of seismic tremors gives warning of possible events, but what Nepal desperately needs is a system of monitoring and communication that addresses actual events so that, when the inevitable occurs, warning can be given in time for populations to escape from the path of the subsequent flood or landslide. Roads, and even villages, can be replaced; people can't.

LEN FISHER, UNIVERSITY OF BRISTOL, UK & BLEDDYN GRIFFITH, ROAD ENGINEER, ADB NEPAL PROJECT

My county for a horse

Sir, What irony that the cover photograph, used to illustrate a feature on the Chalk (*Geoscientist* 26.04, May 2016) depicts a concrete horse. Shame on the BGS for not giving us a chalk horse. Plenty to choose from in Wiltshire!
JOHN SIMMONS (WILTSHIREMAN)

Editor replies: John identifies the very reason this horse was chosen by production design. It may be concrete at surface, but what is it at depth? Hmm? We're subtle like that here at *Geoscientist*.

A Luddite writes

Sir, Computer modelling may have its place but not when a wider view, understanding of the real world or common sense are lost! The colour scheme originally devised by William Smith (See *Distant Thunder*, p. 25) made any geology map universally understandable and aesthetically pleasing. Alas, we now have garish, ugly colours, impossible to interpret at a glance, where limestone outcrops are often shaded red and igneous rocks blue! I detest what the computer whizz-kids have done to the great man's legacy.

Equally frustrating is the BGS app 'iGeology'. Unlike a paper map, which uses no power yet depicts detail as well as the overview at a glance, I find the app fiddly, invisible in daylight, and with those same idiotic new colours – which mean repetitive finger-stabbing, only to reveal less than helpful rock names. The 3D version seems to me a simplistic joke.

In geology, as in sex education, there can be no substitute for hands-on experience in the field.
RICHARD ARTHUR

Holistic fieldwork

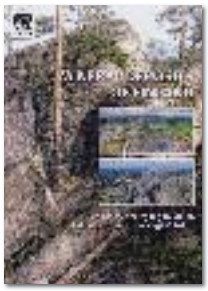
Sir, Geological fieldwork is not just about geology! It is also about learning the value of nature, observation, and more physical problem-solving approaches unique to geoscience and rare in other non-vocational degree fields.

With a large focus (in the fields of health, education and psychology) on the importance of the outdoors and nature to well-being, we should count ourselves lucky as geoscientists to have this activity embedded in our curriculum, and take more time to acknowledge the more holistic educational benefits of being able to look at, and interpret, a landscape.

I continually find value in having had both academic and fieldwork training, both in work and social life. Friends and colleagues have been amazed at how I can 'explain' a previously mundane landscape to them, through basic geological observations.

I see this as incredibly valuable in inspiring wonder, in myself and others, about the natural world - with great potential for increasing public scientific literacy (e.g. Geolodia *Geoscientist* 27.04 p16). Finally, for those geoscience students who may be less academic in the 'traditional' sense, and prefer 'learning through doing', fieldwork is a fantastic way to ensure their potential is not wasted.
JANE ROBB

Mineral Deposits of Finland



Finland is a major European hub for mineral exploration and mine development. The country hosts Europe's oldest rock units and large cratonic blocks, analogous to Western Australia and Southern Africa. Although commodity prices are currently low, one development in the last boom was the recognition that many of the world's currently active ore-producing districts are extremely mature and future resources will have to come from different locations.

Thus this volume fills a gap in the market to provide an up-to-date and inclusive reference available that fully captures the scope of Finland's mineral deposits and their economic potential. It certainly delivers, providing comprehensive coverage of the major mineral occurrences in Finland. But this is significantly more than just a catalogue of occurrences – it is a major piece of scientific work. Each chapter is authored by a group of experts in their field and provides a comprehensive description of the mineral deposits discussed, techniques used in exploration and implications for mineral exploration and extraction.

The book is organised into parts that provide a summary of ore deposit discoveries in Finland; metallogensis of Finland and the surrounding areas; description of magmatic Ni-Co-Cu-Cr-V-PGE deposits; Carbonatite deposits (including kimberlites); Gold deposits; IOCG; VMS; Granite hosted; Black shale and other deposits; Exploration methods and resource definition.

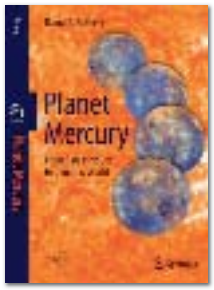
Overall, this organisation is good, and each part is split into chapters where multiple deposits occur - each deposit representing a chapter. Sometimes this can be a little confusing, such as the placement of Sokli Carbonatite deposits in with 'Black shale and other' deposits rather than with Carbonatites; but these are minor points. Overall the book provides a logical study of Finnish mineral deposits.

The volume editing is good and the work largely free of errors. The illustrations are also good and informative. The book should be essential reading for anyone working in Finland in mineral exploration or economic geology - and more widely by those interested in the geology of Europe. The book would make an excellent template to be applied to other parts of the world.

Reviewed by ***Rob Bowell***

MINERAL DEPOSITS OF FINLAND BY WOLFGANG DEREK MAIER, RAIMO LAHTINEN & HUGH O'BRIEN (eds) 2015. Published by: Elsevier; 802pp ISBN: 978-0-12-410438-9 (hbk). Ebook available.
List price: ££190.00 W: http://store.elsevier.com/product.jsp?isbn=9780124104389

Planet Mercury – from Pale Pink Dot to Dynamic World



Messenger's Mercury mission ended today, the day of writing, with a bang and silence, according to the BBC. The mission was remarkably successful, despite widespread doubt that the probe would reach Mercury. Originally planned to include one year orbiting the planet, it was extended twice and lasted four years. It finished when Messenger crashed into the surface because its fuel ran out. The mission produced 270,000 images and 10 terabytes of data.

The book comprises seven, well-illustrated chapters: the first being a good summary of pre-space-age knowledge of the planet. The next three chapters describe, in turn, the probes and equipment for Mariner 10 (NASA, launched 1974), Messenger (NASA, 2004), and BepiColombo (ESA, scheduled 2016). Fairly detailed technical information is presented but, at 64 pages, might be thought to occupy too much of the book. Some will want even more detail, of course.

The remaining chapters give an extended outline of what was learnt from Mariner 10 and Messenger. Much relates to the differing terrains across Mercury's surface – from craters to extensive plains (which cover 27% of the surface), with quasi-linear rises, etc. These major types of topographic feature are fundamental to any understanding of elemental and/or mineral distribution, etc, on which there is also a wide spread of information. Clear evidence exists, among other things, of crustal shortening.

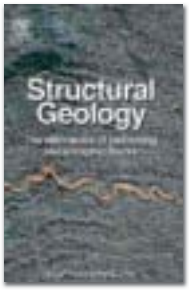
After the surface which, naturally, is covered thoroughly, are chapters dealing with the planet's interior – from mantle to inner core – its exosphere, and its somewhat strange magnetic field, which is off-centre vertically on the rotational axis. The occasional, small, information gems in the book are excellent. Thus, one might think that the sun's proximity would prevent "water" from remaining near the planet's surface. In fact, there is thought to be ice in deep craters near the north pole, never touched by sunlight because of the angle of incidence. A metre of ice here would take 1 billion years to sublime. If it were covered by 10cm lag deposits, the rate would slow a thousand-fold, to one millimetre per billion years.

The editing is disappointing at times, with confusing text and inexplicable variations in the diameter of the same crater. It might have been useful, beyond this, to include both a glossary and a map showing the principal features discussed. Notwithstanding these issues, this is a good book and a pleasure to own. It will live where it can be found easily.

Reviewed by ***Jeremy Joseph***

PLANET MERCURY – FROM PALE PINK DOT TO DYNAMIC WORLD
by David A Rothery, 2015. Published by: Springer International Publishing Switzerland. ISBN: 978-3-319-12116-1. Hbk. 180pp.
List Price €59.49
W: www.springer.com/series/4097

Structural Geology – The Mechanics of Deforming Metamorphic Rocks. Volume 1: Principles



Structural geology has been informed and fundamentally transformed by significant developments made in other allied and interdisciplinary sciences. Recent advances in metamorphic petrology, tectonics and geodynamics, physical metallurgy, non-linear chemical dynamics, continuum mechanics, non-linear mechanics and thermodynamics have revealed important

understandings of the deformational and metamorphic processes operating within the Earth. These insights have often been obtained independently and not integrated fully within the broader framework of metamorphic and structural geology. This book attempts to address this omission and establish a current comprehensive synthesis.

The volume initially develops the basic foundations in mechanics where thermodynamics has a pivotal contribution and then applies these principles to rock masses where factors such as deformation, fluid flow, thermal transport, mineral reactions and microstructural rearrangements influence the evolution of the rock fabric and generate the structures geoscientists observe. The volume is arranged into two main parts, each introduced with an overview section.

Part A is a modern treatment of mechanics including geometry, kinematics, non-linear dynamics and thermodynamics of deforming systems. Particular emphasis is placed on the principles of non-linear behaviour of deforming and chemically reactive systems, a significant change in approach from existing texts.

Part B considers the processes involved in the development of geological structures such as brittle and visco-plastic flow, heat and fluid flow, damage evolution, microstructural rearrangements and non-linear mineral reaction kinetics. A basic knowledge of structural geology and metamorphic petrology is assumed, with a necessary mathematical emphasis on the treatment of the subject. Brief appendices on elementary differential calculus and tensor algebra are included.

With a combined research and teaching experience of over 70 years, the volume is written by two of the pre-eminent authorities in the field. Written in a clear and concise style, the book is presented with numerous (over 300) figures, graphical drawings and photographs that appropriately supplement the accompanying text. Many of these are in colour and significantly enhance the understanding of the textual details.

The expected audiences are graduate geoscientific researchers and professional structural geologists and metamorphic petrologists both in academia and industry. A long overdue treatment of the subject, this book is highly recommended and anticipated to become established as a standard reference work.

Reviewed by ***Mark Griffin***

STRUCTURAL GEOLOGY – THE MECHANICS OF DEFORMING METAMORPHIC ROCKS. VOLUME 1: PRINCIPLES.
Bruce E. Hobbs and Alison Ord. Elsevier. 2015.
ISBN 978-0-12-407820-8. Hbk. 665pp.
List Price: £79.00 W: www.store/elsevier.com

Frederick W Harmer - a scientific biography

Many of the fundamental principles and concepts that underpin geology were given to us a long time ago and when we use or refine them we usually don't remember, let alone give credit to, their originators. In the last couple of years we have celebrated 'The Father of English Geology', William Smith, but what of the other pioneers? John Kington sets out with the express purpose of reminding us of the importance of Frederic Harmer (1835-1923). The style of Kington's narrative is very much 'matter of fact' and there are no revelations to excite the tabloid press; but Peter Norton's excellent Foreword is more open and launches the subject into its historical and socio-economic context.

Harmer is most commonly remembered for his studies based on East Anglian Crag molluscs. Kington takes us through this work and describes how Harmer established a biostratigraphy, identified a cooling trend and expanded on Searles Wood Sr's monograph. But Kington rightly reminds us that Harmer investigated the post-Crag Quaternary. There is particular reference to collaboration with Searles Wood Jr in identifying different ice-sheets from the composition of their tills and in the production of what these collaborators considered to be the first drift map. The author also takes us through what were early discussions on phenomena of recent research importance viz: a pre-glacial River Thames, glacial lakes, post-glacial fluvial misfits and gaps and differential tilting of the landmass. It was Harmer who introduced the concept of glacial Lake Oxford, an oversight that is firmly redressed.

The author is an expert on historical meteorology and he comes into his own in demonstrating that Harmer was ahead of his time in modelling climate change. Drawing on work that has virtually been overlooked, he commemorates the recognition of the importance of global wind patterns, and especially the role of anti-cyclones, in controlling climate. Kington also recounts how the modelling progressed to account for climatic changes that accompanied changes to the landmasses. Personally, I am grateful to Kington for resurrecting Harmer's assertion of the increased significance of easterly gales in Crag times.

The book includes a useful list of Harmer's published and draft works. Among the illustrations are two detailed geological maps and 39 photographs but the quality of their reprographics is disappointing. Despite this and a couple of minor errors, this is the most comprehensive and authoritative account of Harmer's life and work and it achieves its goal of recollecting Harmer's pioneering achievements.

Reviewed by ***Howard Mottram***

FREDERIC W HARMER: A SCIENTIFIC BIOGRAPHY (SPRINGER BRIEFS IN ENVIRONMENT, SECURITY, DEVELOPMENT AND PEACE, VOL 19)
By John Kington, 2014. Published by: Springer-Verlag
ISBN 9783319077031: 97pp (sbk):
List Price £44.99
W: www.springer.com/gp/book/9783319077031

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- **Arthur Smith Woodward - his life and influence on modern vertebrate palaeontology** by Johanson Z. et al. (Eds) Geological Society of London 2016 Spec Pub #430 362pp (hbk)
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PEOPLE *NEWS*

IN MEMORIAM
WWW.GEOLSOC.ORG.UK/OBITUARIES

THE SOCIETY NOTES WITH SADNESS THE PASSING OF:

Armitage, John *
Bishopp, David *
Colley, H *
Davis, Robert Vincent *
Flood, Raymond Edward *
Hawkins, Alfred Brian *
Ramsden, Robert *
Symes, Robert (Bob) Frederick *
Terris, Alexander P *
Wood, Christopher J *

In the interests of recording its Fellows' work for posterity, the Society publishes obituaries online, and in *Geoscientist*. The most recent additions to the list are in shown in bold. Fellows for whom no obituarist has yet been commissioned are marked with an asterisk (*). The symbol § indicates that biographical material has been lodged with the Society.

If you would like to contribute an obituary, please email **ted.nield@geolsoc.org.uk** to be commissioned. You can read the guidance for authors at **www.geolsoc.org.uk/obituaries**. To save yourself unnecessary work, please do not write anything until you have received a commissioning letter.

Deceased Fellows for whom no obituary is forthcoming have their names and dates recorded in a Roll of Honour at **www.geolsoc.org.uk/obituaries**.

York course opens for applications

Postgrad diploma in The Geology of Yorkshire and Northern England is taking applications for 2016 entry, writes **Amanda Pauw**

The postgraduate diploma teaches through the medium of the magnificent geology of Yorkshire and Northern England, including Flamborough Head

Photo: Alison Hunter 2011

The postgraduate diploma in The Geology of Yorkshire and Northern England, launched in September 2015 by the University of York, is currently considering applications for the new intake in September 2016. This two year part-time course is conducted entirely online via distance learning, but also includes a residential week in York at the beginning of each year for field and lab-based study.

Dr Annette McGrath told *Geoscientist*: 'We are so lucky in the UK to have a great diversity of rocks and spectacular landscapes on our very own doorstep, and Northern England in particular has more than its fair share of world-famous geological features. This exciting and unique postgraduate diploma utilises this geological wealth and explores the main principles of geology through a regional examination of the area. The course has been a great success so far and this year we have seen keen interest from a number of potential applicants. Apply soon before it's too late!'

➤ If you are interested, please contact the Postgraduate Administrator, Amanda Pauw, E: **amanda.pauw@york.ac.uk** or T: 01904 328482 for further details

Geoscientists in the news and on the move in the UK, Europe and worldwide

DISTANT THUNDER *Colour coded*

*Geologist and science writer **Nina Morgan*** *speculates on the colourful life of William Smith*

Even his most loyal supporters had to admit that lecturing was never William Smith's strongest suit. As his nephew, geologist John Phillips [1800–1874], noted in his 1844 memoir of his uncle: 'a habit of following out his own thoughts into new trains of research, even while engaged in explaining the simplest facts, continually broke the symmetry of Mr Smith's lectures.' But when it came to expressing his ideas on maps, Smith's concentration was complete.

In his own autobiographical notes, Smith reveals that he 'wasted much time in poring over maps, in contriving how the ranging edges and planes of the different strata could best be rendered intelligible'; but in the end he concluded that 'the plain and simple method of representing them [strata] by colours was at last determined on ... those which bear the greatest resemblance to the colour of the strata would, of course be preferred.'

But matching the colour to resemble the rock type in every case proved difficult, and in Smith's mind plain blocks of colour had some drawbacks: 'To colour the whole width of any stratum then seemed likely to be unintelligible and unfit for making those corrections which were likely to occur as my judgement became mature and my observations repeated.'

No key

The solution Smith finally hit upon was to show the base of each stratum using a strong band of colour which becomes lighter upwards towards the succeeding formation. This style of colouring was first adopted in Smith's map of 1799, A map of the country five miles around Bath, coloured geologically, which incorporated three colours. Even though Smith omitted to provide a key to link formation names to colours, by all accounts, this method proved to be a very effective way of illustrating the geology.

Smith went on to develop a more elaborate colour scheme – consisting of eight colours, to represent strata ranging from the Devonian through to the Chalk – for his 1801 draft General Map of Strata found in England and Wales – again sans key. Puzzling at first, perhaps; but, explains Professor J W Judd in his 1897 review of Smith's maps: 'by reference to the author's [Smith's] later publications it is not difficult to determine what the several bands of colour are intended to indicate.'

The colours used on the 1801 map, notes Judd, were the same as those used on Smith's later maps, which did have keys, and 'thus', he concludes, 'we have in it the first indication of a scheme of colour now very generally adopted by geologists'.

No need

But for Phillips a map key was probably not essential. Although too young to have had any input into the colouring of Smith's early maps, including Smith's magnum opus, the 1815 Map of the Strata of England and Wales, Phillips may well have discussed map colouring with his uncle for some of the later county maps. As a result, Smith's colouring schemes might have become incorporated into the 'family jargon'. This explains how Phillips, who had been lecturing in Manchester, could write to his sister Anne in July 1832 to tell her that his tongue is: 'generally a little better, sometimes of a dark blue colour which would do for the Limestone on the Maps & a brown which would do for the Millstone Grit' and be sure that she would get the joke!

Acknowledgement
Sources for this vignette include: J W Judd, William Smith's manuscript maps, Geological Magazine (Decade IV), 1897, pp. 439-447; Norman Butcher, The Advent of Colour Printed Geological Maps in Britain, Proceedings of the Royal Institution of Great Britain, vol 55, 1983, pp 149-161, John Phillips, Memoirs of William Smith, LLD, John Murray, 1844; a typescript of William Smith's autobiographical notes housed in the archives at the Oxford University Museum of Natural History; and William Smith's Memoir to the map and delineation of the strata of England and Wales, 1815. I am also grateful to Tom Sharpe of the Lyme Regis Museum Trust for helpful correspondence and references about the colouring of Smith's maps.

***Nina Morgan** is a geologist and science writer based near Oxford. Her latest book, The Geology of Oxford Gravestones, is available via www.gravestonegeology.uk

OBITUARY JANE ANN SIMPSON 1945 - 2016

Geochemist and role model for young women, who wrote persuasively about cancer

Jane Ann Simpson (Professor Jane Plant), who died on 4 March 2016, will be remembered for her significant scientific achievements; as a role model for young women in geology; and her brave, prolonged fight against cancer. Born Jane Ann Lunn, in Woodville, Derbyshire, she was the only child of Ralph and Marjorie (née Langton) Lunn, village shopkeepers. Educated at Ashby Grammar School she went to Liverpool University in 1963, graduating with first class honours in geology and the prize for the best degree in her year.

IGS

Joining the Institute of Geological Sciences (now the British Geological Survey - BGS) she was assigned to the Atomic Energy Division, headed by Stanley Bowie. Recognising her potential, she was entrusted with responsibility for a geochemical reconnaissance programme, beginning in the Scottish Highlands and Islands. Establishing protocols which were later adopted world-wide, teams of university students collected stream sediments during the summer months, with the winter months spent in analysis and interpretation.

Working with collaborators like Janet Watson, she used the data to examine the geological and metallogenic evolution of the British Caledonides, leading to a PhD from Leicester University (1977) and a special merit promotion (1983). As sampling moved southwards the programme broadened, creating a geochemical database, which could be applied to economic, health and environmental issues.

> “JANE WILL BE REMEMBERED FOR HER SIGNIFICANT SCIENTIFIC ACHIEVEMENTS; AS A ROLE MODEL… AND HER BRAVE FIGHT AGAINST CANCER”

CBE

In 1990, she joined the BGS Directorate, heading the newly-formed Minerals, Environment and Geochemical Surveys Division, while continuing her scientific work. Her achievements were recognised by her peers with numerous awards. She was appointed CBE in 1997 for services to Earth sciences, elected President of the Institute of Mining and Metallurgy (2001-02), became a member of the Royal Commission on Environmental Pollution (1999-2005) and a Fellow of the Royal Academy of Engineering (2012).

She retired from the post of BGS Chief Scientist in 2005 and was appointed Anglo-American Professor of Geochemistry at Imperial College. Here she pursued her interests in the links between geochemistry and health with the same passion which had characterised her BGS career. These interests were partly stimulated by her own battle with breast cancer which had first affected her in 1987.

By 1993, she had beaten cancer five times but the prognosis was poor. Struck by the low incidence of breast cancer among Chinese women and the absence of dairy products in their diet, she immediately adopted a mainly vegan regime, forgoing all dairy produce. Her cancer disappeared rapidly and she became convinced of a link between cancer and diet, writing of her experiences in a book *Your Life in your Hands* (2000). Other books followed, but to her disappointment her ideas were never accepted by the medical establishment.

Jane died at home, in Richmond upon Thames from a blood clot following chemotherapy. An early marriage was dissolved, leaving her with the name Plant, which she used professionally. She later married BGS colleague and trusted collaborator, Peter Simpson. She leaves Peter, three children and six grandchildren, an army of friends and a scientific legacy which will remain as a lasting memorial.

By **John Mather**

HELP YOUR OBITUARIST The Society operates a scheme for Fellows to deposit biographical material. The object is to assist obituarists by providing contacts, dates and other information, and thus ensure that Fellows' lives are accorded appropriate and accurate commemoration. Please send your CV and a photograph to Ted Nield at the Society.

CAN'T FIND YOUR MEETING? VISIT WWW.GEOLSOC.ORG.UK/LISTINGS FULL, ACCURATE, UP-TO-DATE

ENDORSED TRAINING/CPD

COURSE	DATE	VENUE AND DETAILS
Geocience Education Academy 2016: Free training for UK teachers Geoscience Education Academy	27-30 July	Field Trip, Lecture, Social Event, Workshop, Course. See website for details. Contact Liz Pedley **E:** elizabeth.pedley@geolsoc.org.uk
Lapworth's Logs	n/a	'Lapworth's Logs' is a series of e-courses involving practical exercises of increasing complexity. Contact: info@lapworthslogs.com. Lapworth's Logs is produced by Michael de Freitas and Andrew Thompson.

DIARY OF MEETINGS JULY 2016

MEETING	DATE	VENUE AND DETAILS
Girls into Geoscience Plymouth University	4 July	Workshop, Field Trip. Venue: Plymouth University, Drake Circus. **Time:** 0930-1530. **E:** girlsintogeoscience@plymouth.ac.uk **T:** (01752) 585975. See website for more information.
UK Onshore Oil and Gas: Planning and Environment Summit Open Forum Events	6 July	**Venue:** Manchester Conference Centre M1 3NJ. Time: 0900-1630. Charges apply. **E:** karl.povey@openforumevents.co.uk. See website for details and registration.
Case studies in Engineering Geology & AGM Engineering Group, 2016 Year of Water	6 July	**Venue:** Burlington House. **Time:** 1730 for 1800. Contact Dave Giles **E:** dave.giles@port.ac.uk.
The Hydrogeology of Peat Hydrogeological Group, British Hydrological Society, 2016 Year of Water	7 July	**Venue:** University of Birmingham. Contact Rob Lowe **E:** rob@rigare.co.uk. See website for details and registration.
Developing Seismology - Teaching Seismology in Schools South West Regional	13 July	**Venue:** Torquay Girls' Grammar School, Devon TQ2 7DY. Evening meeting. **Time:** 1800. Contact **E:** swrg@geolsoc.org.uk
Lab visit: Soil Consultants & tour of Hell Fire Caves Home Counties Regional	15 July	**Venue:** Oil Consultants, High Wycombe HP15 6QT. **Time:** 10.00-17.30. **Leaders:** Stuart Wagstaff, Soil Consultants; John Wong. Admission to caves may incur charge. See website for details. Contact **E:** homecountiesnorthregionalgroup@gmail.com
Maps, Meteorites, Mary Anning & the Missing Link Evening Meeting, Open Day	15 July	**Venue:** Burlington House, GSL Library. Charges and discounts apply. See website for details and registration. Contact **E:** library@geolsoc.org.uk

OBITUARY GEORGE THEOKRITOFF 1924 - 2015

A man of great dignity, admired for his skill as a first-rate scholar and teacher

George Theokritoff, who died on 19 December 2015, was born in London on 7 April 1924, youngest son of Lydia and Vladimir Theokritoff, sometime Deacon at the Chapel of the Imperial Russian Embassy in London. He developed an interest in the natural world and, though his career was in science, music and his Orthodox Christian faith remained major influences.

From Chelsea Polytechnic, he went on to Imperial College, where he was awarded his BSc (Hons) ARCS in 1945. A fieldwork enthusiast, he studied the Irish sector of the Midland Valley structure with a view to a PhD, but lack of funds meant he eventually submitted the work for an MSc (Imperial). That work generated the important features of his geological career (trilobites, faunal realms, stratigraphy and tectonic structures) and led to his first publications.

Cleavage

In 1946, he contributed to a PGA article on The relationship of slaty cleavage and kindred structures to tectonics and, in 1949, read his paper Ordovician rocks near Leenane, Ireland at the Royal Irish Academy (published 1951). Concurrent with such studies, George worked as Demonstrator of Geology at Bedford College (1946-48).

In 1949, he was recruited by Imperial Oil Ltd. for field studies in the Ontario Michigan Basin and on the Pennsylvanian rocks of Maritime Canada. By 1951, he was an independent consultant for various companies with interests in the Basin and part-time lecturer in geology at the University of Western Ontario. Finding the university environment more congenial than industry, he applied his experience to instruction and research.

> “THOUGH HIS CAREER WAS IN SCIENCE, MUSIC AND HIS ORTHODOX CHRISTIAN FAITH REMAINED MAJOR INFLUENCES”

There followed posts as Instructor of Geology in Mount Holyoke College, Massachusetts (1954-56) and Bucknell University, Lewisburg, Pennsylvania (1956-60). During those years, he undertook fieldwork in the Taconic Region of Vermont and New York and, in 1960, with a 20-month leave of absence from Bucknell and grants from the National Foundation and GSA Penrose Bequest, completed his thesis *Stratigraphy and Palaeontology of the "Slate Belt" in the vicinity of Hampton in Washington County, New York* for the University of London PhD.

This study was facilitated by the guidance of Marland Billings, Harry Whittington and James Thompson Jr at Harvard University, where he held ‘special student status’. His summer fieldwork involved important collaboration with eminent colleagues and gave rise to significant publications on the lithostratigraphical, biostratigraphical, trilobitic, graptolitic and structural features of the complex Taconic Region when the Iapetus [Proto-Atlantic] Ocean was proposed.

Champion

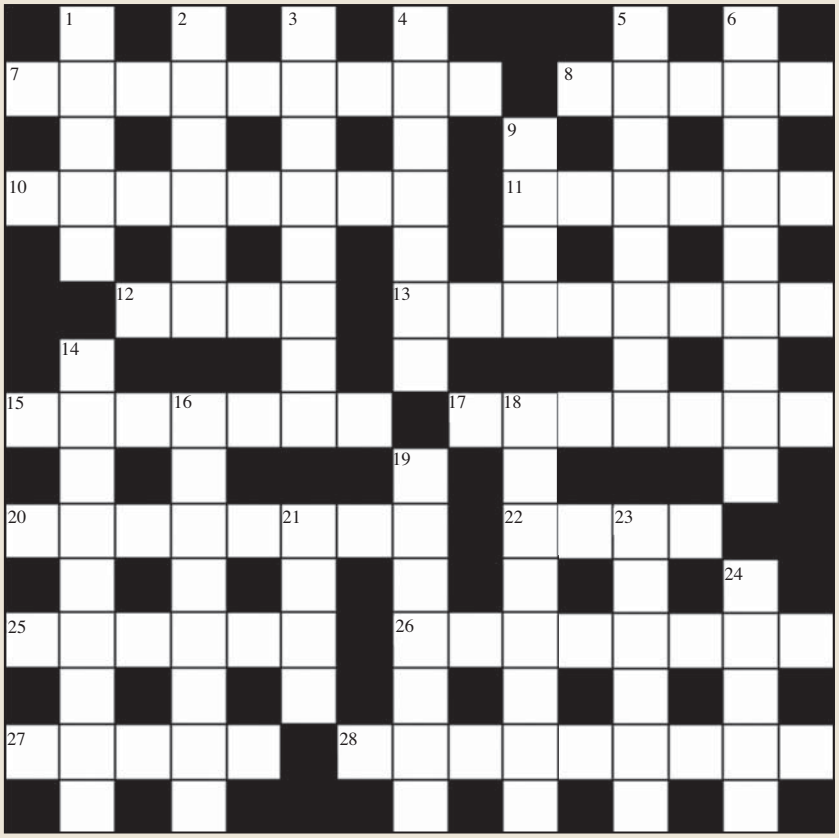
After becoming Assistant Professor in the University of New Hampshire, he had a two-year spell (1962-64) as geologist with the Consumer Gas Co. (Toronto), and as Associate Professor at St. Lawrence University, Canton, NY (1964-67), before beginning at Rutgers - The State University, Newark, NJ, teaching there until 1994. As Professor Emeritus he continued his palaeontological research and published until 2008. In 1990, George married Elizabeth Briere, whom he had met during a sabbatical in London.

An uncompromising champion of academic standards, he was also a popular professor, who was generous with his help and encouragement. Friends and acquaintances from all walks of life remember him warmly both for his fund of interesting stories and for his good humour, courtesy and gentleness.

By **Terence Fletcher & Elizabeth Theokritoff**
A longer version of this obituary may be read online. Editor.

HELP YOUR OBITUARIST The Society operates a scheme for Fellows to deposit biographical material. The object is to assist obituarists by providing contacts, dates and other information, and thus ensure that Fellows' lives are accorded appropriate and accurate commemoration. Please send your CV and a photograph to Ted Nield at the Society.

CROSSWORD NO.204 SET BY PLATYPUS



ACROSS

7 Any granitic rock (9)

8 Plant-derived sticky substance which fossilizes to amber (5)

10 Fundamental unit of cross-stratification (5,3)

11 Glacial period (3,3)

12 NE Arizona native American people (4)

13 Rocky or metallic inter-planetary body (8)

15 French mixture, much found in Anglesey, for example (7)

17 Ice-river (7)

20 Bivalve muscle that closes (8)

22 Youngest Jurassic epoch (4)

25 Abbreviation strictly referring to a road surfacing material bound with an end product of coal distillation (6)

26 Sudden superfluity bringing increase in wealth, good fortune, or profits (8)

27 Large(st) expanses of time, as originally spelt (5)

28 Potassium nitrate (9)

DOWN

1 Small Scottish coastal town where Jurassic coals were formerly mined (5)

2 The cultural and educational arm of the United Nations (6)

3 Squirrelling away - hoarding, colloquially (8)

4 Violent, cold, N-NW wind that funnels through the Rhone and Durance Rivers and towards the Camargue (7)

5 Originally meaning 'thrown up in the air', now used to refer to water, worldly success and shooting stars (8)

6 Concealed behind a deceptively adopted appearance (9)

9 Neglected grade between mud and sand (4)

14 River source, upstream tributary (9)

16 Firm substructure at the ends of a bridge span or dam, upon which the structure rests (8)

18 Yellow iron oxide mineral (8)

19 Shield underlying one of the most oil-rich regions on Earth (7)

21 Parasite and disease vector, often encountered in fieldwork, much burned out with cigarettes (4)

23 Sand lens within a mud (6)

24 Aragonitic/organic opalescent molluscan shell lining (5)

WIN A SPECIAL PUBLICATION!

The winner of the May Crossword puzzle prize draw was Lynda Garfield of Pentyrch.

All correct solutions will be placed in the draw, and the winner's name printed in the September 2016 issue. The Editor's decision is final and no correspondence will be entered into. **Closing date - August 5**.

The competition is open to all Fellows, Candidate Fellows and Friends of the Geological Society who are not current Society employees, officers or trustees. This exclusion does not apply to officers of joint associations, specialist or regional groups.

Please return your completed crossword to Burlington House, marking your envelope "Crossword". Do not enclose any other matter with your solution. Overseas Fellows are encouraged to scan the signed form and email it as a PDF to **ted.nield@geolsoc.org.uk**

Name .....

.....

Membership number .....

Address for correspondence .....

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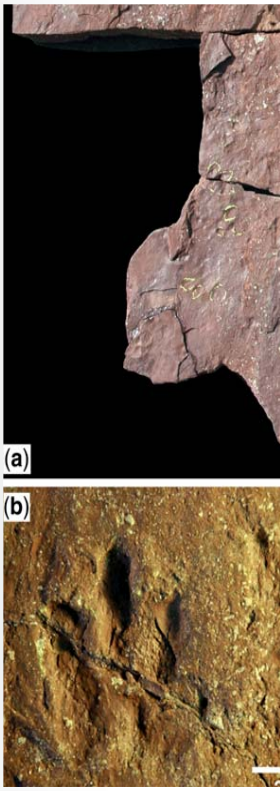
Postcode .....

SOLUTIONS MAY

ACROSS:
7 Ventifact **8** Argon **10** Diopside **11** Anoxia
12 Mere **13** Gypcrete **15** Ellipse **17** Windsor
20 Atropine **22** Ouse **25** Irrupt **26** Ophidian
27 Steps **28** Gibraltar

DOWN:
1 Aegis **2** Steppe **3** Officers **4** Acreage
5 Armoured **6** Foliation **9** Warp **14** Clathrate
16 Isosulph **18** Isochore **19** Aerobic
21 Iota **23** Saddle 24 Basal

The Full Book COLLECTION



Fellowship of the Geological Society of London brings many benefits, including access to content within the Lyell Collection, **writes Jenny Davey, from the Geological Society Publishing House**

As part of GSL membership, fellows receive access to the Book Archive – giving access to book content published up to 31 December 2012. That includes Special Publications and Memoirs, to view Special Publication content visit the Lyell Collection: **http://sp.lyellcollection.org/content/by/year;** and for Memoirs go to: **http://mem.lyellcollection.org/content/by/year.**

Access to this book content is in addition to the journal content fellows choose to receive when taking out membership or renewing.

The Full Book Collection costs £83 per calendar year, **as a special offer fellows can purchase the collection for £41** for access for the rest of 2016. To find out more about adding the Full Book Collection to your Fellowship contact the membership team by email: **membership@geolsoc.org.uk or phone: 0207 434 99 44**

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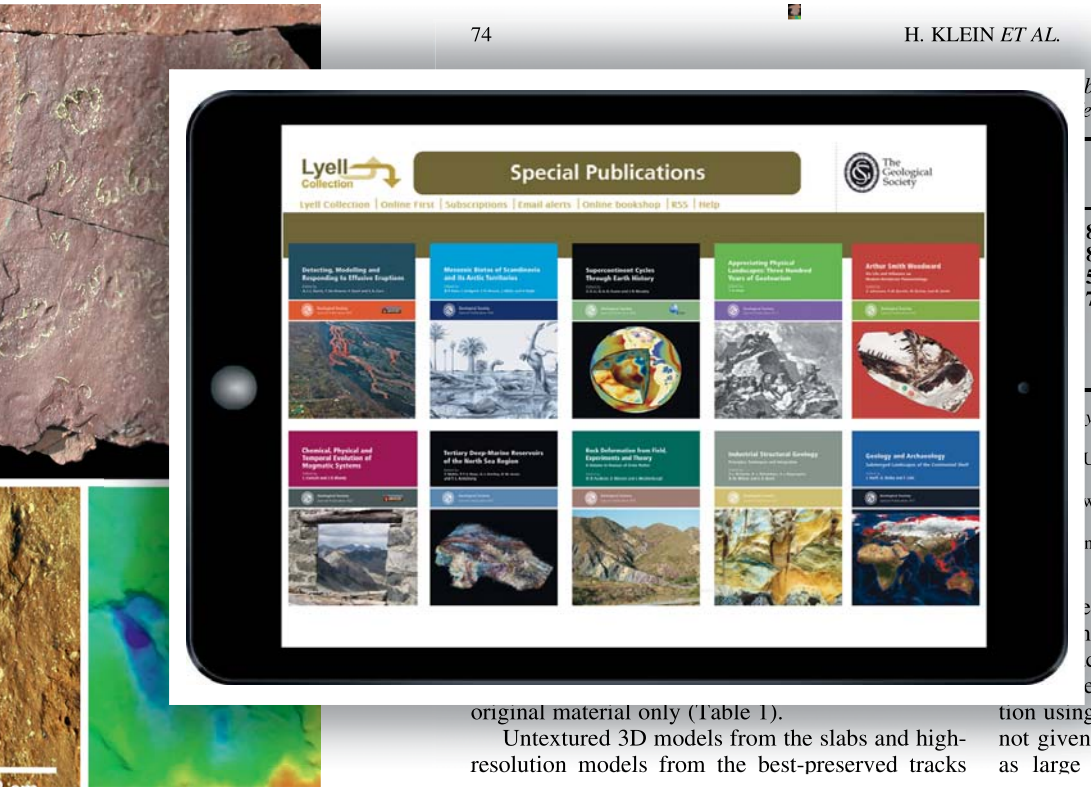

bed in this study compared with selective erent localities

	B. thuringiacum†		*B. parvum*‡
8.0–19.0§	14.0–17.0	13.0	**13.**
8.0–19.0§	14.0–17.0	14.6	–
5.8–9.7	6.0–8.0	5.9	–
7.3–11.0	8.0–9.0	8.2	–
40–55		74	–
–		–	92
–		–	153

ychirotherium type locality and horizon) (from Karl &

USA (from Lucas *et al.* 2010). Notice all imprints being

width (in cm); p I–IV, divarication between pedal digit

nly, except values in bold that include digit V.

edzki *et al.* 2014). Until now, they were fig- hout details or only symbolically on a map ck surface (Jenkins *et al.* 1994; Sulej *et al* etails of their morphology and documenta- tion using close-up photographs and sketches were not given by these authors, and their identification as large chirotheres, therefore, cannot presently

original material only (Table 1).

Untextured 3D models from the slabs and high-resolution models from the best-preserved tracks

What is the Full Book Collection?

The Full Book Collection, for an additional fee gives Fellows access to papers published from 2013 to the present within the GSL Special Publications and Memoirs series. This means fellows who purchase the Full Book Collection can access the most recently published research within the Lyell Collection, as well as *Online First* book content. *Online First* content enables articles to appear online soon after they have been accepted for publication and ahead of the printed volume or issue.

The Full Book Collection enables Fellows who have purchased to:

- Download each chapter or paper as a PDF to print or read later
- Read peer-reviewed content online – particularly useful when travelling or for accessing content 24 hours a day.
- Access over 40 books in a variety of geoscience subject areas.
- View the most popular content in the Lyell Collection
- Keep up-to-date with the most recent research and developments.

Or for details of the content you can access contact the Publishing House by email: **sales@geolsoc.org.uk or call: 01225 445 046.** The full range of fellowship benefits can be found on the website at **www.geolsoc.org.uk/benefits** or to request a brochure contact GSL using the details above.

The Geological Society
serving science & profession

The Geological Society
Career and Industry Days 2016

Wednesday 9 November 2016
Venue: BGS, Keyworth, Nottingham, UK
www.geolsoc.org.uk/careersday16nottingham

Wednesday 23 November 2016
Venue: Our Dynamic Earth, Edinburgh, UK
www.geolsoc.org.uk/careersday16edinburgh

The Geological Society Career and Industry Day is an essential meeting place for geoscience students and the geoscience industry, and is the most recognised geoscience careers focused forum in the country.

The day will include short career/industry presentations throughout the day covering different areas of geology and academia. There will be an exhibition consisting of industry and professional bodies, and higher education institutions promoting MSc and PhD programmes, and there will be a CV and careers workshop running alongside the talks.

Registration

This event is free to attend but there are limited numbers so you will need to pre-register. Please send an email to naomi.newbold@geolsoc.org.uk. A student manual, lunch and drinks reception are included..

Contact Information

Naomi Newbold, Conference Office,
The Geological Society, Burlington House,
Piccadilly, London W1J 0BG
T: 0207 432 0981
E: naomi.newbold@geolsoc.org.uk
Follow these events on Twitter: #GSLcareers16