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School of Earth & Environmental Sciences

Newsletter Number 16

July 2019



Welcome from the Head of School

Dear All

You will no doubt have seen the headlines regarding St Andrews breaking the Oxbridge hegemony to take 2nd place in the league tables for student satisfaction. Digging into the data a bit more deeply, SEES tied with Oxford for 2nd place in the Earth sciences category. Deeply satisfying indeed but, not to put a cloud on the sunshine, we must not lose sight of the fickleness of the league tables. However, from where we started a decade ago to now it is undeniably a measure of my colleagues' dedication and efforts to create and maintain the highest standards in education. It is gratifying to be recognised for such efforts, even within St Andrews as per our very own Paul Savage winning an Excellence in Teaching award this year (clap, clap, clap for Paul!). Of course, in this day and age of having to be evaluated at every step of the way, the big test on the horizon is the upcoming REF2021, the tortuous navel-gazing that UK HE goes through every 5 years to assess research worthiness... watch this space.

The ebb and flow of staff continues...this is not unexpected---when you create one of the most dynamic and youthful Earth and environmental sciences programmes anywhere, staff get cherry picked and we, too, do our share of cherry picking. Jonathan Cloutier, the architect of our MSc in Mineral Resources who left in December, is enjoying his new life at the University of Tasmania. Nick Gardiner, an expert in tin mineralisation and the application of hafnium isotopes and U-Pb dating who has spent the past several years doing postdocs in Perth (the Australian one) and Melbourne, is replacing Jonathan. Nick will hit-the-ground running in September and we look forward to his complementing and enhancing the hard-rock portion of SEES. The volatile portion of our hard-rock-ers has also received a boost in that Will Hutchinson, currently a postdoctoral Fellow in SEES, has won a prestigious NERC Fellowship to evaluate volcanic processes and climate. These Fellowships are as rare as hen's teeth and we are very proud of Will's achievement. As I mentioned previously, Michael Byrne (formerly of that other 2nd-place programme, Oxford) and his family will also become part of the SEES clan in September. Michael is recognised as one of the finest young climate modellers around. Thus, SEES' expertise spanning from evaluating natural resources, to interrogating key events in Earth history, to investigating geodynamic processes, to addressing the issues of climate change, is truly solidifying into the finest pound-for-pound geoscience programme to be found anywhere.

Best wishes to all and to all a pleasant summer.

A handwritten signature in blue ink that reads "Tony". The signature is written in a cursive style with a long horizontal stroke at the top that extends to the left and then curves down to form the letter 'T'. The name 'Tony' is written below the 'T'.

PS.
Promotions
It is with enormous pleasure and deep satisfaction that we congratulate *Claire Cousins, James Rae, Will McCarthy* and *Rob Wilson* on being promoted in July. Claire and Will become Senior Lecturers, James becomes Reader and Rob becomes Professor Wilson. Well done to them all. This is a testament to the quality of work they have achieved and continue achieving

.STAFF NEWS

Paul Savage was awarded one of the University's four Teaching Excellence Awards for the academic session 2018-19. Congratulations and well-deserved.

Neil McGlashan (BSc 2002) is back with us at St Andrews. He has joined us to work on the ERC Lost Frontiers Project, and also to help out in the STAiG isotope labs.

Elyse Allender was selected as one of only six Early Career Science Ambassadors for the European Association of Geochemistry.

Nick Gardiner has completed all the paperwork to take up his academic post with SEES. We all look forward to seeing Nick here later this summer so a hearty welcome. He is the replacement for **Jonathan Cloutier** who has moved to Tasmania.

Will Hutchison has been awarded a NERC Fellowship with **Andrea Burke** and **James Rae** to assess volcanism's impact on influencing climate change using S isotopes from modern volcanic ashes.

In early May, Workforce Planning Group agreed to make **Tommaso Di Rocco's** Research Officer position permanent and move him to a standard contract.



Thomas

Two new postdocs, **Cristina Castillo** and **Thomas Lamont** recently joined SEES. **Thomas** is from Liverpool and will be working with **Dick White**. Tom completed his PhD at Oxford University at the end of last year and investigated the metamorphic evolution of the Cycladic Islands in Southern Greece. He's interested in the processes associated with mountain building, particularly the formation and emplacement of ophiolites, high pressure metamorphism and the formation of metamorphic core complexes.



Cristina

Cristina is from Mexico and will be working with **Nicky Allison**. Cristina recently handed in her PhD thesis from Geosciences Environment in Toulouse. Her project was about experimental determination of Ni isotope fractionation during adsorption and co-precipitation on/with calcite to assess its application as a proxy of the precipitation rate of calcite. Here at SEES Cristina will work on calcite precipitation to determine how the calcification environment affects its trace element and isotopic composition, and the effects of biomolecules on proxy relationships.

Claire Cousins, collaborating with colleagues at the Natural History Museum, was awarded a 3-year UK Space Agency grant through the Aurora programme to study “Geochemistry to Geology for ExoMars 2020: visible to near infrared spectral variability”.

Congratulations to *Eva Stueeken* and *Sami Mikhail* who obtained a UK Space Agency grant in May, which will support a co-supervised 3.5 year PhD studentship. The project will determine the nature of magmatic carbon on Mars and their collaborators include Edinburgh University, Carnegie Institute in Washington DC and the Open University.

New staff member *Helen Innes* writes ‘I am from Aberdeen and completed my BSc (Hons) Geology and Petroleum Geology at the University of Aberdeen in 2016. I continued on to St Andrews University where I graduated with an MSc in Geochemistry from SEES in 2018, completing a research project focusing on the use of tephrochronology for creating Quaternary age-depth models. This led to my current employment in SEES as a lab assistant, working for *Andrea Burke* and *James Rae* doing isotopic analysis of volcanic sulphur in ice cores.’



Helen

We welcome our new Front of House Secretary *Janet Delalonde*.

In June, *Claire Cousins* was awarded a grant from the Carnegie Trust to help fund her work on “Terrestrial hydrothermal environments as a window to prebiotic worlds.”

RESEARCH NEWS

In May, the School hosted a FRESH Symposium on the theme “The Evolution of Earth’s Atmosphere”. FRESH stands for Frontline RESearch at St Andrews. Four keynote speakers began each of the four sessions: Professor James Farquhar (University of Maryland), Dr Ben Mills (University of Leeds), Dr Lydia Hallis (University of Glasgow) and Professor Heather Stoll (ETH, Zurich). Eight members of SEES each gave a talk on their speciality.



Sami Mikhail presenting his lecture

Chris Junium from the University of Syracuse is visiting SEES until the end of July, supported by the St Andrews Global Fellowship scheme. Chris is a sedimentary and organic geochemist. He is involved with preparation and instrumentation for compound-specific carbon, nitrogen and sulphur isotope analyses.

POSTGRADUATE NEWS

Anouk Borst was successful in obtaining Global Challenges Research Funding. Anouk, along with *Adrian Finch*, *Antonia Santos* and *Geraldine Tchimbali* (our 2 Angolan undergrads) and colleagues Pete Siegfried (Namibia) and Aurora Bambi (Universidade Agostinho Neto de Luanda) will study the critical metal resource potential of alkaline-carbonatite complexes in Southern Angola. This work is also aimed at creating a partnership between St Andrews and the Universidade Agostinho Neto de Luanda and establishing a research programme to investigate associated

and economically relevant mineral deposits in Brazil and Namibia that have received very little attention to date.

Annual Research Postgraduate Conference 2019

The following list of our post-graduate students who presented aspects of their research in May shows the vibrancy and range of research activity in the School.

Simon Jones - Basin-scale fluid flow and alteration associated with the White Pine Cu-Ag deposit, Michigan, USA

Vincent Twomey - The use of rock magnetism and palaeomagnetism to unravel shallow-level magma emplacement dynamics and associated host rock deformation; Case studies from SE Iceland

James Edwards - The structural and isotopic relationships between the Etive Pluton, smaller intrusions and mineralisation at Cononish.

Oliver Dixon - Quantifiably assessing the alteration associated with porphyry copper deposits

Krzysztof Sokol - Fenitisation associated with alkaline-silicate complexes. Implications for HFSE mobility in late-stage fluids, Gardar Rift, SW Greenland

Toby Boocock - The evolution of the Earth's atmosphere as recorded by the continental crust

Filippo Formoso - The speciation of nitrogen in silicate melts

Oliver Herbort - The formation and evolution of terrestrial exoplanet atmospheres and the stability of water

Jianxun Shen - Microbial N cycling in the Atacama Desert as a Mars analogue

Arola Moreras Marti - Characterisation of two Icelandic Mars-relevant geothermal systems, and study of $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ potential biosignatures

Natalya Zavina-James - Cu isotope evidence for aerobic methanotrophy in the Late Archaean
Bethan Gregory - Photochemical modelling of atmospheric oxygen levels reveals three stable states

Paul Ross - Dendroclimatology of Scots pine *Pinus sylvestris* in Scotland: An ecological approach to methodological advances.

Laura Crick - Evolution of sulphur isotopes across volcanic eruptions

Molly Trudgill - An optimized batch method for the measurement of $\delta^{11}\text{B}$ in complex matrices

Eloise Littley - What is the role of the North Atlantic Ocean in rapid climate change?

Sarah Boyd - The application of an eroding coastal heritage site dataset to test models of coastal erosion susceptibility and historic coastal change

Molly Trudgill passed her PhD candidacy exam in late-May. She'll spend the next few years marching through Earth History characterising ocean acidification based on Boron isotopes, one anoxic event at a time, starting with the Triassic-Jurassic extinction.

Heartiest congratulations to **Toby Boocock**, who passed his PhD candidacy exam in June. He will be spending the next three years attempting to unravel records of surface nitrogen cycling from the continental crust.



UNDERGRADUATE NEWS

Charlotte Barlow won 2nd prize in the Alex Richardson Award. What is remarkable about this is that the AR Award is given by the Spanish Dept to students whose research elevates some aspect of Spain and /or Spanish culture. Charlotte made an outstanding case that her dissertation work on the atmospheric CO₂ content preserved in air bubbles encased in Messinian evaporites along Spain's southeast coast will elevate and inform on Spain's natural heritage. Talk about thinking outside the box!



Charlotte

Mining Institute of Scotland

St Andrews entrants: **Rory Changleng** 3rd year MGeol (honorable mention), **Lot Koopmans** 3rd year BSc Geology (2nd place) and **Abigail Robinson** 4th year MGeol (1st place in Scotland) progressed to the UK finals competition in London in early May to represent Scotland at the UK final in the 2019 Mining Institute of Scotland's Young Person's Lecture Competition.



Joining finalists from Heriot-Watt, Glasgow, and ScotGold Plc., Lot Koopmans (first on left), Rory Changleng (third from left), and Abigail Robinson (second from right)

Evening Degree in Geology

The ES1901 module has had another successful year with 13 students enrolled on the course, coordinated by alumna *Rosalind Garton* (BSc 1978). The photo below shows the group on their field trip to St. Monans at the end of April.



Evening Degree students on their field trip at St Monans



The end of term BBQ in May, in St Mary's garden, organised by the student Geological Society



Graduating class of 2019, with a few staff in attendance

ALUMNUS NEWS

On 12 March, six representatives of the Geological Society headed down to the House of Commons in Westminster to quiz MPs on topics relating to science and policy for “Voice of the Future 2019.” Two of those reps were St Andrews geology alumni, **Catherine Mottram** (BSc 2010) and **Megan O’Donnell** (BSc 2014). Megan, Policy and Outreach Intern at the Geological Society, asked the Science and Technology Committee about the Immigration White Paper. Catherine raised the issue of Rare Earth metals and their role in decarbonisation.

<https://blog.geolsoc.org.uk/2019/04/01/young-scientists-represent-the-geological-society-at-houses-of-parliament/>

Dr Jessica Barnes (BSc 2011) is currently at NASA’s Johnson Space Center and in the autumn of 2019 will take up an assistant professorship at the University of Arizona.

The good news is that Jess has been selected to lead one of nine teams to continue the science legacy of the Apollo missions by studying pieces of the Moon that have been carefully stored and untouched for nearly 50 years. Jess’ team will study how curation affects the amount of hydrogen-bearing minerals in lunar soil, which will help us better understand how water is locked in minerals on the Moon.

Dr Richard Wakefield (BSc 2000 Environmental Geoscience) has just finished his six years leading the consenting work on the Kincardine Floating offshore wind farm, 20km south east of Aberdeen, which had its first turbine installed in late 2018. This will be the world’s largest floating offshore wind farm when completed next year (50Mw). This

has led to a move to Flotation Energy plc which will look to develop the next round of floating offshore wind over the next 10 years.

He is also currently the vice-chair of the board of trustees for the Institute of Marine Engineering, Science and Technology (IMarEST) and in this role supports the MASTS (Marine Alliance for Science and Technology Scotland) programme led by Prof David Patterson, St Andrews University.

Dave Cook (BSc 1972, PhD 1976) joined Esso Exploration and Production UK Ltd (ExxonMobil) as an exploration and production geologist in 1976 after conducting a PhD research project in the Southern Uplands of Scotland. After 31 years of employment in a variety of technical, supervisory and managerial roles in the UK, USA and Indonesia with ExxonMobil, he retired. Since retiring, he has been undertaking voluntary work for the American Association of Petroleum Geologists (AAPG), is currently Vice President Regions and lives in Houston, Texas.

Douglas Carroll (BSc 1959) sent us his biography and the accompanying photograph. "Our small Honours year (5) got to know the staff really well: Bill Harry, Roy MacGregor, Roland Goldring, Tony Weir and Bob Johnston. Prof. Davidson advised us to the importance of producing a readable report and also of learning language skills. [ED: *Prof. Davidson was a fluent Russian speaker*]. We ran a sweepstake on how many times the word "Witwatersrand" would be mentioned in a term's lectures [ED: *Davidson had worked on gold placer deposits in South Africa*]. A highlight of the academic year was the annual Geological Society dinner, a very convivial evening with witty speeches from students, staff and invited guests. I hope this continues. Most of all I enjoyed fieldwork, both locally and elsewhere. I was pleased to see myself in a photo of the group on a very rainy summit on Raasay, where we danced a reel or two. [ED: *the photo is in the Miscellanea section of the History of Geology book.*]

After graduating, I held a Colonial Office Research Studentship in Soil Science at Oxford University and at the Regional Research Centre of the University College of the West Indies, Trinidad. I was then appointed to the overseas



Geology class in a Cornwall quarry, March 1958. Prof Davidson, (2nd left, seated), Fred Hubbard (3rd right, seated), Douglas Carroll, 2nd right, seated)

pool of Soil Surveyors and carried out soil and land use surveys in St. Kitts, Barbados, Lesotho and north-east Nigeria. Returning to the UK, I worked with the Soil Survey of England and Wales based in Yorkshire. My final job before retirement was with the Commonwealth Soils Bureau where I edited the abstract journals '*Soils and Fertilizers*' and '*Irrigation and Drainage*'.

My publications, apart from numerous soil and land use survey reports, embraced mineralogy of some Caribbean volcanic soils, road-making materials in the Caribbean, air photo interpretation and remote sensing for soil mapping, the organic soils of England and Wales, soils associated with Carboniferous limestone and palaeosol features in soils from northern England."

[ED. In the photograph is Fred Hubbard, a St Andrews alumnus, who became an academic in Dundee.]

George Lees (BSc 1983) writes "I did Geology at St Andrews before moving to Manchester University for a PhD in palaeontology / sedimentology. I had a superb time at St Andrews and loved the course we did there, especially the strong fieldwork component. I now work in marine conservation for Scottish Natural Heritage."

James Mortimer (BSc 2011) writes "I followed a long line of St Andrews graduates to The Open University where I completed a PhD in lunar geochemistry in 2015. For my PhD research, I focussed on identifying the abundances and likely sources of volatile elements (C, N, He, Ne, Ar) in a range of different Apollo lunar basalts and soils.

In 2016, I became involved with a European Space Agency project called PROSPECT, which aimed to send a 1.2 m sample drill and miniaturised geochemical gas analysis laboratory (the size of a shoebox) to the surface of the Moon to search for water ice and other volatile species in cold regions near the lunar south pole. As part of that work, I spent 6 months working at the Université Claude Bernard, in Lyon, France where I investigated the isotopic fractionation behaviour of water ice when it undergoes sublimation at cold temperatures in a vacuum. I then moved back to

The Open University where I was employed to characterise carbonaceous chondrite meteorite standard materials for use in verifying the performance of the PROSPECT geochemical lab instrument during the development phases. I am currently working on redefining the PROSPECT mission requirements for volatile preservation, using laboratory experiments to determine what is a safe temperature to hold a lunar soil sample at, and for how long, before it loses too much water ice to be measured by our on-board mass spectrometers, or before it becomes so fractionated and altered that we cannot tell anything meaningful about its likely Solar System source(s).

Since Spring 2017, I have also been working on another ESA-funded project in the context of a future sample return mission to Phobos, a moon of Mars, looking at how spacecraft thruster exhaust gases might cause contamination of the area directly under a landing spacecraft, and at how long it might take for any such exhaust gas contamination to degas.

All of my studies and work since leaving St Andrews have been heavily lab-based, so I enjoy escaping and doing some fieldwork whenever I can find time, particularly around the Fife coastline where I did my undergraduate dissertation studying the *Arthropleura* trackway fossils in the Carboniferous sandstones at Crail and Kingsbarns."

James visited SEES in April to give a talk about his work on Lunar rocks and how his career developed since leaving St Andrews. He also had on display a selection of Lunar rocks and soils.



James in action



A selection of Lunar rocks and soils set in resin

Andrew Gize (BSc 1976)



Andrew (right) reconnoitring fumaroles on White Island, New Zealand, in 2017 with his son Stefan

Apart from becoming an academic at the University of Manchester, his other interest was fencing.

“I was Captain of fencing at St. Andrews 1974-5, and continued coaching and competing, wherever I lived. Recently I fenced in Wrexham (Wales). For one competition the Irish team were missing a sabre squad, and so I was transferred from Wales to Ireland, as one of the “Wirish sabreurs.”

Mark Stacey (MGeol 2014) and his team (NGN, SWECO and Geo2) have recently been awarded the prestigious 2019 Ground Engineering Award for Sustainability. The award was presented for an innovative, solar powered, heavy oil remediation system installed on the site of a former gas-works in the North East of England. The work will be presented at the upcoming Geological Society Contaminated Land Group Conference.



Mark on the right

Liam Anton (BSc 1988) took up employment mudlogging for Exlog after graduation. He worked in various places and various rigs around the North Sea, Holland, Norway and Texas, where he spent some time in Houston and the Texas hill country. Latterly he became regional technical support lead for Norway area, working from home in Inverness. In 2000, he decided on a career change and took up roles with a couple of small internet start-ups that didn’t come to much. He then moved to the “Costa del Clyde” in 2001 to work for a major global Investment Bank, supporting computer systems. Despite the occasional siren call of the Highlands, he doesn’t see himself moving back. In his spare time he throws bits of feather and fur at wild brown trout, in a mostly fruitless attempt to fool them into believing it’s edible. He still enjoys days in the hills and maintains

an amateur interest in Geology. He is father to teenage twins.



Liam with friend

Keith Eastwood (PhD 1977)



“I graduated in geology from Newcastle University in 1970 and then worked for two years on a deep South African gold mine where the 3D exposure of 2.5 billion years old stratigraphy and structure was exceptional. This led to an interest in clastic sedimentology and I arrived in St. Andrews in the autumn of 1972 with the intention of studying the local Carboniferous succession for evidence of tidal deposits. In preparation for this it was deemed

sensible to look at some present-day tidal deposits in the nearby Eden estuary. And there I stayed for the next three years researching the shape, structure and migration of intertidal zone bedforms. I never did get to work on the Carboniferous of East Fife.

However, this study of modern sediments and a St. Andrews connection did get me a job with Shell International as a production/reservoir geologist. I worked on multiple assignments in the Netherlands, UK and Oman for 28 years. Ten years as a technical professional in petrophysics and production/reservoir geology was followed by management positions in petroleum engineering, upstream natural gas/LNG project development, reservoir characterisation research and global production technology deployment.

There was life after Shell and I had an interesting and rewarding twelve more years in the industry as an adviser on upstream oil and gas matters to a variety of organisations including a technology management consultancy, a corporate finance house and finally an American firm of research associates that analysed and offered insights into trends in global oil and gas production. My petroleum geoscience career concluded with the evaluation of unconventional resource (shale gas and coalbed methane) production potential in Australia, China, India, Indonesia and South America.

Shortly after retiring I embarked on a distance-learning Postgraduate Diploma in The Geology of Yorkshire and Northern England run by the Centre for Lifelong Learning at York University. The opportunity to catch up on current thinking about the origins of this region was too good to miss and brought me full circle, back to my roots both personal and geological, after being away for nearly 50 years.”



OUTREACH

In March, SEES hosted a visit from the Principal, Sally Mapstone. In attendance was *Ian Duncan* (BSc 1994), now Lord Duncan, who sits in the House of Lords. He talked about the lack of science expertise in the House of Commons, though the House of Lords has more STEM representation.

In late-May, *Jennifer Brooke* and *Tony Prave* attended the inaugural meeting of the Scottish Geology Trust, a new Scottish charity devoted to representing and funding geodiversity in Scotland. SEES, GeoBus and geoHeritage Fife are stakeholders in this project.

In early June, *Richard Batchelor* attended a meeting of the Scottish Geodiversity Forum at The Lyell Centre in Edinburgh, which met to discuss updating the existing Scottish Geodiversity Charter to which SEES, GeoBus and geoHeritage Fife are signatories. Other signatories include Hunterian Museum (Glasgow), James Hutton Institute, BGS, Transport Scotland, Arran Geopark, Tayside Geodiversity, Mr Wood's Fossils and Glasgow Council. While there Richard met up with alumnus *Martin Gillespie* (PhD 1989) who works for BGS.



Chair of Scottish Geodiversity Forum (Angus Miller) is seated 2nd from left; Richard is seated second from right.

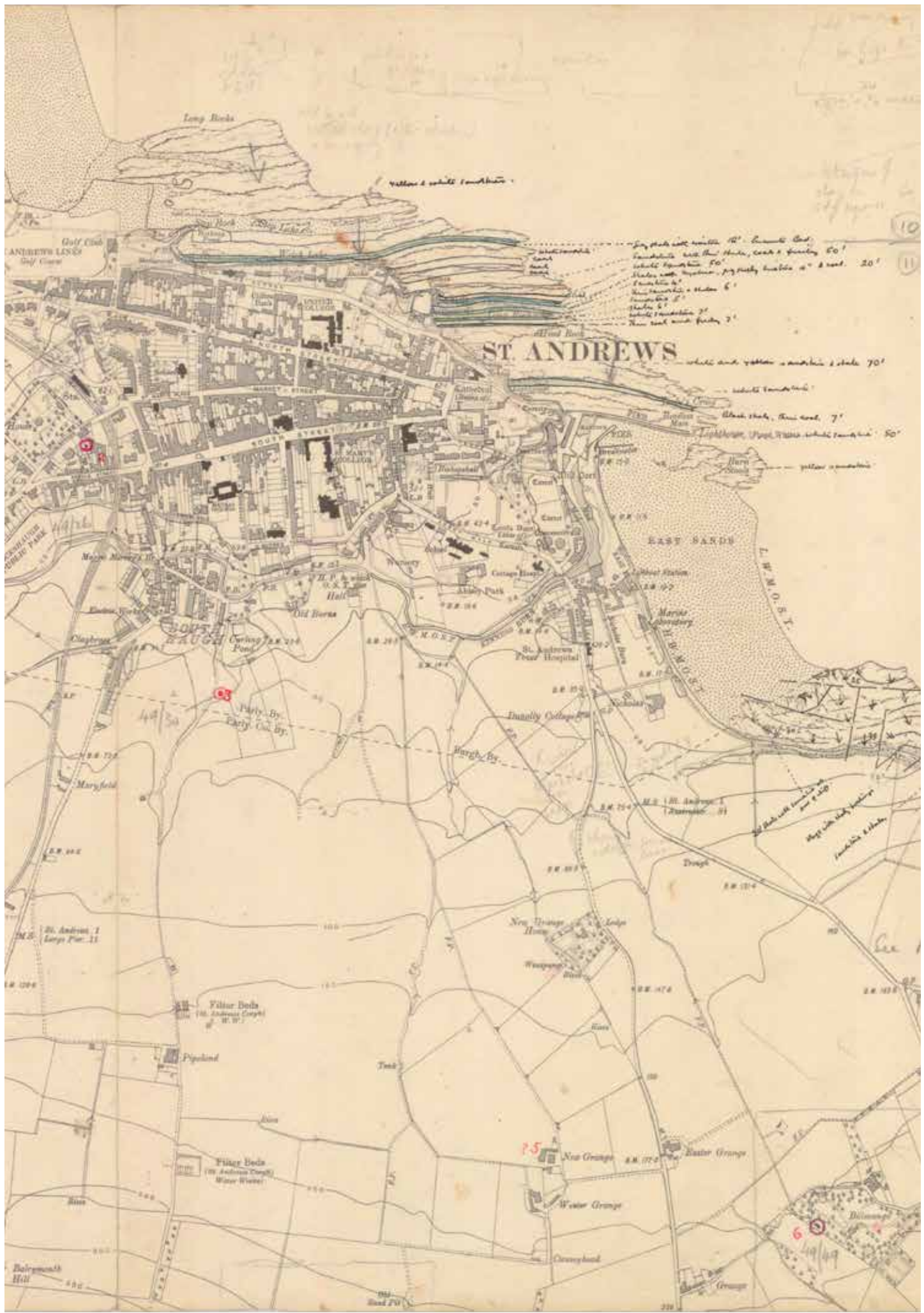


Estonian geologists visit Scotland



Mapping in Ullapool (Tony Prave on the left, Catherine Rose 3rd right at the rear)

At the beginning of May, **Tony Prave**, **Catherine Rose** and **Batzi Fischer** led a group from the University of Tartu in Estonia (six MSc and PhD students and two professors) on a trip to see the geology of Scotland in 11 days. Based initially in Anstruther, they visited the Rock and Spindle and the surrounding sedimentary rocks of the Midland Valley, before leaving Fife for their tour. They visited the Highland Boundary Fault and then crossed into the Caledonian orogen to see the classic metamorphic rock sequences of the Barrovian and Buchan zones in Aberdeenshire. This was followed by several days in the NW Highlands: the Lewisian gneisses around Scourie, the Stoer group sediments of the Torridonian Supergroup (including the impactite at Stac Fada) at Clachtoll, and the Cambro-Ordovician sedimentary sequence and its disruption as part of the Moine thrust at Loch Eriboll. After being familiarised with the NW Highland geology, the students spent a couple of days independently mapping the Moine Thrust imbrication in Ullapool. On the drive back to St Andrews, the Moine rocks at Corrieshalloch Gorge and the obligatory stop at a whisky distillery rounded off the Scottish experience. We hope to see them again sometime!



Long Rocks

Yellow & white sandstone

ST. ANDREWS

Grey shale with small 10' sandstone bed
Sandstone with thin shale, coarse & fairly 50'
shale thickness 50'
Shale with impure, pyritous limestone 20' & red 20'
Sandstone 4'
Thin sandstone - shale 6'
Sandstone 5'
Shale 6'
shale sandstone 2'
Thin sand with fossils 2'

white and yellow sandstone & shale 70'

Black shale, thin bed 7'

Limestone, fossiliferous, white sandstone 50'

yellow sandstone

EAST SANDS

ST. ANDREW'S TOWN

63

P-5

6

10
11

Golf Club
ANDREW'S LINKS
Golf Course

CONRADING
PUBLIC PARK

St. Andrew's 1
Large Pier 11

Fisher Docks
(St. Andrew's Docks)
W. W.

Fisher Docks
(St. Andrew's Docks)
Water Works

Balgownie
Hill

Sea Level

20



Irvine Building

USEFUL LINKS

<http://earthsci.st-andrews.ac.uk>

<https://www.facebook.com/standrewsgeologyalumni>

<http://soi.st-andrews.ac.uk>

<http://www.geobus.org.uk>

<https://www.st-andrews.ac.uk/development/alumni>

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We are always interested to receive news from our alumni which we are pleased to publish in the Newsletter and the SEES website. Contact the editor: Richard Batchelor (rab@st-andrews.ac.uk)

Front Cover photo: Students on Eilean nan Cholmain, Isle of Mull, Scotland (Adrian Finch)

Previous page image: Field slip of St. Andrews. Revised by F.W. Anderson, 1938, reprinted from 1921 version. Reproduced by permission of the British Geological Survey. EA17/096