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Geoscience Society
of
New Zealand

GEOSCIENCE SOCIETY OF NEW ZEALAND
A member body of the Royal Society of New Zealand
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FEATURE ARTICLES

GEOSCIENCE QUIZ

"Working in geology, there is no danger of an awe deficit!". Carolyn Boulton, February 2021 ▶

James Scott
President

Worldwide there is a worrying trend of decreasing student enrolment in Earth science classes at University. This trend has now reached New Zealand. What is surprising is that this is in a time that Geology is at the front in science. Geologists contribute (and lead) the understanding of climate change, volcanoes, earthquakes and associated hazards, amongst other things. These three topics feature widely and commonly in the news media (and Marsden successes) – and yet fewer high school students are seeing Earth science as an encouraging career pathway than in the recent past. Why? There are probably many factors that influence this decision. One may be that Earth science at high school (usually by the acronym ESS for Earth and Space Science) has a perception that it is an inferior science to the big three – maths, chemistry and physics. But we know that Earth science unites these aspects. Another is the perception that geology = mining and extraction = devastation. Bet we also know that society we live in relies on the use of extractable resources and that it will be Earth scientists that will lead the transition to alternative energies.

But what strikes me is that many of stories being presented to the public are negative. Earthquakes, volcanoes and climate change are all fundamental issues and need to be addressed – but they are commonly presented in in the reference frames of: another suite of deaths, ice sheets are melting and sea level is rising, expect the big Earthquake soon. Do the positive messages balance out these perspectives? How about we—the people actually in the know—tell good stories and lots of them? How impressive is it that it is Earth science researchers that are guiding exploration of other planets. Did you know that the Mars rovers are basically robot geologists? When we eventually arrive on Mars, it will be the Earth scientists that will assess the resources available to build habitation. Our 2020 conference generated many interesting new discoveries that can be cast in positive lights. I recommend that you—the people who can know the truth—start to use your media contacts to help promote interesting aspects of your work to the public because we must halt the increasing disinterest in Earth science.■

Janis Russell
Editor

It is a great pleasure to present this issue of the Newsletter for 2021 as the new editor. There are always challenges in any new role and this has been no exception. However, I am grateful for the tremendous support, and patience, from the committee and the outgoing editor, Glenn Vallender. You can find his letter on page xxxx

I feel privileged to become the first woman editor of the newsletter. The role invites both creative freedom and responsibility for maintaining professional standards. That responsibility includes both the design and content of this newsletter.

You'll notice that the design has changed, yet again. My hope is that the new format will improve the navigation and readability for readers as well as increase flexibility for future issues. In terms of content, I can primarily only collate and format what is provided. However, there is scope to introduce material that stretches the general appeal, and diversity, of the content while retaining the professional tone of the publication.

People form the heart of any organisation. We are fortunate enough to have enthusiastic leadership, a collaborative committee and a supportive and adaptable readership. Therefore, my first goal for this is publication is to create a regular feature article (or articles), centred around a theme, and some that highlight geoscientist(s) as people rather than just a descriptive account of their work. Their output, in all its technical glory, can often be accessed elsewhere.

Two main events have shaped the theme for this issue's feature articles (p64). Firstly, as I write, February 11th is the International Day for Women and Girls in Science. On the desk in front of me sits a book—The Role of Women in the History of Geology (Cynthia Burek and Betty Higgs eds.)— that presents sobering reading about the inequaity in social context for women geologists of yesteryear. Today's young, women geoscientists will be relieved to know that, at least, they no longer have to give up their careers/posts once they get married!

Secondly, as a resident of Christchurch, the 10th anniversary of the earthquake on 22nd February looms large and presents an equally sobering reminder of the disruptive power of geological forces on our lives. Awareness is the first step to understanding and there is no doubt that our nation's population is now acutely aware of the impact these events can have on our wellbeing as well as our infrastructure.

In light of these two themes, this issue's feature throws a spotlight on the experiences of two esteemed women at different stages of their careers. I was lucky enough to hear one of own pioneering geoscientists, Margaret Bradshaw, speak about her experiences in Antarctica, at the GSNZ conference in November, last year. Complementing Margaret's article, there is an interview with Carolyn Boulton who shares some experiences and thoughts as an Early Career Researcher and as the recipient of two international awards (highlighted in the previous issue). With Carolyn, both themes intersect as the thrust of her work lies in understanding more about the processes involved in earthquake generation. ■

Mt.Titiroa, Fiordland. Photo credit Janis Russell

James Scott
President

Birthplace: Ōtepoti/Dunedin

What is your first memory of being interested in an aspect of geoscience?

As a primary school student, I had a rock collection that I kept in a box under my bed. I have no idea what I thought was interesting back then though! I've always enjoyed tramping in the Southern Alps, and so that definitely shaped my interest in landscapes and mountains and I suppose counts as geoscience.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

I'd like to spend it with one of my international collaborators. I enjoy talking about geology with them and – right now, given the state of the world – I think an in-person evening with one of them would be really rewarding. However, I'd like the evening to be somewhere deep in the Southern Alps, sitting around a campfire, beside a river, with a clear star-lit night sky overhead.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

It's hard to say exactly what I've specialized in...Perhaps I'd say I was a high-temperature geochemist, but then I also study sedimentological processes and forensic work on Pacific pottery. Anyway, as an undergraduate, I thought that I'd like to study glacial processes preserved in the geological record - but I got distracted by Fiordland geology.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

I would keep a xenolith of mantle peridotite from under the Southern Alps of New Zealand. These rocks provide information about the geology of the base of Zealandia from a depth that we will never ever be able to sample. They are rare, some are billions of years old, and they're also commonly a beautiful, strikingly green colour. A close second is a Martian meteorite. The first time I held one – actually the type sample of Nahklite - you could probably have heard my heart pounding from the excitement of holding a piece of another planet. ■

MEET THE COMMITTEE

Janis Russell
Newsletter Editor

Birthplace: Glasgow, Scotland

What is your first memory of being interested in an aspect of geoscience?

The first time I visited Takapuna Beach, in Auckland where I grew up, and spotted Rangitoto out in the Hauraki Gulf. It was an intriguing shape, and I wondered how it got to be that way, but it was years before I actively looked for answers.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

It is difficult to choose only one but for me it would be Alexander von Humboldt. His synthetic and multidisciplinary approach to science gels with my own— a generalist who sees a multitude of interconnections. He travelled the world extensively and would have had great stories to tell about what he encountered there. It is the sharing of these kinds of science stories that I find most fascinating and the reason I chose to become a science communicator.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

My university study period was a prolonged and discontinuous one which I fitted in around the demands of family, work, volunteering and sport. However, it gave me a chance to re-evaluate my choice of major frequently—some changes were forced upon me but others were more deliberate. I was keen on igneous geomorphology which I guess has its roots in those early childhood experiences wondering about Rangitoto. My current geoscience interests lie with plutonic rocks, reflecting my desire to understand the often-hidden aspects of things. I think I could easily have been persuaded to follow this as a career path except that my love of language and story telling within science communication seemed like a better fit for my generalist persuasion. Still, the grippy granites and gabbros are great to climb on and are important components of the landscapes where I feel most at home, in Scotland and here in Aotearoa.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

Again, this is a difficult choice. Who set these questions?! It would be hard for me to go past the Lewisian Gneiss that is three billion years old. While my ancestral heritage runs deep into the past on the Isle of Lewis in Scotland is doesn't quite go that far back! It feels like such a privilege to lay your hands on such an ancient part of the Earth and try to imagine how long ago that really was. ■

Jennifer Eccles

Immediate Past President

Birthplace: Tāmaki-makau-rau/Auckland

What is your first memory of being interested in an aspect of geoscience?

Although I'm sure watching documentaries had been going on for a while it probably wasn't until early high school when I started deliberately choosing projects with a geoscience slant – I remember mucking around with plaster simulating fossils etc.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Alfred Wegener so I could let him know he was vindicated in the end!

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

I actually started off my BSc as a Chemistry major so Geochemistry may have been more obvious pathway than my eventual Geophysics but at the time the Geology and Chemistry timetables weren't compatible past 1st year.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

While I do love my window sill collection I'd probably hang onto a boulder opal my parents bought from me from the miner in Queensland and we had set in a pendant - personal as well as professional meaning to that!. ■

Angela Griffin

Elected Member

Birthplace: Kirikiriroa/Hamilton

What is your first memory of being interested in an aspect of geoscience?

Wondering why a local hill (Houto "mountain" in the Mangakahia Valley) was shaped differently to others in the area (e.g. Tangihua ranges).

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Mary Anning – she would have a lot of interesting stories/titbits to tell regarding where she found all her interesting fossils, and just to have a good old gossip over a nice glass of wine (or two)!Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

I would love to be digging up ancient remains around Egypt or Britain (wannabe archeologist), but I'm not sure it would have been easy.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

A diamond (preferably of reasonable caret and quality). My birthstone is a diamond, and I think it would be really neat to be able to find one (the bigger the better!) for myself (in the most ethical and humane manner possible!). ■

Kat Holt

Vice President

Birthplace: Ahuriri/Napier

What is your first memory of being interested in an aspect of geoscience?

When I was 5 years old we did a class study on dinosaurs. I had never really encountered them before, but I was hooked. I would tell my family I wanted to be a palaeontologist. Most of them didn't know what that was...

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Lorraine Lisiecki, to get tips on how to succeed as woman in the geosciences, and just to chat about orbital cycles.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

Volcanology

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

Anything from the Chatham Islands, as it's where I did my PhD. ■

Andrew Lacroix

Committee member

Birthplace: Vancouver, Canada

What is your first memory of being interested in an aspect of geoscience?

Collecting agate on the banks of the local river as a kid.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

William "Strata" Smith, of course. So I could pick his brains about biostratigraphy.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

Global tectonics always interested me.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

T-Rex skull to sit on my mantle. ■

Sam McColl
Publication Sales

Birthplace: Te Awakairangi/Lower Hutt

What is your first memory of being interested in an aspect of geoscience?

As a kid, my family was nearly hit by a collapsing section of the marine cliffs on the walk to Te Kauwae-a-Māui/Cape Kidnappers. The rockfall was frightening, but the event and the plume of dust extending some hundred metres out to sea fascinated me.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Darwin I suppose. I am sure he would appreciate hearing how influential and accepted his ideas have been for so many branches of science including geoscience.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

I could have happily wandered down any path of geoscience, though I am sure none would be 'easy'.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

I have a large chunk of ultramylonite with pseudotachylite veins in it from the Alpine Fault. It is not particularly rare or beautiful as far as rocks and minerals go, but it tells an impressive story. As a bonus, given my interest in landslides, it was part of an ancient rock avalanche from the hanging wall, which is now mostly buried by river aggradation so the boulder I wacked it off from is no longer accessible. The fieldtrip I collected it on was also one of the more memorable and fun I have been on, so it is a nice memoir. It is also heavy so makes a great door stop. ■

Photo credit: 'Bromo National Park' by Bambang Achmad (2020 GSNZ PhotoComp winner of Macro- and microscale geoscience category).

Sebastian Naeher
SIG Coordinator

Birthplace: Beautiful Germany

What is your first memory of being interested in an aspect of geoscience?

Difficult one… I have always been interested in science and nature. First, I wanted to become an archaeologist, but loved other sciences too. When it was time to decide which subject to choose when starting university, I wanted to do a combination of various fields, so earth sciences appealed to me… However, I was surprised at first to learn so much about rocks but realised immediately that this is very interesting too.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

So many fantastic geoscientists out there, in past and present! I would probably select Alexander von Humboldt, just because he was able to combine various research fields (including geology), so could do kind of "everything". The variety is fun. Discovering the world like Humboldt during his many travels seems very exciting!

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

I would always pick geochemistry again! It does not matter which area in geochemistry as all streams in that field are exciting. Biomarkers/organic geochemistry, isotope geochemistry, geochronology, isotope hydrology, all those are great topics.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

A sedimentary, ideally fine-grained rock from another planet to see if we find organic matter or any geochemical/isotopic evidence of life. ■

Alex Nichols
Canterbury Branch Representative

Birthplace: Oxford, U.K.

What is your first memory of being interested in an aspect of geoscience?

I remember watching news of the eruption of Mt St Helens on 18 May 1980 on BBC's Newsround (a news programme for kids). I was lucky enough to go to Mt St Helens on a family holiday in 1986 and subsequently devoured all the books I could find on the eruption and the human stories. When it came to doing a project on a volcano at school a little later there was only one choice for me – although in retrospect I should probably have chosen a different volcano to get a more rounded knowledge.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Jason Morgan, the proponent of the mantle plume theory, to see what he thinks about the ongoing debate on his theory's validity.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

I don't think I could have 'easily' specialised in any branch of geoscience. It hasn't been easy to specialise in the branch that I am in – I guess igneous petrology, geochemistry, occasionally volcanology. In my undergraduate education I would have liked to have had the opportunity to spend more time studying vertebrate paleontology, it was all microfossils and invertebrates for biostratigraphy in the petroleum industry where I was. I really enjoyed metamorphic petrology as an undergraduate – the most beautiful rocks with an amazing story to tell – which is lucky because, after not giving it all that much thought for 20 years, I am now teaching it...

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

Chalk. I grew up on it – it was all over the garden, and it made up the Ridgeway that I could see out of my bedroom window – so it reminds me of my childhood and the rolling chalk downs of southern England. And it's useful – you can write with it. I would like a piece of obsidian too – for the contrast.

Photo credit: 'Te Mari Fumarole' by Murray Baker (2020 GSNZ PhotoComp winner of New Zealand Geoscience category).

MEET THE COMMITTEE

Alan Orpin
Treasurer

Birthplace: Whangārei

What is your first memory of being interested in an aspect of geoscience?

Walking barefooted across red scoria – what was it, how did it form and why was it so sharp?

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Charles Cotton (1885-1970) had a wonderful eye for landscapes and the link between geomorphology and the underlying rocks. It would be so interesting to show him modern high-resolution bathymetric maps of the seascape. Cotton was apparently quite reserved but I'm sure just watching him sketch would be captivating enough – perhaps drawing during the day and drinking whisky around a camp fire in the evening?

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

I've always had a hankering for thin sections and igneous rocks. I did a summer scholarship at ANU RSES researching peridotites from Africa, looking at thin sections and analyzing then on a microprobe.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

A small carbonate chimney from the outermost Otago shelf that were the topic of my MSc and are still a soft spot, more of a rose-tinted emotional attachment. Fishers dredging for scallops first discovered these carbonate concretions off Otago some years prior. On the morning of our first research voyage to the shelf edge the skipper of the Munida (Chris Spiers) checked and corrected their possible location with an old fishing contact. It was needle in a haystack stuff, pre-precision GPS, but we found them with the help of a TVNZ ROV on our second attempt, embedded in the seafloor at 220 m water depth some 20+ km off Otago Peninsula. How cool was that!.

Jenny Stein
Secretary

Birthplace: Tūranga-nui-a-Kiwa/Gisborne

What is your first memory of being interested in an aspect of geoscience?

When I was three or four, watching "More Dinosaurs" (1985) and going fossil hunting in streams with my parents.I

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Assuming I can get two for the price of one since they're married, I would choose an evening with Charles and Mary Lyell. It would be fascinating to talk to two people whose combined efforts laid much of the groundwork for development of modern geoscience, and who also had to grapple with the multiple paradigm shifts in scientific thinking that their work was contributing to.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

Yes, too many, the result of which has so far been that I have not specialized in any one branch and have instead begun exploring the interconnectivity between the various branches of geoscience, and of geoscience with other disciplines.

If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

I would keep my "water stone" that was given to me when I was a young rock collector. The nondescript, fist-sized lump of quartz is not much to look at but when shaken you can hear a tiny amount of trapped fluid sloshing around inside. Unfortunately, the specimen did not come with detailed location data so I have no idea what hydrothermal deposit it must come from or how old it might be. But I like to keep it as a reminder of the fascinating stories it is possible for rocks and minerals to tell (and the importance of keeping detailed records!). ■

Looking north, a dyke and a wharf protrude into Akaroa Habour on the Duvauchelle side. Photo credit: Janis Russell

Phaedra Upton
Committee member

Birthplace: Ōtepoti/Dunedin

What is your first memory of being interested in an aspect of geoscience?

Going on a geology fieldtrip with family friend who was a geologist near Santa Barbara when I was about 12. Possibly along the San Andreas Fault.

If you could spend an evening with any geoscientist, from any period in history, who would you choose? And why?

Richard Norris. I miss his incredible knowledge of structural geology and often think I would like to be able to ask him about something or other. Today, I've been reading one of his papers while I try to write up my thoughts of what the mechanical implications of the Nevis-Cardrona Fault System are for deformation across Otago.

Is there any another branch of geoscience in which you could have easily specialised (other than your current one)?

Anything that involves understanding processes and not having to remember lots of details! Glaciology maybe or river dynamics.

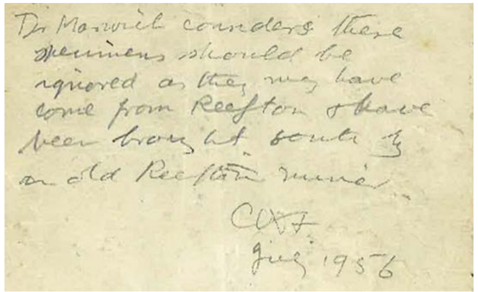
If you were permitted to choose and keep only one sample of rock, mineral or fossil, what would it be? And Why?

Tough question, I'm not really a rock collector, more a collector of images of landscapes. I do have a piece of Dun Mountain ophiolite from the Red Hills in west Otago which I'm very fond of, a piece of the mantle brought to the surface by tectonic processes. ■

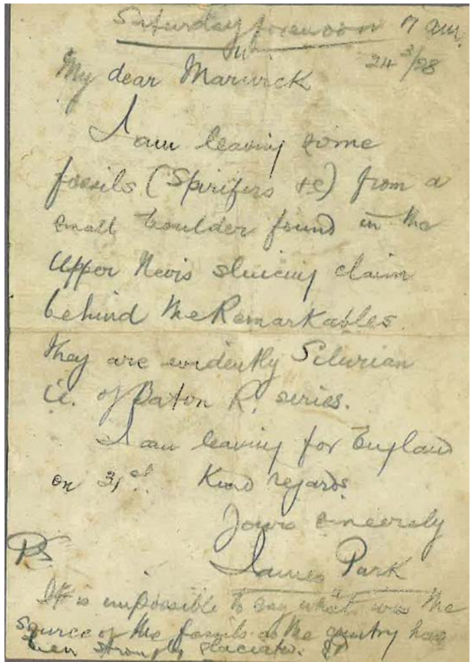
NEVIS BRACHIOPODS

Don MacFarlan

In September 2020 Ewan Fordyce, Marcus Richards and I were working in the basement of the Geology Department, sorting some boxed material that had been left by Doug Campbell. We came across a small block of grey silty mudstone with spiriferide brachiopods and crinoid columnals on bedding plane surfaces. It was accompanied by a series of handwritten notes spanning fifty years by James Park, Charles Fleming and Roger Cooper.



Dr Marwick considers these specimens should be ignored as they may have come from Reefton & have been brought south by an old Reefton miner.
CAF
July 1956



Saturday forenoon 17 am 24/3/28

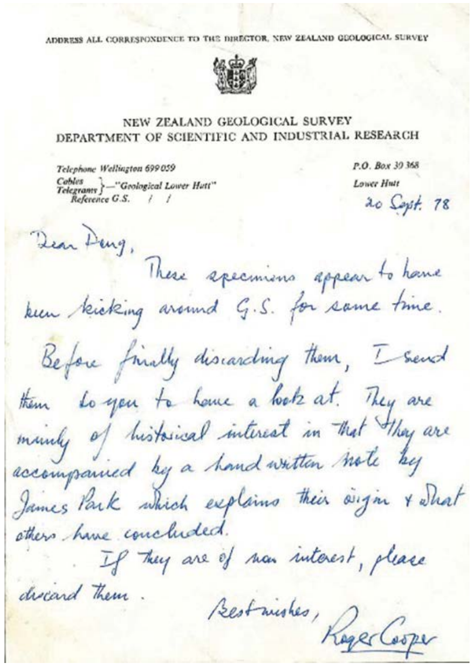
My dear Marwick,

I am leaving some fossils (Spirifers etc) from a small boulder found in the Upper Nevis sluicing claim behind the Remarkables. They are evidently Silurian i.e. of Baton R. series.

I am leaving for England on 31st. Kind regards.

Yours sincerely
James Park

PS It is impossible to say what was the source of the fossils as the country has been strongly glaciated.



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NEW ZEALAND GEOLOGICAL SURVEY
DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

Telephone Wellington 699 059
Cables Telegrams "Geological Lower Hutt"
Reference G.S. / /

P.O. Box 30 368
Lower Hutt

20 Sept. 78

Dear Doug,

These specimens appear to have been kicking around G.S. for some time.

Before finally discarding them, I send them to you to have a look at. They are mainly of historical interest in that they are accompanied by a hand written note by James Park which explains their origin & what others have concluded.

If they are of no interest, please discard them.

Best wishes,
Roger Cooper

ARTICLES

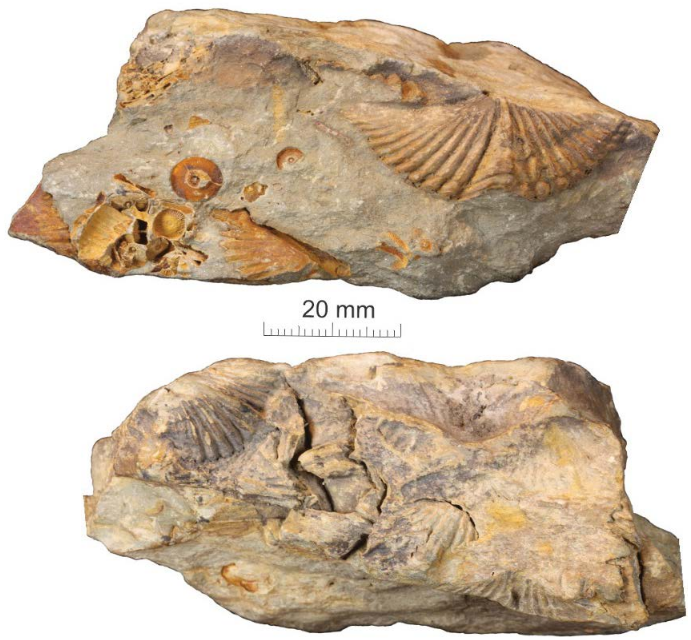
The largest "Spirifer" is an internal mould of a dorsal valve with part of the hingeline missing. It is provisionally identified as Mauispirifer hectori Allan. (see Allan 1947 and Earp 2015). This has been catalogued as OU 47287.

Other smaller, strongly costate partial valves may also belong to this species. On the reverse side of the slab, the largest specimen is a partly exposed ventral valve with a large well-developed muscle field, and strong costae anteriorly. This might be Spirifer coxi Allan.

The rock is weathered, with all shell material removed. The rock is therefore not strong, and the fossil bands represent zones of additional weakness. Long distance travel seems improbable.

The specimen was compared with material in the GNS Reference Collection in December 2020. The matrix compares well with lighter-coloured material from Reefton, while the Baton River specimens are a medium to dark grey.

> **Dr Marwick considers these specimens should be ignored as they may have come from Reefton and have been brought south by an old Reefton miner. C.A.F. July 1956**



The alluvial workings in the Nevis are in Pleistocene and Recent fanglomerates and alluvial gravels, which are mostly schist-derived (L&M Mining 1991).

The nearest Devonian fossils to the Nevis are from sandstone erratics at Lake Haupiri (Johnston et al 1980), west of the Alpine Fault and about 380 km north-northeast of the Nevis. Ordovician Greenland Group, into which the Reefton group outliers at Reefton are downfaulted, are present in Northern Fiordland about 110 – 140 km to the northwest, also on the western side of the Alpine Fault. Both seem unlikely sources.

Therefore, Marwick was probably right, and this specimen was most likely collected at Reefton. If more turn up in the Nevis, and can be shown to have reached there naturally, a fascinating tectonic-stratigraphic puzzle will result. ■

Acknowledgements
This note began with discussions with Ewan Fordyce and Marcus Richards, and has benefitted from comments by Mike Johnston, David Waghorn, Marianna Terezow, Chris Clowes and Liz Kennedy.

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UPCOMING REGIONAL EVENTS:

AUCKLAND BRANCH:

19th April	How tectonic and surface processes interact to shape our landscape
20th April	How tectonic and surface processes interact to shape our landscape
20th April	An integrated geodynamic view of The Southern Alps/Kā Tiritiri o te Moana
7th May	Field Trip: A multi-day field trip to the King Country and West Taranaki

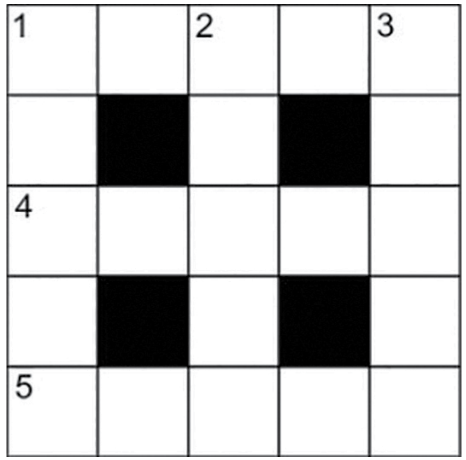
TARANAKI BRANCH:

7th Oct	Field Trip: A multi day trip to the Wellington area

GEOSCIENCE QUIZ 33
CRYPTIC GEO-CROSSWORD

by Aenigmatite

Difficulty: easier to solve than to set!



Across
1. She has been stony and colonial since the Triassic (5)
4. It sounds like his continental mountain range (5)
5. Deformation of hares! (5)

Down
1. What OPEC lays down contains sticky minerals (5)
2. Confused digger lost a gram in the middle of the ocean (5)
3. Resale returned without end to aid ablation and LiDAR (5)

Answers on page 58.

PARTNERSHIP EVENT:

16th SGA Biennial Meeting 2021: The critical role of minerals in the carbon-neutral future.

15th-18th November, Rotorua

Details for all these events can be found on our website:
https://www.gsnz.org.nz/news-and-events/national-and-regional-events/

A NEW KIND OF PEAK OIL IN THE 21ST CENTURY?

Paul White: GNS Science

Introduction

'Peak oil', here term 'peak oil supply', was first described in 1956 and predicted a future where oil availability (i.e., the 'supply-side') declined following initial oil field discovery (Wikipedia 2021a,b; Sibson, 2003; White, 2003). The term pointed to future oil availability that was limited by foreseen discoveries, reservoir characteristics and production rates with peak world production occurring in about 2000 and declining significantly in the 21st Century (Wikipedia 2021a).

However, the concept of peak oil supply has been contentious for decades, particularly because:

- actual oil production in 2000 (approximately 75 billion barrels/year; BP, 2021a) was much larger predicted peak oil supply that was calculated in 1956 (approximately 13 billion barrels/year; Wikipedia 2021a);
- oil production has showed no signs of declining in the first two decades of the 21st Century. In fact, production has increased significantly to approximately 95 billion barrels/year in 2019; BP, 2021a,b) and calculated world oil reserves continue to increase over time, e.g., from approximately 1300 billion barrels in 2000 to approximately 1700 billion barrels in 2019 (BP, 2021a);
- 'demand-side' oil economics were not considered by proponents of the peak oil supply hypothesis (Wikipedia 2021a; White, 2003).

The demand-side remains a key factor in the oil industry today where use is impacted by international competition, pestilence, politics, market conditions and subsidies. For example, OPEC influence prices by setting oil production rates in a complex political process (Wikipedia 2021c). Price is a key to innovation. High world oil prices in 2008 assisted with a development of hydraulic fracturing technologies in the US and a rapid increase in US oil production from that time (Wikipedia 2021a). Oil subsidies, in the form of tax breaks for oil development and consumer petrol prices, are common in many countries.

Some demand-side effects have been demonstrated by world oil prices that have varied widely since 2000. The June 2008 high of 140 $US/barrel was associated with 'the American occupation of Iraq ... rapidly increasing oil demand from China and ... recurring violence against the Nigerian oil industry' (Wikipedia 2021c) and the April 2020 low of -40 $US/barrel (yes, prices dropped below zero!) was caused by a dramatic decrease in demand associated with world-wide covid-related lockdowns (BBC, 2020).

A new kind of peak oil ('peak oil demand') was considered where oil demand may stop increasing in the 21st Century as a response to 'the combined forces of improving efficiency and building pressure to reduce carbon emissions and improve urban air quality' (Dale and Fattouh, 2018). Climate change response, one driver for the reduction in carbon emissions, led to the Paris Agreement aims to 'keep the global average temperature well below 2° C above pre-industrial levels, while pursuing efforts to limit the temperature increase to 1.5° C (Ministry for the Environment, 2021). However, global CO_2 emission targets were not part of the Paris Agreement.

Some projections suggest global oil demand could peak soon after 2025, others expect growth in demand to 2040 and beyond (Dale and Fattouh, 2018). However, Dale and Fattouh (2018) did not find strong evidence for peak oil demand, concluding that 'a sharp discontinuity in behaviour' associated with the 'timing of the peak' is very unlikely as 'even after oil demand has peaked, the world is likely to consume substantial quantities of oil for many years to come.' However, they add 'Peak oil demand signals a break from a past dominated by concerns about adequacy of supply. A shift in paradigm: from an age of scarcity (or, more accurately, "perceived" scarcity) to an age of abundance, with potentially profound implications for global oil markets.' 'Many oil producers would be forced to run large and persistent fiscal deficits or to cut back sharply on social provisions, which, in turn, would likely have knock on implications for global oil production and prices.' This shift could also provide the threat of new economic 'pandemics', such as a global spread of the Dutch disease, with risks of national economic destruction as currently observed in Venezuela (Wikipedia 2021d,e).

The response to climate change policies in the 21st Century are of key relevance to Geoscience Society members as fossil fuels (i.e., oil, coal and gas) have provided a key driver for earth-science research and exploration in, at least, the last few hundred years. Anthropogenic climate-change response has spawned multiple efforts to reduce greenhouse gases in the atmosphere; see Scientific American (2020) for a recent review. The response may limit oil production, e.g., as recognised by BP: 'Within 10 years, we aim to: increase our annual low carbon investment 10-fold to around $5 billion a year; and focus our oil and gas business on value, reducing production by 40%, with no exploration in new countries.' (BP, 2020a).

Therefore, this article reviews the current importance of fossil fuels to world energy consumption and some trends in 21st Century fossil fuel consumption by some major economies. Then, historic CO_2 production from fossil fuels since the 1970s is summarised and 21st Century CO_2 production to 2100 is calculated. Lastly, global warming and future fossil-fuel energy demand is discussed in the context of Paris Agreement aims, with some thoughts on oil's future in the 21st Century.

Fossil fuels are the mainstay of energy production. World energy supply has been dominated by fossil fuels (i.e., oil, coal and gas) from the 19th Century. Currently, fossil fuels provide approximately 84% of world energy consumption (Table 1).

Table 1. World primary energy consumption in 2019 (BP, 2020b).

Source	World (%)
Oil	33.1
Coal	27.0
Gas	24.2
Hydro	6.4
Nuclear	4.3
Renewables*	5.0

*Renewable energy (excluding hydro) plus biofuels.

In the 21st Century, world primary energy consumption has grown from approximately 400 exajoules to approximately 580 exajoules in 2019 (BP, 2021a). Fossil fuels have provided most of this growth. Total fossil fuel consumption increased by approximately

140 exajoules including increases of approximately 36%, 88% and 20%, for the use of oil, coal and gas, respectively.

The recent past has seen some remarkable changes in fossil energy consumption by major economies. UK electricity production saw a large reduction in the use of coal and a large increase in the use of renewables (Table 2).

Table 2. UK electricity generation by source (Carbon Brief, 2019a).

Source	Electricity generation (TerraWatt-hours)		Change in period (%)
	2000	2017	
Oil	6.5	2.2	-66
Coal	120	23	-81
Gas	148	133	-10
Nuclear	85	70	-18
Renewables*	9.9	99	900

*Renewable power including wind and biofuels.

In the US, a reduced coal use was mostly matched by increases in the use of gas and renewables (Table 3). In China, coal consumption increased from 0.99 billion tons (1990) to 4.64 billion tons in 2018 when coal provided 59 percent of the country's energy use (China Power, 2021).

Table 3. US primary energy consumption (U.S. Energy Information Administration, 2021).

Source	Primary Energy consumption (Quadrillion BTU)		Change 2000 to 2019 (%)
	2000	2019	
Oil	38	37	-3
Coal	23	11	-52
Gas	24	32	33
Nuclear	8	8	0
Renewables*	6	11	83

*Renewable power including wind and biofuels.

Energy from fossil fuel and CO_2 generation

The growth in fossil fuel use is calculated to result in a near-tripling of calculated world CO_2 emissions between 1971 and 2100 (Table 4 and Table 5).

Table 4. World CO_2 production from fossil fuels 1971 - 2015 (Worldometer, 2021).

Year	Fossil CO_2 emissions (Billion tons)	Population (Billions)	Specific CO_2 emission (tons/capita)
1971	15.7	3.8	4.2
1980	19.8	4.5	4.4
1990	22.5	5.3	4.2
2000	25.6	6.1	4.2
2010	33.6	7	4.8
2015	35.6	7.4	4.8

*Renewable power including wind and biofuels.

Table 5. Calculated world CO2 production from fossil fuels 2020 – 2100.

Year	Fossil CO_2 emissions (Billion tons)[1]	Population (Billions)[2]	Specific CO_2 emission (tons/capita)[3]
2020	34.3	7.8	4.4
2030	37.4	8.5	4.4
2040	40.5	9.2	4.4
2050	42.7	9.7	4.4
2075	46.6	10.6	4.4
2100	48	10.9	4.4

*Renewable power including wind and biofuels.

[1] Calculated as population * specific CO2 emission.
[2] World population estimate (United Nations, 2021).
[3] Average (Table 4).

This includes:

- an historic increase of approximately 20 Billion tons of CO_2/year between 1971 and 2015 (Table 4); and
- a projected increase of approximately 14 Billion tons of CO_2/year between 2020 and 2100 (Table 5). These calculations assume that specific CO_2 emission remains constant in the remainder of the 21st Century

Anthropogenic global warming and future fossil-fuel energy demand

- Climate change calculations to 2100 considered scenarios of future total annual anthropogenic CO2 emissions, including CO2 production from fossil fuels and industrial processes (Intergovernmental Panel on Climate Change, 2014).

The scenarios of Representative Concentration Pathways (RCPs) were in two classes:

- RCP8.5 is 'a high-end baseline scenario' (Carbon Brief. 2019b) where anthropogenic CO2 emissions increase to 2100 (Intergovernmental Panel on Climate Change, 2014) and
- other scenarios that assume 'some level of mitigation is employed in the future' (Carbon Brief. 2019b) including the timing of peak anthropogenic CO2 emissions and CO2 reduction, e.g., RCP2.6 (a 'very stringent' CO2-reduction pathway; Wikipedia, 2021f) assumes that CO2 'emissions start declining by 2020' and CO2 emissions 'go to zero by 2100' (Wikipedia 2021f; van Vuuren et al., 2011).

The projections for temperature change make sobering reading because of the large reductions in CO2 emissions required to reach the Paris Agreement, e.g., RCP2.6 is the only scenario that calculates global temperature which is 'unlikely to exceed 2°C' (Intergovernmental Panel on Climate Change, 2014; van Vuuren et al., 2011). Probably, humankind's biggest challenge this century is the reduction of dependence on fossil fuels. The difficult challenge to keep the world on the "two-degree pathway" foreshadows more aggressive future energy and economic policies to meet any CO2 emission targets (McKinsey and Company, 2019).

In the 21st Century, the dominance of fossil fuels as the world's primary energy source seems likely to continue with fuel demand increasing as the world's population grows and as economic development remains a primary aim of societies. For oil, a low-cost future looks a strong possibility as we move into an 'age of abundance' (Dale and Fattouh, 2018). Demand will result in continued investment in oil infrastructure. However, a low-cost future means that economic drivers for oil substitution will be reduced and that social disruption amongst oil-producing countries will increase.

Climate-change policies must address substitution of fossil fuels to get near to any CO2-emission targets. Substitution may include replacement of inefficient production and alternative power technologies. Some fossil-fuel substitution will prove beneficial to CO2-emission reduction. In the UK and the US (see above), this substitution will have led to less use of coal and reduced unit CO2 emissions because coal is inefficient (i.e., producing approximately 98 kg CO2/GJ) compared to oil and gas (producing approximately 76 kg CO2/GJ and 56 kg CO2/GJ, respectively, for electrical power generation (Wikipedia 2021g). Alternative power technologies mean the 'rise of electrification and the growing use of renewables' (McKinsey and Company, 2019).

The problems faced by such policies will be exacerbated by a low-cost future for oil. Hence, climate-change policies will require effective economic components to be successful, including:

- rewards for fossil-fuel energy production efficiency (i.e., aiming for reductions of unit CO_2-emissions);
- removal of fossil-fuel subsidies (Supran et al., 2020);
- effective carbon taxes to reduce fossil fuel demand (Metcalf, 2020). ■

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COMMENTARY ON:

A NEW KIND OF PEAK OIL IN THE 21ST CENTURY?

Mac Beggs: Martinborough

Paul White has drawn our attention to a relatively modern and increasingly popular view that the future of the long-important oil and gas industry will be governed by contracting demand rather than a previously popular analysis where it would ultimately be constrained by availability (supply).

It is interesting to go to the newsletters of 18 years ago which he refers to and reflect how far the present situation is from the views prevalent at that time (to which Paul expressed some far-sighted scepticism). The "old" meaning of "peak oil" has fallen apart due principally to classes of petroleum resource not then contemplated, proving to be both commercially attractive and voluminous in the very geographic range (USA "lower 48") where the peak oil concept was first developed by MK Hubbert in the mid 1950's.

New, shale-hosted classes of resource in North America (mainly) have been re-balancing the geopolitical equations around petroleum, and contributing both directly and indirectly to the collapse in oil and gas prices since 2014, and a widespread sense of plenty. But, petroleum resource volumes have not been rendered infinite.

As Paul documents, global consumption has tended to continue rising, particularly in developing countries off a low base, notwithstanding major policy shifts away from these forms of energy in developed economies including our own. Most governments now have policies related to the Paris Agreement so that counter to economic factors, where lower prices would lead to higher consumption, instruments to avoid greenhouse gas emissions continue to incentivise alternatives to petroleum and coal, and hence put some downward pressure on their consumption. Hence, predictions of a reversal in petroleum demand growth.

The combination of flat or falling demand and already low prices may present the illusion of an easy backstop in, and even after, the continuing energy transition toward a net zero carbon system. But falling demand and consumption will still be voluminous consumption. Demand can be lower than at present and will still exceed corresponding supply at some point in the future.

Let's remember and acknowledge that oil and natural gas are finite resources: we almost certainly will need some for a long time and hence have good reason to maintain the capabilities for discovery, appraisal, development and production. Oil and gas will be in short supply relative to high value uses in due course.

A recent column by AAPG Director David Curtiss in the "Explorer" has drawn attention to the severe reductions in capital investment in recent years, with a study by Boston Consulting Group and the International Energy Forum suggesting that "investment [in oil and gas discovery, development and production] must increase 25% per year from 2020 levels for the next three years to avoid crisis, with far more investment by 2030 to assure stable energy markets." Perhaps the current complacency driven at least partly by belief in "peak oil demand" will seem as naïve in a few years, as the 2003 consensus on peak oil does to us now. ■

ONE HUNDRED YEARS AGO:

MILLIONS IN OIL FRAUDS.

Wholesale indictments of oil stock promoters in New York prove that Barnum was right when he referred to the birth rate of a certain class of people. A Federal grand jury has rounded up four oil companies, 10 brokerage houses, and about 50 individuals. It is claimed that millions of dollars have been confided to this gentry by trustful souls who had visions of being millionaires over night. The promoters would pay an occasional dividend out of the sale of stocks as a lure for more contributions from Mr. and Mrs. Easy Mark.

Millions In Frauds, NZ Truth, Issue 798, 26th February 1921, Page 2.
Source: National Library of New Zealand.

NZOG'S NEW EXPLORATION VENTURE?

DON HAW

Within New Zealand NZOG has been a staunch and popular explorer for oil and gas and over time many of us have been supporters and indeed have had a financial interest in this brave Company. Probably still the case for some of us. Thus it is perhaps timely we look at their latest venture in the offshore northern Carnarvon Basin in western Australia.

In late 2018 NZOG farmed in to the Western Australian 359P permit on the Western Australian shelf region, which is held by its own listed subsidiary Cue Resources. Seems a bit incestuous, maybe it is, but however it's worked and, importantly, they have together, come to a "co-ordination agreement" with BP for the latter to enter into the permit. This is clearly based upon BP agreeing to operate and drill the major prospect there, namely Ironbark. Sounds like what we used to call a "Farm In". It has been agreed BP will earn a 42.5 % interest in the permit. Beach Energy, an Australian Explorer 'associated' with BP is coming along with them to earn 21% and is the other interested party with Cue who will keep 21.5%. NZOG will retain a 15% interest.

I can see the objective of BP who, clearly recognising the value of the prospect, is willing to carry along these relatively minor Explorers. If it does succeed they (BP) will buy them out and a major successful enterprise will develop. It will be a win-win situation.

And now it's happening. The Ocean Apex rig spudded in the committed well, Ironbark-1 on the 31st October 2020. The prospect is considered to be a "giant" within the Triassic Mungaroo Formation where multiple sandstone reservoir objectives are expected. It is however still a frontier well. The primary target is at approximately 5670 metres TVD. The fact that it has been embraced by BP speaks volumes (in more sense than one) because BP has openly said it is not interested in "small stuff" offshore and would only commit to operate prospects with large potential reserves. Ironbark is estimated to have between 12 to 15 trillion gas reserves, which sounds pretty big to me!!.

Nevertheless the Ironbark prospect is significant and encouraging especially knowing these reservoirs have been explored in shallower water parts of the basin where discoveries have been made at the Gorgon, Goodwin and North Rankin fields. Ironbark is however taking a major step into somewhat deeper water (298 metres) and deeper target sub-sea. Clearly BP's review of the geophysics has been encouraging and recognizing the financial commitment these companies are taking, Ironbark might turn out to be a major discovery for both BP, NZOG and Australia.

5th Nov 2020

ARTICLES

IN MEMORY OF HARD-COPY REPRINTS

Cam Nelson
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Over the past couple of decades the historically time-honoured practice of researchers requesting physical reprint (or offprint) copies of publications from authors in their field of research interest has largely fallen away to extinction with the development of all kinds of reader online journal access options (e.g. Google Scholar).

In the course of my 50 years of geological research, first at Victoria University of Wellington, then the University of Auckland, and for the bulk of my working career at the University of Waikato, I accumulated a large personal library of reprints across a wide range of disciplines in the Earth sciences, and especially in the broad fields of sedimentary and marine geology.

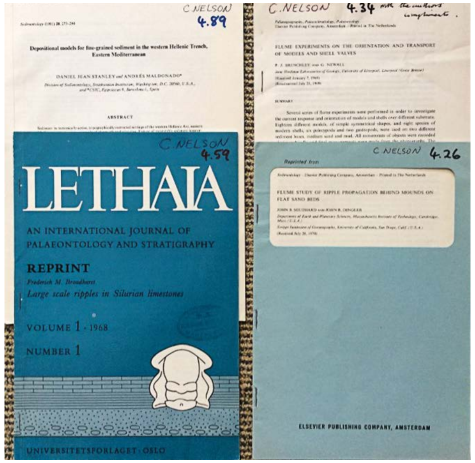
Over time, and assisted by paid student-vacation workers, each reprint was catalogued according to one or other of about 80 topic (sub)categories. They were assigned a unique running number that enabled retrieval at any future time, initially via a card cataloguing system and eventually using EndNote bibliographic management software once it appeared in the 1990s. Each topic category, including any subcategories, was assigned a numbered manila cardboard lidded box. As each filled with reprints a second or third or more boxes in that category was created. The total number of boxes ended up at about 120, housing almost 7000 catalogued reprints.

On retirement from the University of Waikato in 2012 I remained open-minded about continuing, at an appropriately sedate retirement pace, my research interests. So the question arose as to what I should do with my large library of boxed reprints? Might I desire continued access to the reprint boxes from time to time? Probably not, given the relative ease these days of online access to the research literature, especially via Google Scholar. Nevertheless, at the time I remained reluctant to simply throw the reprints away and no one was particularly interested in taking them on board. Given we had loads of attic storage space at home I finally decided to shift all the reprint boxes from my university office to home. Since then I have on occasions certainly been appreciative of their ready availability, although I confess such access has dwindled significantly with the passage of time.

In late 2020 Hamilton City Council instigated a new rubbish collecting system with recycling bin options. This prompted a rethink about the ultimate fate of my reprint collection and I eventually decided I would discard most of them. Slowly, over the next several months, the reprints in each box will be checked for staples, cut out where necessary, and placed in a paper pile for the recycling paper bin each fortnight. Naturally enough, along the way I have spotted the occasional 'must keep' reprint of seemingly particular relevance to some of my current research interests, and these end up in a special new carton. As I sort papers, I confess to be hugely impressed by the vast amount of truly excellent and innovative Earth sciences research outcomes that are locked up in my otherwise now 'historical' reprint collection. It is gratifying to know that most of this work remains preserved through online accessibility at the present day.

Also as I sort through the reprint boxes I am reminded that for at least three decades (1970s to 90s) I visited the University Library most weeks to check out the 'new arrivals shelves' for journals and books. Early on, armed with 'reprint request cards' bearing the University logo and department address, these would be filled in by hand and sent off by airmail to the authors of papers of special interest. Several weeks later a reprint, often signed and including a short message, would arrive in your mail tray in the department. I estimate that about 20% of my reprint collection included author signatures or comments. Sometimes authors further personalised their reprints with the addition of a full or windowed cardboard cover, company or institution logo, or other information (e.g. see accompanying Figure).

In later years, with the appearance of ever more flash and quick copying ('Xerox') machines, it became more common to request the Library send a full journal issue across to you in the department via the internal mail system after it was taken off the 'new arrivals shelves', and then personally copy from it the article(s) of interest. Whatever, in contrast to the past couple of decades with relatively easy access to most online journals and their articles, the 'reprint request' and 'Xerox' options for acquiring physical hard-copies of reprints were essential activities in those later 20th century decades for keeping up with the latest examples and advances in your research and publication field(s). ■



Examples of some hard-copy reprint types from my Sediment Transport and Structures category box (no. 4): 4.89 - Standard reprint; 4.34 - Author acknowledged reprint; 4.59 – Full cardboard-covered reprint; 4.26 – Window cardboard-covered reprint.

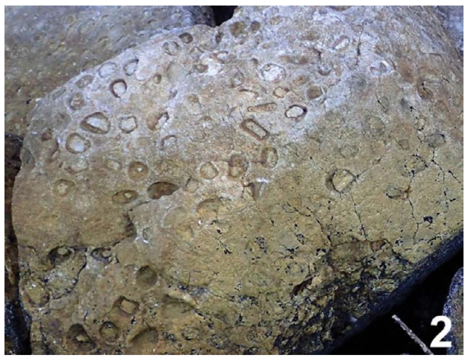
AN ORBICULAR GRANITE TRAIL IN NEW ZEALAND

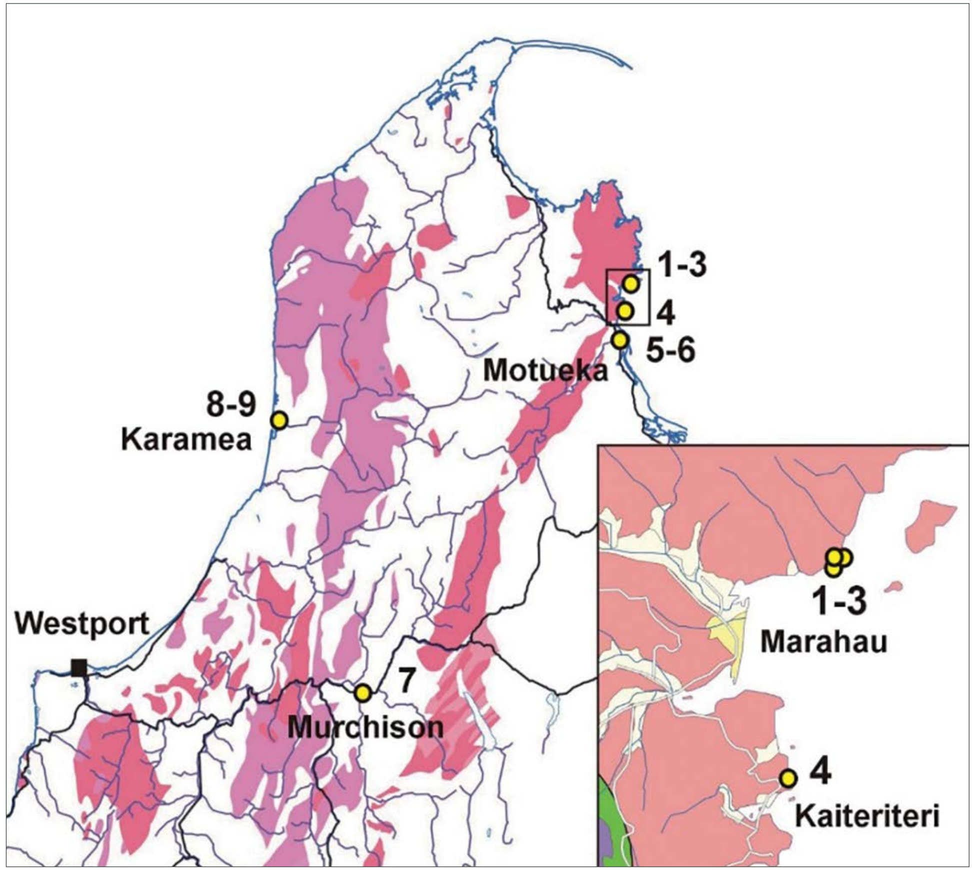
Bruce W. Hayward

What geoscientist does not swoon over a decent orbicular granite? We in New Zealand are fortunate to have a number of plutons in the northwest of the South Island that provide examples (e.g. Marshall, 1946; Kobe, 1988; Sagar et al., 2016). There have been a number of finds of rare float boulders and cobbles in the beds of tributaries of the Glenroy, Wangapeka and Karamea rivers and on Mt Radiant (DGB in Reid et al, 1972), but only good luck will result in seeing an example of orbicular granite at these places if you visit them. There are, however, at least nine places where a visit is guaranteed to be rewarded. Four, along the Tasman Bay coast north of Kaiteriteri, provide both in-situ examples and associated cobbles and boulders close by. These in-situ sites and several others nearby were initially found by M. Heath and documented by Huko Kobe (1988) and are unique examples of in-situ orbicular granite in New Zealand. The remaining five "inland" localities are all of river boulders that have been moved to a town's museum, information centre or DoC office for public viewing, I have put all nine localities together as an orbicular granite trail for the enthusiast to follow.

1. Abel Tasman Track - several orbicules (~10 cm diameter) in the tourist track – look at what you are walking over. In a Separation Point Granite pluton. About 1 hr walk from Marahau, between turnoffs to Coquille and Apple Tree bays. ~40.989°S, 173.035°E.

2. Apple Tree Bay - 80m around the rocks from the south end of the beach (access at mid-low tide); about 1.5hrs walk from Marahau. In-situ at high tide and in boulders up to 2m diameter intertidally. In a Separation Point Granite pluton. For more detail see Kobe (1988) and Hayward (2020). 40.998716°S, 173.036264°E.



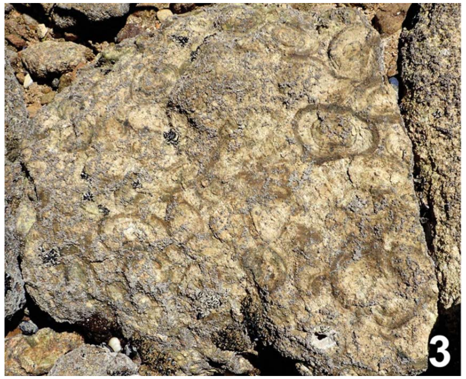


Orbicular granite trail localities:
Granite outcrops coloured from 1:1 million GNS Science map 2016.

TRIPS & TRAILS

3. Coquille Bay - 200 m around the rocks and sand from the north end of the beach (access at low tide). Can be accessed on a good low tide by clambering 150 m around the intertidal rocks from Apple Tree Bay and then continuing on to Coquille Bay (or vice versa). 1.3 hrs walk from Marahau. In intertidal boulders and cobbles in a small embayment. In a Separation Point Granite pluton. For more detail see Kobe (1988) and Hayward (2020). 40.989395°S, 173.034181°E.

4. Breaker Bay - in-situ in mid-low tide rocks at the north end of the beach, partly obscured by barnacles and sometimes partly buried by sand. Most easily accessible location but often the poorest exposure. In a Separation Point Granite pluton. Outcrop figured in Marshall (1946, p. 76). For more detail see Kobe (1988) and Hayward (2020). 41.032475°S, 173.021355°E.



5. Motueka District Museum, 136 High St (main street). 1 m diameter boulder beside front fence. Source unknown, possibly Apple Tree Bay. 41.110679°S, 173.011002°E.

6. Motueka Department of Conservation office, 406 High St (main drag). Sourced from Wangapeka River, collected by Harry Ferris (pers. comm. Dave Dawber, 2020. Small boulder under tree beside carpark off High St. 41.124886°S, 173.009828°E.

7. Murchison Information Centre, 1.5 m diameter boulder beside footpath at front. Diorite from Mt Cann Pluton, Glenroy River area (Reid et al., 1972; Sagar et al., 2016). For more detail see Hayward and Sagar (2020). 41.799971°S, 172.326020°E.

8. Karamea Information Centre, 3 Bridge St. Beautiful 1 m+ boulder inside centre. Multi-shelled orbicular granite, possibly from same source as the Elford Creek boulder or boulders purchased/collected by Marshall in 1930s and 1940s. 41.25123°S, 172.12869°E.

Photo bcredit: Christine Major.

9. Karamea Museum, 40 Waverley St (Hwy 67), 41.24890°S, 172.11757°E. Three slabs from two boulders on display, all labelled "from Elford Creek". The multi-shelled appears to come from the same boulder that was sent as slabs to a number of museums around the world by Pat Marshall in the 1940s. "After sending slices around the

Photo credit: Simon Nathan.

world, there was a lot of material left over, which Marshall stored at the Dominion Museum where he was probably an honorary geologist in the 1940s" (pers. comm., Simon Nathan 2020). This orb in Karamea Museum is possibly one of the pieces left over after that boulder was cut up. It seems there were possibly several boulders that Marshall acquired in the 1930s-40s and he had slabbed for distribution (Marshall, 1946; Grapes, 1996; Watters et al., 1998, 1999; Kobe, 1999; Gage and Nathan, 1999, p. 5; Keam, 2001; Grenfell and Fleming, 2016; Simon Nathan, pers. Comm.) and the other two slabs in this museum may be from a second boulder with different orbicule texture. Note Karamea Museum has limited opening hours.

In New Zealand, additional slabs of Marshall's Karamea orbicular granite are held by (some publicly viewable at) Auckland Museum, GNS Science (Lower Hutt), Te Papa (Wellington), Canterbury University and maybe elsewhere in New Zealand.

Acknowledgements
I am indebted to Dave Dawber, Christine Major, Simon Nathan, Diane Toole and Simon Walls for information on and photographs of some of these localities and sources. ■

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BANKS PENINSULA BEST BITS

POST-CONFERENCE FIELD TRIP

Janis J Russell and Sam Hampton

Twenty keen souls stood huddled under a tree, at the University of Canterbury Biology carpark, as the rain began to set in. We were waiting for the two UC vans to arrive which carried our leaders: Darren Gravley and Sam Hampton. Earlier that morning, the weather forecast had confirmed that it wasn't going to be an ideal day to enjoy the beautiful scenery that often greets visitors on the drive over towards Akaroa from Ōtautahi/Christchurch.

Undeterred, and with formalities completed, we piled in and set off on our trip to explore Te Pātaka o Rākaihautū/Banks Peninsula Geopark.

This field trip's itinerary was designed to link key sites where research has been undertaken there over the last ten years, largely by Frontiers Abroad Aotearoa, in conjunction with UC's School of Earth and Environment.

Banks Peninsula is the result of significant Miocene intraplate volcanism. It mainly consists of two large overlapping Miocene volcanoes—Lyttelton (11.0-9.7 Ma) to the northwest (oldest) and Akaroa (9.7-8.0 Ma) the southeast (largest), plus two smaller eruptive centres at Mt Herbert (9.7-8.0 Ma) and Diamond Harbour (7.0-5.8 Ma).

On arrival at our first stop, Waikakahi/Birdlings Flat, we all introduced ourselves before wandering up and down the beach, crunching over the Quaternary gravels on the southern margin of Lake Ellesmere. Several of us spent time on hands and knees hunting for agates and other collectibles swept in on ocean currents and deposited on the beach.We had a welcome caffeine fix

In 1952, H.H. Reed wrote: "The best geologist is, other things being equal, he who has seen the most rocks". Source: D.V. Ager (1969) Almost 70 years later, Anke Zernack, a young female volcanologist collects as many from Birdlings Flat as she can hold in her hand.

at Wairewa/Little River prior to travelling over the hill to Hilltop where we were due to have a planned stop. Unfortunately, the view was non-existent. However, as we made our descent down the other side to Akaroa Harbour, the distinctive teardrop shape of Ōnawe Peninsula emerged from the gloom in front of us. Geology-wise, it lies close to the centre of the Akaroa Volcanic complex and is home to trachytic intrusions, basalt lava flows and scoria, airfall deposits, vent breccias and gabbro/syenite exposures.

It is also the site of Historic Ōnawe Pa where a siege and attack by Te Rauparaha, aided by Captain Stewart of the Brig Elisabeth in November 1831, eventually led to a massacre and burning of the pa.

We pulled into the carpark, which is situated above a tuff cone, and followed down the track

The Ōnawe peninsula bisects Akaroa Harbour into two bays. Facing north, Barry's Bay lies to the left and Duvauchelle to the right.

to the south before doubling back along the western shoreline of the northern end to look at some basalt scoria and trachytic intrusions.

On the way uphill to the view point, we passed some photogenic weathered trachyte. The cloud still hadn't lifted and created great light

Contact between a chemically weathered trachyte dyke and scoria units in the shore platform cliffs at the neck of Ōnawe Peninsula, Akaroa Harbour.

A trachytic dyke protrudes into Akaroa Harbour just below the water level

conditions for photography. Further on, Sam described some of the elements of historic pa site and told us more about the fishing and advanced construction methods Māori had used there.

Our goal was the highest point of peninsula with a commanding view of the topography surrounding Akaroa Harbour. Piwakawaka, korimako and kōtare were seen in the pockets of native scrub near the top.

Small areas of exposed gabbro can be found on the peninsula but they are difficult to access. After a group photo in amongst the syenite boulders—the only plutonic outcrops available to us— we wandered back down the hill to travel to our next destination: Ōtepatotu.

The outcrop at this scenic reserve, just off the Summit Road, rises around 25m out of the surrounding vegetation which has been described as a 'goblin or faerie' forest.The upper welded units reflect the short time intervals between deposition events allowing heat retention in the spatter deposits. At this point, some of the group had flights to catch so we parted ways with a few heading to the airport.

A quick stop on the way to Lyttelton was at

Ōtepatotu is an extensive welded scoria unit and provides a haven for local rock climbers. Individual spatter clasts are unwelded at the base of the sequence becoming lava like as you ascend the cliff face. Julian examines the finer details.

Conical Hill, a pre-Lyttelton Volcanic rhyolite dome. The Summit Road follows around the edge of the dome, with decimetre columnar jointing fanning around the road bends. This site also provided a Lyttelton Harbour Overlook where one can observe the topographic signatures of each period of volcanic activity.

From Conical Hill the group travelled to Pony Point, a small reserve offering views of the harbour, Otamahua / Quail Island and Diamond Harbour. The latter having eruptives and sedimentary deposits that occurred within and infilled a paleo-Lyttelton Harbour 8-5.8 Million years ago. The field trip finished at Eruption Brewery in Lyttelton with some great food, cold beverages, and conversations. ■

Acknowledgements: A major function of the Geopark is to engage locals and visitors in the landscapes and stories of Banks Peninsula, informing them about its geology, landscape, flora, fauna, archaeology, histories, communities and organisations. Thank you to Darren & Sam who managed to do exactly that.

Group amongst the syenite boulders near the southern the tip of Ōnawe peninsula

AUGA FIELD TRIP TO WAIPARA FOSSIL LOCALITY

Nathan Collins and Michaela Dobson

The Auckland University Geoscience Association (AUGA) ran a post-GSNZ conference field trip to the Waipara Gorge led by Paul Scofield (Canterbury Museum) and Leigh Love a self-taught geologist who has devoted the past 15 years to investigating the fossil fauna of the Waipara. The trip was attended by 14 geology students (from UoA, UC, and Vic) who were all very keen to find a diversity of fossil fauna.

We began with a geologic overview of the Waipara Gorge from Laidmore Road overlooking the diverse geologic landscape. We then headed down to the Waipara river. Here well-developed fluvial terraces satisfied those in the group more interested in landscape evolution, but the main prize was the Cretaceous–Paleocene boundary! —a ~20 cm horizon consisting of an iridium anomaly which has been used as a proxy for meteorite impacts. This particular layer has been dated to 65 million years and therefore records the meteorite impact which resulted in the mass extinction event that wiped out the dinosaurs!

Michaela and Nathan posing with the K/T boundary.

After stopping several minutes to take pictures with this "rock-star" outcrop we continued our way down section into the fossiliferous Conway Formation. The Conway Formation is famous for a stunning array of marine reptile bones, most of which are contained within large (1-2 m in diameter) concretions.

Photo credit: Georgia Warren

Walking down-sequence along the Waipara River into the foreboding Conway Formation.

The students split off and claimed a patch of land, frantically looking for a plesiosaur (Nessie!) or mosasaur bone. The tag "richly fossiliferous" didn't apply to the Conway Formation that day, however Leigh found a whale vertebra, a marine reptile bone and shark teeth, whilst some students managed to find plesiosaur bones, petrified wood and a giant fossil worm burrow. As the majority of the students were Aucklanders, they have a keen eye for Miocene molluscs, but not so much Cretaceous marine dinosaurs so unfortunately the Conway Formation kept its secrets.

After lunch the weather started to pack in so we quickly ate before making our way to look for crab fossils at our last stop—Motunau Beach. Unfortunately, by the time we got there, the rain was pouring, the wind howling and the tide was too high. We called it quits, but we all had such a great time nonetheless, and it conveniently provided the excuse to come back again. ■

Photo credit: Thomas Stolberger

Paul giving an informative talk by the concretions in the Waipara River

Photo credit: Thomas Stolberger

Leigh has found something!

Acknowledgements
AUGA would like to thank Paul and Leigh for guiding and inspiring us, and for the GSNZ for generously funding van hire.

Post-dinosaur hunting group photo.

ONCE-IN-A-LIFETIME FOSSIL DIGS AT MANGERE SEWAGE WORKS

Bruce W. Hayward

In November and December 2020, paleo-enthusiasts from Auckland Geology Club and Auckland University took part in two "once-in-a-lifetime" opportunities to dig and search for Late Pliocene (Waipipian, Wp) marine fossils in the biggest heap of fossil-bearing shell sand they are ever likely to come across.

The 60 x 10 x 4 m heap, containing ~2500 cu m of spoil, had been stockpiled in a paddock near the Mangere Wastewater Treatment Plant (Auckland's sewerage works) by many trucks transporting away material excavated from two shafts put down adjacent to Mangere Lagoon explosion crater.

The shafts, one 16 m in diameter and the other a whopping 31 m in diameter, were excavated as part of the central interceptor project that is digging a 4.5 m-diameter tunnel under Auckland to bring wastewater 14.7 km from Grey Lynn, in the central city, to the treatment plant. The shafts were excavated with small dozers down to a depth of 42 m where they bottomed in more solid Waitemata Sandstones (early Miocene).

As they went down they dug out vast quantities of Pleistocene and Late Pliocene sediment that had accumulated in the Manukau embayment/harbour that would have been connected to the Tasman Sea. The interval of most interest was the richly fossiliferous shell sand of the Otahuhu Formation (proposed by Marwick, 1948) (known colloquially by well drillers and many geologists as the Kaawa Shell bed aquifer) at 33-38 m depth. In this instance the shell sand is dominantly comminuted shell containing mostly abraded and broken marine mollusc shells.

Some of the Auckland Geoclub enthusiasts searching and digging for Pliocene fossils in the huge shell sand heap at Mangere.

The fossils are dominated by heavy-shelled dog cockles (Glycymerita), large thick-shelled oysters (Magallana ingens) and numerous morning star shells (Tawera duobrunnea). The assemblage of over 70 mollusc species is a mix of those that lived on intertidal rocks (e.g. limpets, thaids, cat's eyes), intertidal sediment (e.g. pipi, whelks, horn shells, volutes), subtidal somewhat exposed sandy beaches (e.g. tuatua, and thick-shelled trough shells of the Mactridae), and mostly those that live subtidally in strong current-swept environments (harbour channels) such as dog-cockle, morning star shell, slipper shells (Maoricrypta), circular slipper limpets (Sigapatella) and large thick-shelled oysters.

The sediment includes occasional well-rounded cobbles and pebbles of Waitemata Sandstone, greywacke and occasionally red chert and a small piece of silicified wood. These latter two rock types provide a link to the Late Pliocene Clevedon River that has been inferred to have flowed from the Coromandel Peninsula area westward across the yet to founder Hauraki Rift, past the red cherts and greywacke of Waiheke and north east Hunua Ranges and through the Clevedon half graben to discharge into the Manukau embayment (e.g. Hayward et al., 2010). The fluvial and estuarine sediments of these Late Pliocene west-flowing rivers belong to the Puketoka Formation s.s. (Battey, 1949) which is known to interfinger with marine fossil-bearing deposits where exposed around the southeast shores of the Manukau Harbour (e.g. Hayward, 2017; Hayward et al., 2006).

Various strategies were used to find and uncover the Pliocene fossils buried in the loose shell sand. Note the 10 m width of heap on top.

The fossil digs came 75 years to the month since a similar "once-in-a-lifetime" opportunity for collecting similar Late Pliocene fossil collections occurred at Otahuhu's Waitemata Brewery well (6 km to the east of Mangere Treatment Station). The similarity of the two situations is remarkable. At Otahuhu, a water well shaft (unknown diameter) was dug by hand down through a similar sequence stopping in shell sand near the base of the Otahuhu Formation at 30 m depth. The sediment was hauled to the surface in buckets and many of the prominent New Zealand paleontologists of the time were given permission to dig through it. These included John Bartrum and Charles Laws (Auckland University College), Baden Powell (Auckland Museum), Cyril Firth (Auckland), Jack Marwick and Charles Fleming (NZ Geological Survey, Wellington).

Marwick (1948) published a Survey Paleontology Bulletin on 41 species of larger molluscs (24 described as new) from Otahuhu based largely on collections made in Nov 1945 before the dig had reached the most productive and best preserved shell bed (bed 20). Laws (1950) published a second Survey Paleontology Bulletin on

140 additional, mostly micromolluscs (40 described as new), collected from the well site by him in January 1946, when the best shell material was being excavated from the bottom part of the shaft. This brought the total recorded molluscs from the Otahuhu well to 181, well in excess of the diversity so far obtained from Mangere, largely because of the poorer preservation, particularly of the micromolluscs, at Mangere.

The Mangere fossils include many species in common with the Otahuhu well, some of which had only ever been recorded from the well prior to this Mangere opportunity. The Mangere deposit appears to contain a greater proportion of normal-marine salinity molluscs than Otahuhu and lacks some of the estuarine-restricted taxa recorded from there.

In total, 53 people from Auckland Geology Club, Auckland University Geoscience Society and employees of the contractor consortium Ghella Abergeldie Joint Venture attended one or other of the two digs. Although well-preserved fossils are sparse in the Mangere shell deposit, searching by this number of people turned up a number of notable finds. The most astounding were the two oldest fossil flax snails (Placostylidae) in New Zealand and the world. They were dug up by Stefano Vittor (of Ghella Abergeldie Joint Venture) and geoscience student

New Zealand's oldest fossil flax snail, from Mangere.

Avocational paleontologist Lyn Hellyer with her Mangere find of the first cone shell specimen from the Pliocene of New Zealand

Julianne McCoun (University of Auckland). Prior to the finding of these new 3-3.5 myr old specimens the oldest "Placostylus" in New Zealand was ~100,000 yr old shells in Last Integlacial deposits in the far north. This new species is being described by Fred Brook and belongs to the genus Maoristylus which also contains the present-day species ambagiosus (North Cape area) and hongii (Whangaruru-Poor Knights).

Other significant finds include the first record of a cone shell from the Pliocene of New Zealand, many specimens of a previously unknown large thaid gastropod, a large (warm-water) high-spired Tectus, a vertebra of a baleen whale, and a number of other previously unknown gastropods. The assemblage and new records are currently being worked up for publication by Alan Beu and myself.

In addition to the molluscs the fossil fauna contains minor components of foraminifera, bryozoa, serpulid polychaetes, rhodoliths, barnacles, echinoids, and a solitary coral. All specimens will be lodged in the collections of Auckland Museum.

At the "digs", a number of bucket-loads of the more common larger fossils, such as the large fossil oysters and dog cockles, were collected for the Watercare contractor's public relations communicators to use in their outreach activities with visiting school groups. They have a small sand heap where the school classes visit and as an activity the children are tasked with looking for fossils from the shaft that the communicators have buried for them to find. ■

Acknowledgements
I am grateful to Alex Parma of Ghella Abergeldie Joint Venture and Shayne Cunis of Watercare for allowing and facilitating access to this valuable fossil material and Grant Reid (Waiau Pa Bulk Haulage) for arranging access to further material spread out over a 2 ha area on adjacent Puketutu Island biosolids (dry treated sewage) disposal site.

Some of the Auckland Geology Club paleo-enthusiasts after the "great fossil dig."

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SJ HASTIE AWARD REPORT

Jade Humphrey: 2019 recipient

As I'm sure you are all aware it has been an interesting year completing research while contending with the difficulties posed by Covid-19. After receiving the S. J. Hastie award at GSNZ 2019, I continued my work unravelling the complexities of the 1929 Buller Earthquake. I completed field work over the 2019-2020. Based on this fieldwork together with a re-evaluation of existing data the 1929 event may have been a multi-fault rupture of the White Creek, Glasgow and Kongahu faults together with several smaller flexural-slip faults east of the White Creek Fault (Figure 1). We are currently developing elastic dislocation models to replicate the uplift profile from the earthquake revealed by relevelling of train tracks across the Murchison Basin. I presented some of my work on the 1929 Buller Earthquake recently at the 2020 GSNZ annual conference in Christchurch and won best poster by a MSc student.

I had plans of attending and presenting at the Deformation and Earthquakes in Taiwan and New Zealand meeting in Taiwan in early March and travelling abroad before starting my MSc thesis in April, however Covid-19 had other plans. I spent lockdown in Christchurch and with little to distract me other than baking, the sunshine and learning Python, I managed to get my proposal submitted and approved with a slightly delayed start date in late May.

My thesis project is part of the Resilience to Nature's Challenge earthquake and tsunami theme (RNC2). I am comparing the paleoseismic record of faults in the wider Wellington and Wairarapa regions to synthetic earthquake catalogues produced by earthquake simulators, such as RSQSim. This will involve validating the synthetic model with the available geological data to test the utility of these models for understanding real earthquakes and their hazards. I am also looking for evidence to support the occurrence of multi-fault ruptures in central New Zealand and exploring the conditions that favour these complex ruptures.The synthetic seismicity model is now at the stage of being interrogated and validated using the Python code we created.

My own compilation of the paleoseismic records for active faults has contributed to updates of the National Seismic Hazard Model (NSHM) and new Community Fault Model (CFM). I have been collaborating with the paleoseismology team at GNS Science and working at the Avalon GNS offices. We are currently reviewing these data and then it will be ready for comparison to the synthetic earthquake catalogue.

I have also been studying LiDAR-derived topographic models and have identified other potentially active faults that are currently unmapped and require investigation through field work to confirm their activity.

Thank you to the S. J. Hastie fund, GSNZ and the University of Canterbury for supporting my research this far as I am thoroughly enjoying fulfilling my passion for earthquake research. Thank you to my supervisors Andy Nicol, Nicola Litchfield, Russ Van Dissen and Andy Howell for all their help and support so far. I am also grateful to all the others in the CFM, NSHM RNC2 and GNS paleoseismology teams that have contributed to my project. I am excited to be working on earthquakes and to see the results of my research. ■

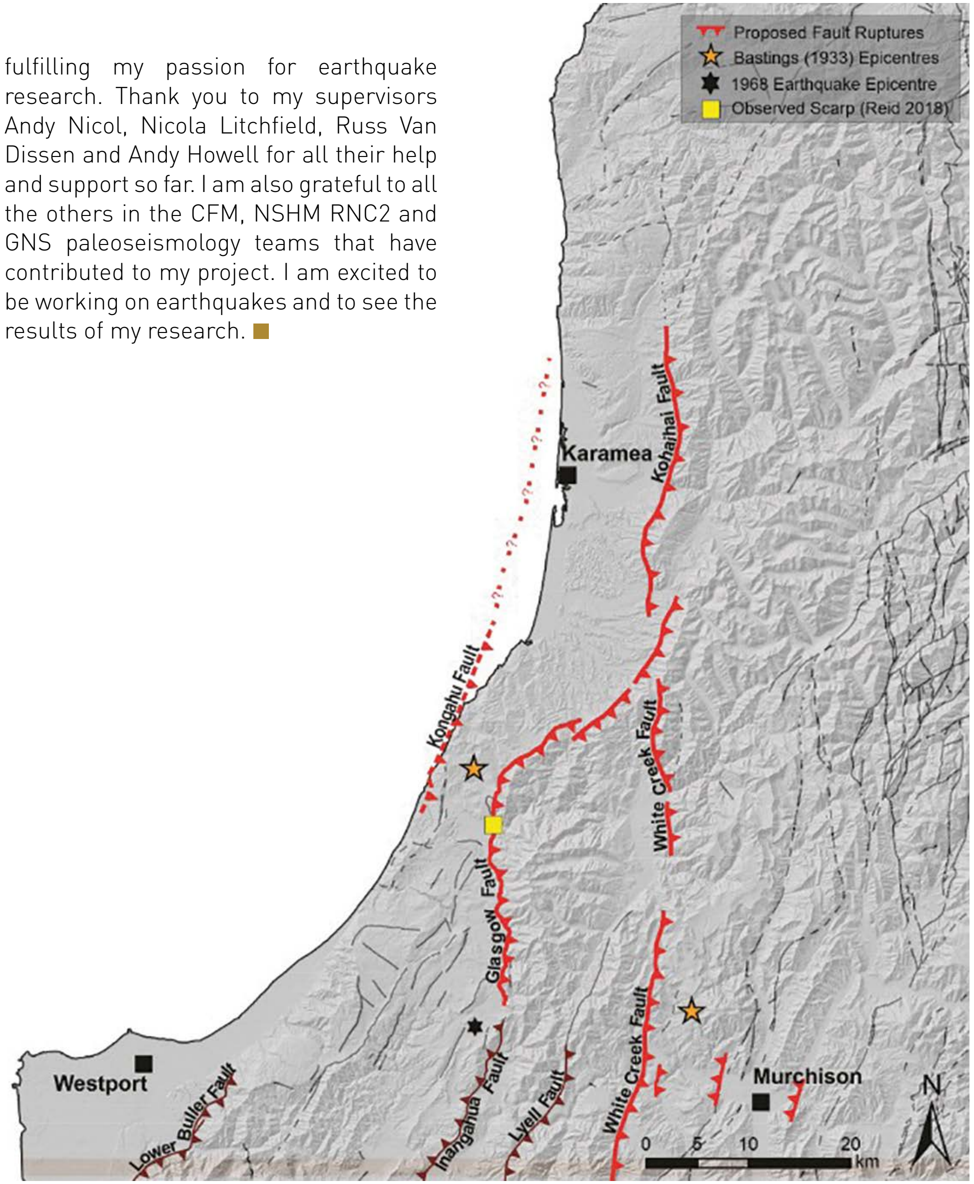

Figure 1: Faults that we propose may have ruptured in the 1929 Buller Earthquake are shown in bright red. Dark red faults are other mapped active faults in QMAP. Orange stars are epicentre locations (Bastings, 1933) and the black star is the location of the 1968 Inangahua epicentre. The yellow square is a potential scarp we have located that we believe is associated with the 1929 event. We are currently working to revise the epicentre locations of both the main and aftershocks.

SJ HASTIE AWARD

SUPERVISOR'S SUPPORT LETTER: JADE HUMPHREY

December 8th 2020

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

National Executive Committee
Geoscience Society of New Zealand
PO Box 7003
Newtown
Wellington 6242

Dear National Executive Committee,

Re: Jade Humphrey - SJ Hastie Scholarship awardee 2019 supervisors' support letter

Jade was awarded the GSNZ SJ Hastie Scholarship last year and is now completing an MSc thesis under my supervision at the University of Canterbury.

The year started slowly for most of us with the rapid onset of covid restrictions in March 2020. During the summer of 2019 and 2020 (and covid lockdown) Jade was able to progress work started in her MSc papers year to determine which fault(s) ruptured the ground surface during the 1929 Buller Earthquake. This work included multiple fieldtrips to the Murchison region to collect new data and re-examination of the literature on the earthquake. She presented this research as a poster at the 2020 GSNZ conference and was awarded the best MSc poster prize (an excellent effort on Jade's part). We have every hope that this work will be published in NZJGG in the coming year.

Due to the March-May 2020 covid lockdown (and subsequent restrictions on university activities) Jade started her MSc thesis in late May 2020, three months later than originally planned. She is making stellar progress in her MSc thesis. She has compiled all of the available geological and paleoseismic data for her study area and has commenced analysis of these data. In addition, Jade has started interrogating a synthetic earthquake catalogue and comparing synthetic and natural earthquakes for central New Zealand. To my knowledge such comparisons have rarely been attempted worldwide and her results could have global application. This work has required several trips to GNS Science in Lower Hutt where she has been collorating closely with Nicola Litchfield and Russ Van Dissen (who are co-supervising her thesis). Results to date are very encouraging and we are presently considering submitting an application for Jade to transfer her MSc thesis to a PhD.

I would like to take this opportunity to thank GSNZ for their support of Jade and, more generally, for their continued encouragement and support of post-graduate students in the field of earth sciences throughout New Zealand.

Yours sincerely,

Andrew Nicol

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AWARD WINNERS 2020

ANNOUNCED AT THE 2020 CONFERENCE DINNER

General Awards

Honorary Member:	Glenn Vallender
McKay Hammer:	Susan Ellis, GNS Science
Hochstetter Lecturers:	Darren Ngaru King, NIWA and Daniel Hikuroa, University of Auckland
New Zealand Geophysics Prize:	Fabio Caratori Tontini, GNS Science
Hayward Geocommunication Award:	Hikurangi Subduction Margin Project Team
Kingma Award:	Jane Chewings, Victoria University of Wellington
Wellman Research Award:	Marlena Prentice, University of Waikato
Harold Wellman Prize:	Jonathan Dale
Pullar-Vucetich Prize:	Callum Rees
Werner F Giggenbach Prize:	Sophie Gangl, University of Otago

Student Awards

Jim Ansell Geophysics Scholarship:	Bryant Chow, Victoria University of Wellington
SJ Hastie Scholarships:	
University of Auckland:	Sam Hudson
University of Waikato:	Ben Roche
Massey University:	James Ardo
Victoria University of Wellington:	Callum Whitten
University of Canterbury:	Matthew Parker
University of Otago:	Jakob Morgan

REMEMBERING CHUCK LANDIS:

A GSNZ TRIBUTE

A memorial event for Chuck Landis (1938–2020) was held on Saturday 13 February 2021 in the Waitati Hall, Waitati, north of Dunedin, bringing some closure to family, friends and colleagues. Chuck died peacefully in Dunedin Hospital on 11 July 2020 after suffering a stroke two days prior. A public funeral could not be held at the time because US family members could not get to NZ.

GSNZ wishes to compile a tribute to Chuck. This will be a stand-alone digital GSNZ Miscellaneous Publication with limited printing of hard copies planned for a nominal price of $15–20 per copy (incl. GST and postage). The final price will depend on the level of interest and the number of written tributes received.

Hamish Campbell has agreed to act as Compiler. In terms of style and content, it will be similar to the dedicated GSNZ Newsletter Issue 19A (2016) compiled by Cam Nelson in 'Remembering Bob Carter'. If you wish to prepare a written tribute to the memory of Chuck Landis, please communicate directly with Hamish at: h.campbell@gns.cri.nz. Please use the template for written tributes available from the GSNZ website: https://www.gsnz.org.nz/assets/MP15x_Landis_tribute_template.docx

Deadline for tributes is 30 June 2021. Publication is planned for July or August 2021.

HONORARY MEMBERSHIP

A THANK YOU FROM OUR IMMEDIATE PAST EDITOR

GSNZ Committee members, nominator(s) and Society members,

What an enormous honour and surprise it was to be awarded an honorary membership of this Society at the 2020 conference in Christchurch. I am thrilled that it not only recognises a personal lifetime commitment to Geoscience education (beginning for me in 1972), but also through this, acknowledges and honours the importance of this branch of geoscience to those earlier society members who firmly established GeoEd as an integral part of the wider geosciences and as a part of what this Society does. Although still with many significant challenges, it is very satisfying to see the Society and institutional growth in the understanding of the vitality of teaching and learning in the geosciences. It would be great to come back in 50 years' time to see where it is at.

Thank you to your committee(s) for enabling a longish stint (for me, under six different presidents) as editor of the Society newsletter. This has been challenging at times but immensely rewarding. Unlike the momentary social media of today, these newsletters chronicle the key histories and Society issues of the day, and in years to come, will be a valuable archival source of quaint historic information. Let's hope that the electronic archives will be readable in the future.

I have been privileged to have been able to make a contribution to this Society. Thank you for this opportunity. All that needs to be done now is to try and explain to people what dunite is.

With best wishes and thanks to all.

Glenn Vallender

(Honorary member 2020)

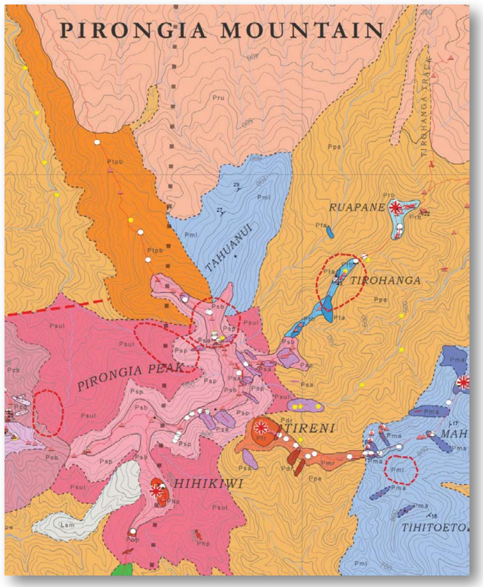
GEOLOGY OF PIRONGIA VOLCANO

GEOLOGICAL MAP REVIEW

Bruce W. Hayward

Geology of the Pirongia Volcano, Waikato: 1:30,000 Geological Map. Geoscience Society of New Zealand Miscellaneous Publication No. 156, 60 p. by Oliver McLeod, Adrian Pittari, Marco Brenna and Roger Briggs, 2020. $30 (order from GSNZ web site).

I recommend this map and its full-colour explanatory book to anyone planning a recreational visit to Mt Pirongia (great one- or two-day tramps in Pirongia Forest Park), southwest of Hamilton. Even if you are not planning a visit in the near future, I recommend you procure a copy. If, like me, you have often puzzled over why Pirongia and the rest of the Alexandra Volcanic Lineament exists perpendicular to the plate boundary and erupted unusual arc-related ankaramite basalts (and rare andesite) during the Plio-Pleistocene then this publication will answer many of your questions.



This is a truly magnificent publication presenting the results of some incredible geodetective research by Oliver McLeod, which was the basis for his recently awarded PhD from University of Waikato. The majority of the volcano is covered in thick soil and native forest with exposures limited to major ridge crests, inland bluffs and waterfalls between stretches of gravel in the radiating stream beds. Oliver used the excellent coastal cliff exposures of nearby sister volcano Mt Karioi as an analogue for helping to understand the possible complex relationships between the different packets of extrusive and intrusive rocks he was recognising and attempting to map.

To his credit, Oliver has combined volcanic facies mapping criteria (Appendix A), petrography, geochemistry and 12 radiometric dates, to recognise and map six stages (formally named as chronostratigraphic Members) in the volcanic edifice's history between 2.5 and 1.6 Ma (see Fig. 7 map summary; and map legend).

Most Members contain a package of lavas and vent-related rocks (dikes, domes, pyroclastics). The first three stages involved eruptions from three different vent areas. Stages IV and V were major sector collapses to the south (2.1 Ma) and west (1.7 Ma). The last phase saw reactivation of eruptions from the summit area and a large fissure eruption on the lower eastern flanks. The poorly exposed ring plain deposits are mapped separately as a multistage deposit.

It is a shame that GNS Science, the usual provider of geological maps in New Zealand, was unable to publish this work, presumably for financial reasons. It would have been a comfortable companion to their superb 1:60,000 geological map of Tongariro National Park (Townsend et al., 2017), 1:50,000 geological map of the Okataina Volcanic Centre (Nairn, 2002) and the classic maps of Taranaki Volcano (Neall, 1979), Banks Peninsula volcanoes (Sewell et al., 1992) and Dunedin Volcano (Benson, 1968). Faced with a similar situation as to this in the past, Waikato University itself has published 1:50,000 geological mapping by their staff and graduate students in the Bay of Plenty (Briggs et al. 1996, 2006). In 2020, the Geoscience Society of NZ is to be congratulated for picking up the ball and agreeing to be the publisher of this magnificent Pirongia map and accompanying book. It should be noted that publication was sponsored by GSNZ and Waipa District Council. The latter sponsorship allowed complimentary copies to be sent local museums, libraries and local schools.

The full-colour map has been produced at an unusual scale of 1:30,000 – the highest resolution possible to show all of Pirongia volcano on an A0 sheet. The map's boundaries are not rectangular but determined by the desire to show all of Pirongia's products (except for a poorly exposed area of distal sector collapse deposit in the south). The outcrop distribution of non-Pirongia Volcano rocks beneath and mantling Pirongia's eroded rocks is sourced from GNS maps. The map is printed on slightly more glossy paper than most maps, so only time will determine if it is more robust, especially along the folds. On the map the outcrop distribution of 36 new volcanic lithostratigraphic units are mapped, along with the location of studied exposures (x), a few strikes and dips, dikes, vent centres and sector collapse margins. Units formed during the same stage (Member) are shown in shades of the same colour/s, although it is difficult in places to distinguish between units of stages I and V1. This could have been clarified if the abbreviations for units in the same Member on the map started with either the same capital letter or stage number. Three cross sections below the map show the inferred internal structure of the volcano

> **I recommend this map and its full-colour explanatory book to anyone planning a recreational visit to Mt Pirongia (great one- or two-day tramps in Pirongia Forest Park), southwest of Hamilton.**

and also very nicely speculate the shape and elevation of the pre-eroded cones. Up to 400m is inferred to have been removed from the summit of the last-stage cone, making Pirongia Volcano New Zealand's largest post-Miocene terrestrial basalt volcano.

Not only did Oliver McLeod undertake all the fieldwork (usually alone though accompanied by his personal locator beacon) but he also plotted and interpolated the units into GIS layers from which the published map was generated. Hopefully GNS will now show interest in obtaining a copy to add to their public-good geological database from which new and improved one-off maps are provided.

The map is accompanied by a book detailing the geology and eruptive history of Pirongia Volcano. The reference to the publication has four co-authors with Oliver McLeod listed first. The cover of the book, however, states "McLeod with Pittari, Brenna, Briggs" as the authors. This unusual format undoubtedly reflects the real situation where Oliver did the mapping, map production and initial book writing. The two middle authors were his official PhD supervisors who I am sure provided sage advice, ideas and review. Oliver notes that Roger Briggs's contribution was immense through mentoring and providing a framework for the entire project based on all his 1980's work on the physiography, geochemistry and age of the volcano (e.g. Briggs, 1983, 1986; Briggs et al. 1989).

The authors set themselves a formidable challenge by targeting a broad audience ranging from volcanologists to local farmers, trampers, and high school teachers and students. The geological descriptions and discussions in the book are no less rigorous than most geological maps and do contain much terminology a layperson would struggle with or become bored by.

The introduction, summary and some other sections, like the box on basalts on p. 11, are well written at a level understandable by most enthusiastic non-geologists.

The numerous colour photographs, often with explanatory text and sketches over them and accompanied by sketches, detailed maps and cross-sections help explain the geology to non-specialist and specialist alike. For example the 1:12,500 map of the geology of the well-exposed summit ridges greatly complements the fold-out 1:30,000 map.

The book's introductory sections explain the objectives, the mapping methods, the local and regional geological and geodynamic settings with speculation on the cause of the Alexandra Volcanic Lineament. Like all books that accompany a geological map the bulk of the text and figures (30 pages) describe the map units. There is no glossary for the layperson but in this day and age definitions of all technical terms are readily available with a simple google search on the web.

The high quality of this production and the scholarship of the new research upon which the map and book are based will make this the "go-to" reference for Pirongia for many decades to come. It is also a model for future mapping of other complex and eroded terrestrial stratovolcanoes largely hidden beneath dense forest. ■

GEOSCIENCE QUIZ ANSWERS (from page 25):

Across: 1 Coral. 4 Andes. 5 Shear. Down: 1 Clays, 2 Ridge, 3 Laser.

Co-author and "father of Alexandra Volcanic geology" Roger Briggs (left) passes on the geological baton to first author Oliver McLeod of the next generation, beside a karst boulder of ankaramite on Mt Pirongia, 2020. The hammer did not touch this fine boulder.

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THE INTERNATIONAL UNION
OF GEOLOGICAL SCIENCES AND NEW ZEALAND

Nick Mortimer: Dunedin

The International Union of Geological Sciences (IUGS) is one of many global scientific unions which represent their disciplines on the world stage. Membership is through national geoscience societies, on a country-by-country basis, rather than being open to individuals. The Geoscience Society of New Zealand is one of about 120 national geoscience societies that is affiliated to the umbrella IUGS in this way, and GSNZ has appointed me as the current New Zealand National Delegate to IUGS.

In this article I explain a few things about IUGS, especially the opportunities it offers for us New Zealanders to network and collaborate internationally. For convenience, I have included numerous embedded hyperlinks;for hardcopy readers all the links can be found by starting at the home page of the IUGS website https://www.iugs.org/

What IUGS does

IUGS promotes and supports Earth Science research, especially that of world-wide significance and involving international cooperation. In this regard it is very much like a globally oriented GSNZ. As with GSNZ, the showpiece highlight of the Union is its major scientific meeting, the quadrennial International Geological Congress, and there is a small, elected Executive Committee that meets regularly and works behind the scenes. IUGS publishes the quarterly journal Episodes, as well as regular e-bulletins. Most IUGS work is done through topic-specific Commissions, Task Groups, and Initiatives - the equivalent of GSNZ's Special Interest Groups. Some of these are organised jointly with other organisations such as IUGG (International Union of Geodesy and Geophysics) and UNESCO (United Nations Educational, Scientific and Cultural Organisation).

New Zealand participation in IUGS-related activities

As of early 2021, New Zealanders contribute to several IUGS Commissions and Task Groups. While these are officially sanctioned by the IUGS Executive, they depend entirely on motivated individuals to progress their work and fulfil their purpose.

International Geoscience Program (IGCP)

IGCP is a joint initiative between UNESCO and IUGS; it was formerly known as the International Geological Correlation Programme, but now has a much wider scope than just stratigraphy. Hamish Campbell (GNS) is Chairperson of New Zealand's National Committee for IGCP, as well as being a panel member of ICGP Theme 3: Geohazards. New Zealanders have participated in at least two recently completed IGCP Projects: IGCP 628 Gondwana Map project and IGCP 632 Continental Crises of the Jurassic.

Ongoing New Zealand participation in IGCP includes Joshu Mountjoy (NIWA) in IGCP 640 S4LIDE (Significance of Modern and Ancient Submarine Slope LandSLIDEs). Joshu was a co-editor on one of the main outputs of IGCP 628, the 2020 Geological Society of London Special Publication GSLSP 500 'Subaqueous mass movements and their consequences: advances in process understanding, monitoring and hazard assessments' (this reminds me, IGCP has an arrangement with the Geological Society of London for the high profile GSLSPs to be the preferred publishing destination for papers arising from IGCP projects). Károly Németh (Massey U) is involved in IGCP 692 Geoheritage for Geohazard Resilience and has made contributions on the dilemma of geoconservation of monogenetic volcanic sites under fast urbanisation and infrastructure developments in Auckland.

IUGS Task Group on Igneous Rocks (TGIR)

In late 2020 IUGS approved a new task group to update the classification and nomenclature of igneous rocks. The group of 17 researchers is drawn from 11 countries and its Secretary is Georg Zellmer (Massey University). Announcements of the new group are just being made, and input to the group's work will be sought from igneous petrologists.

IUGS Commission for the Management and Application of Geoscience Information (CGI)

Mark Rattenbury (GNS Lower Hutt) is Councillor and Treasurer of the IUGS Commission for the Management & Application of Geoscience Information (CGI), the Chair and Member of CGI's Geoscience Terminology Working Group (GTWG), a member of/contributor to CGI's EarthResourceML Working Group, its GeoSciML Standards Working Group and also IUGS's new Deep-time Digital Earth (DDE) Project. Unsurprisingly, because of Mark's very active IUGS-CGI participation, GNS has been in the forefront of incorporating IUGS-CGI data standards into southern hemisphere geoscience datasets wherever possible. Important recent data releases from New Zealand that are GeoSciML compliant include bathymetric and tectonic maps of Te Riu-a-Maui/Zealandia at 1:8.5M scale and the Antarctic GeoMap project under Scientific Committee for Antarctic Research (SCAR) auspices which is a continent-wide Antarctic geological map dataset.

IUGS Commission on the History of Geological Science (INHIGEO)

The primary objective of INHIGEO involves promoting studies in the history of geological disciplines.New Zealand has played an active role through Mike Johnston who was on the board for eight years as Vice-President Australasia/Oceania. In 2020, Mike stepped down and was succeeded by Carol Bacon of Australia.

IUGS Commission on Global Geochemical Baselines (CGGB)

Adam Martin is the New Zealand representative of CGGB. GNS Science's five-year programme (2019-2024) on national geochemical baselines in soils continues. The New Zealand Trace Elements Group (TraceNZ) held its conference at the University of Waikato in February 2020.

Whitestone Waitaki Aspiring Global Geopark
In Nov 2019 the Waitaki Whitestone Geopark Trust submitted its final dossier to UNESCO. Field evaluation by UNESCO was originally planned for May 2020. However, due to the COVID-19 pandemic, the validation mission will be delayed until it is safe and straightforward for the evaluators to travel. The mission may be scheduled for May/June 2021. We are still optimistic about the eventual establishment of New Zealand's first Global Geopark.

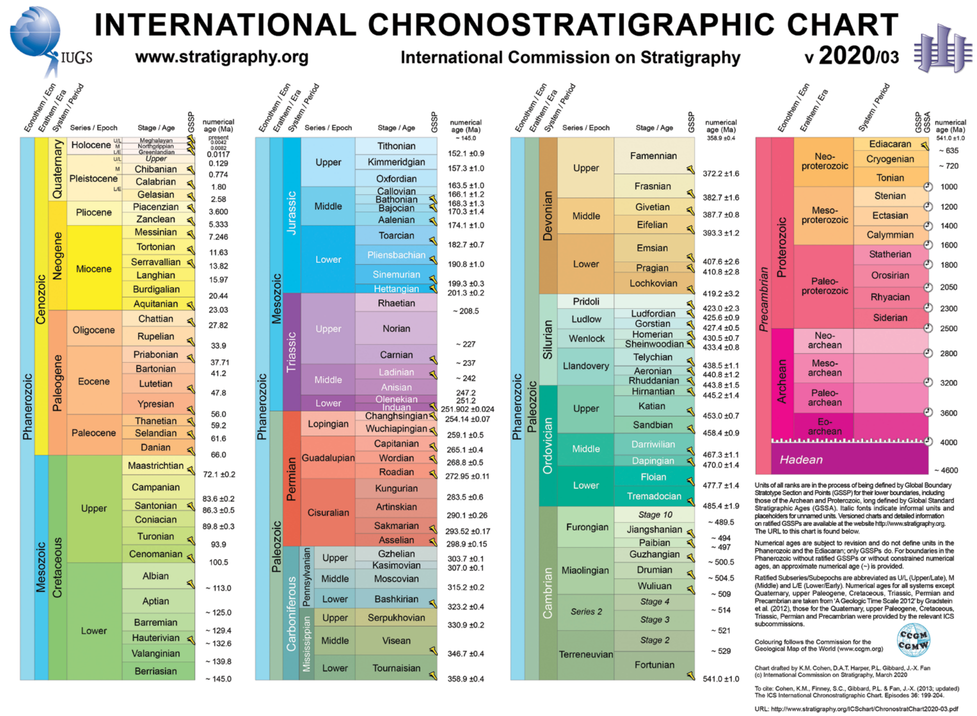
36th International Geological Congress, ~~New Delhi 2020~~
The quadrennial International Geological Congress is attended by thousands of geologists and is also the time when new a IUGS Executive is elected and many Commission and Task Groups business meetings take place.

Some readers may recall the successful 34th IGC which was held in Brisbane in 2012. The biggest disappointment of 2020 as regards IUGS and New Zealand was the repeated postponement of the 36th IGC. As a presenter and New Zealand IUGS delegate I was looking forward to going to New Delhi, India in March 2020 not just for the science meeting and cuisine but also to attend the IUGS Council meeting and to get a better handle on the range of IUGS activities and opportunities available to us. Because of COVID-19 the Congress was initially postponed until October 2020, and then August 2021. But it may now only take place as an online conference, or maybe not at all. We look forward to the 37th IGC planned for Busan, South Korea in 2024 and the 38th in St. Petersburg, Russia in 2028.

Potential for more New Zealand involvement in IUGS
I'd like to encourage more New Zealand participation in IUGS initiatives, to get maximum value from our membership. The advantages are two-way; we get the benefit of international linkages and I'm sure every IUGS project or task group appreciates scientific input from a country like New Zealand. There is certainly room for more participation in the aforementioned IGCP projects, commissions and task groups described above.

And, as far as I know, we are unrepresented in the following: ICS (International Commission on Stratigraphy), the body that brings us the International Chronostratigraphic Chart; TecTask. IUGS Commission on Tectonics and Structural Geology), COGE (IUGS Commission on Geoscience Education), ICG (IUGS Commission on Geoheritage), IFG (IUGS Initiative on Forensic Geology), ILP (the International Lithosphere Program, joint with IUGG). A couple of dozen IGCP projects are active and a full listing can be found on the IGCP website. A couple that might be of particular relevance to us are IGCP 636 - Geothermal resources for energy transition and IGCP 685 - Geology for sustainable development.

I am impressed at the depth and breadth of work undertaken by all these IUGS bodies. They are not just symbolic or prestige affairs, there is substance and advancement to them. There have to be some New Zealanders and GSNZ Special Interest Groups who could benefit from more or new connections with some of these. I'm here to encourage New Zealand participation. If you are already connected, and I don't know about it, please let me know.



IUGS Direction
In November 2020, John Ludden was elected IUGS President for the next four years. His manifesto to delegates emphasised that the geological sciences are at a turning point and risk being sidelined. The climate change community has been proactive in identifying the problem of climate change and John believes that IUGS has a major role to play in bringing people's attention to the need for new resources to achieve a NetZero-C economy. IUGS will make this point via its membership on the ISC (International Science Council).

IUGS, IGC, IGCP, CGI, ISC etc. It's easy to regard these acronyms as a soup of little relevance or benefit to us. However, life is what you make it. To misquote John Kennedy 'ask what IUGS groups can do for you and what you can do for IUGS groups'. New Zealand individuals and institutions can and should be internationally active and IUGS is a ready-made means to do that. I encourage you to follow the various links in this article to learn more and connect with the parts of IUGS that are relevant to you. Please keep me informed of your involvement in IUGS activities and contact me if I can help in any way.

FEATURE ARTICLES

EXTRAORDINARY WOMEN GEOLOGISTS

Chris Duffin: Scientific Associate at Natural History Museum, London

Report by Gordon Judge: Horsham Geological Field Club*

Chris came into our homes via Zoom to talk about that group of women, scattered through history since at least the 12th century, many of whose names do not readily come to mind in connection with geology. Indeed, it's only relatively recently that women have had a significant public presence in science. He began with a group of pioneers, in terms of both the science which they loved and the injustices they overcame.

Hildegard von Bingen (1098–1179)

Hildegard, a mediaeval nun, believed that God had put everything, including minerals and gemstones, on Earth for the benefit of its people. Because they had been formed through the combination of water and fire, they held corresponding powers and were promoted as remedies for bodily ailments. She built up a mineral collection from the locality and donations by travellers.

Martine Bertereau (c.1600– after 1642)

Martine Bertereau came from a noble French family in the Touraine who were traditionally engaged in mining. She married Baron Jean de Chastelet, an expert in mining. They spent 16 years travelling around Europe, seeking out sources of ores and water, both essential for the mining industry. In 1626, they were commissioned by the French king Henry IV to survey France for possible mine locations, but the clergy in Brittany suspected that black magic was being used (she had unwisely revealed that they used 'divining rods' to detect minerals), and were forced to leave France, although Louis XIII later invited them back. Her 1632 report listed 150 possible mining locations. In a poem, published later, she portrays herself as the latest in a line of women "expert in arts and speculative sciences". It also included a plea to be paid for the work, but this – and the suspicion of magical powers – led to them both being imprisoned until their deaths.

Etheldred Benett (1776–1845)

The half-brother, Aylmer Bourke Lambert, of Etheldred's sister-in-law was a keen fossil collector, which encouraged her to spend much of her life collecting and studying fossils that she discovered in south-west England. She worked closely with many principal geologists and her fossil collection, considered one of the largest at the time, played a part in the development of geology as a field of science. Gideon Mantell was so inspired by her work he named a Cretaceous ammonite, Hoplites bennettiana, after her. Although wealthy and with good (male) geological connections, her Wiltshire address, illness and family problems limited her involvement with the London-centred geological establishment. And confusion over her name sometimes led correspondents to conclude she was a man. As she wrote: "Scientific people in general have a very low opinion of the abilities of my sex".

Elizabeth Philpot (1780–1857) and sisters

Elizabeth's brother rented a house in Lyme Regis around 1705 for himself and his four sisters. Elizabeth and two sisters settled there for life, and began fossil hunting. William Buckland, a frequent visitor to Lyme, had seen their collection and introduced them to Mary Anning. One of Elizabeth's letters to Mary Buckland included a sketch of an ichthyosaur head, painted using ink from a fossil squid, found by Mary. The sisters' collection of around 400 fossils, includes more than 40 type specimens and is now in Oxford's Museum of Natural History.

Maria Graham (née Dundas, later Calcott, 1785–1842)

A travel writer and naturalist, Maria was particularly interested in botany, geology and mineralogy. Aged 18, she had engaged with scientists in Edinburgh society. In 1822, widowed, she experienced a series of earthquakes in Chile: her account of it in the Transactions of the Geological Society was its first contribution by a woman. "The whole shore is more exposed and the rocks are about four feet higher out of the water than before", she wrote, concluding that the earthquake was to blame. Charles Lyell cited it in his Principles of Geology, as it supported his own theory that earthquakes could cause uplift of the land; but another eminent (male) geologist, George Greenough, doubted that such measured observations could have been made under such conditions. When her second husband and her brother offered to duel Greenough, she is reported to have said: "Be quiet, both of you, I am quite capable of fighting my own battles, and intend to do it". Fortunately, Charles Darwin was later able to confirm her observations when he witnessed a similar event in 1835.

Mary Anning (1799–1847) ▲

Well, what don't we know about this geological heroine? But just in case there was something, Chris recommended a recently published book: The Fossil Woman: a life of Mary Anning, by Tom Sharpe (Dovecote Press, 2020).

Barbara Rawdon-Hastings (née Yelverton, 1810–1858)

Grandly titled '20th Baroness Grey de Ruthyn', after her father's early death, and 'Marchioness of Hastings' after her 1831 marriage, Bwarbara was an avid collector of fossils, specializing in vertebrates. In 1845, she married a naval captain, Hastings Reginal Henry, who took her maiden name of Yelverton. Some of the 1500-odd items in her collection, now in the British Museum, were (surprisingly?) praised by Richard Owen as "some of the finest in the world". She later

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*Editor's note: This report was published in Horsham Geological Field Club's Newsletter 'Stonechat' in December 2020 and results from a Zoom meeting talk given by Chris Duffin. It is reproduced here with permission. The content extends the theme of early women geologists beyond our times and our shores and sets the scene for Simon Nathan's New Zealand account on p68.

(bravely?) complained to Owen that he didn't look after his specimens properly. Geologist Edward Forbes described her as "one of the most excellent (and without exception the cleverest) woman I ever met" – a change from the more demeaning terms used for women geologists in the Victorian era.

Stressing how male-dominated the public face of geology was, Chris went on to mention women whose invaluable assistance to their better-known husbands or relatives was rarely acknowledged.

Mary Buckland (1797–1857) was a source of fossils and illustrations for George Cuvier and William Coneybeare and helped her husband by writing-up and illustrating his books. She amassed a vast collection of fossils and other specimens and taught in a village school in Islip, near the family's country home, where she died.

Mary Ann Mantell (1795–1869) famously spotted an Iguanodon tooth while husband Gideon was attending a patient. She also made many fine lithographs from Gideon's drawings.

Mary Elizabeth Horner Lyell (1808–1873) was the daughter of a professor of geology. In 1832 she married Charles Lyell. She was his scribe and translator, but her own speciality was conchology, having collected and categorised land snails in the Canary Islands. She also corresponded with Charles Darwin and Elizabeth Agassiz.

Charlotte Murchison (1788–1869) was studying science when she met her cavalry officer husband, Roderick. Roderick left the army and, after a few years of fox-hunting, Humphrey Davy and science writer Mary Somerville encouraged him to pursue science. While Roderick did surveys, Charlotte made sketches and did the fossil hunting, notably with Mary Anning at Lyme. When Charles Lyell refused to let women attend his lectures in Geology at Kings College London, Charlotte and Mary Somerville were part of the 300-strong crowd of men and women that responded by turning up to his second lecture. It is her presence that is said to have resulted in Lyell's capitulation.

Caroline Amelia Owen (1801–1873), having married Richard Owen in 1835, was never going to see her work acknowledged! Even Wikipedia has no separate entry for her, only the briefest mention in its entry for her father, William Clift, and Google can't come up with an image. Nevertheless, as with many others in this survey, she was an illustrator and translator for her husband.

Anne Phillips (1803–1862) was sister of John Phillips, professor of geology at Oxford. Her most notable geological achievement was in fieldwork which proved Roderick Murchison's theory of the origins of the Malvern Hills to be wrong: the Malvern ridge had formed before the Silurian seas deposited their sediments. Brother John generously wrote to her: "Whatever I possess is as much yours as mine, for without you I should not have won it".

Chris then introduced us to the 'graptolite girls': **Ethel Mary Reader Shakespear** (née Wood, 1871–1946) and **Gertrude Elles** (1872–1960) together wrote a monograph, British Graptolites, and **Nancy Hartshorne Kirk**.

Other recent geologists were: **Marie Stopes** (yes, she was also a serious and well-qualified palaeobotanist!); the NHM's fossil mammal curator **Dorothea Bate**, who identified the first Palestinian extinct elephant tusk (see Books below); **Inge Lehmann**, a Danish seismologist and geophysicist who discovered the discontinuity in the Earth's core; **Janet Vida Watson** published with, husband John, a major thesis on the Lewisian complex of north-western Scotland and, with Herbert Read, a 2-volume Introduction to Geology (see Books below); **Zofia Kielan Jaworowska**, a Polish palaeobiologist who worked extensively in the Gobi Desert and rose in the academic world to become Professor Emerita in Oslo University's institute of Palaeobiology; **Emily Rayfield**, Professor in Palaeobiology at Bristol; **Jane Francis**, Director of the British Antarctic Survey; and the late **Jenny Clack**, Professor of Vertebrate Palaeontology at Cambridge.

Chris ended with a quote from Dana Hunter, writer of a blog in Scientific American:

"Geology has many fathers, and we know them well. But few of us can name its mothers. Mothers who sacrificed far more than most of the men did - many women could only succeed in the geosciences if they remained unmarried and childless (and some organizations, like the British Geological Survey, made that a formal requirement). They fought discrimination and doubt. They worked hard for a fraction of the recognition their male colleagues got. Despite all the decks stacked against them, they made important contributions to our knowledge of the world. Forgetting the women who left us geoscience legacies is intolerable. We need to remember." ■

Books:
Discovering Dorothea, by Karolyn Schindler (HarperCollins, 2005; NHM, 2017)

Introduction to Geology, by H Read & J Watson, Vols 1 & 2 (Macmillan, 1962 & 1975)

Hunting for Dinosaurs, by Zofia Kielan Jaworowska (MIT Press, 1970)

The Role of Women in the History of Geology, edited by Cynthia Burek & Betty Higgs (Geological Society Special Publication 281, London, 2007)

Web links:
Animation of Mary Anning's story:
https://www.bbc.co.uk/bitesize/topics/zd8fv9q/articles/zf6vb82

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FEATURE ARTICLES

WOMEN IN NEW ZEALAND GEOSCIENCE

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Introduction

Geoscience, covering the related fields of geology, geophysics and physical geography, has traditionally been one of the most male-dominated areas of science. No woman was employed in geoscientific work in New Zealand until World War 2. A gradual change over the last sixty years means that women are now involved in most areas of geoscience, although generally still a minority. This paper has been prepared to record the pioneering efforts of a small number of women geoscientists in the second part of the twentieth century who paved the way for a second generation in the 21st century. It builds on two previous short articles (Nathan 1999 & 2006), as well as interviews and further research, and is an attempt to answer the challenge laid down by Hannah (2017) to ensure that the history of science fairly reports the contributions of both women and men.

Until the 1970s, social pressure limited career choices for professional women in New Zealand mainly to teaching and nursing. The few women who moved into science were restricted to fields such as mathematics, botany and entomology, which could be mainly carried out in the office or laboratory. There were also two specific factors that ruled out a career in geoscience for women:

1. Legislation passed in the nineteenth century, based on that in Britain, banned the employment of women underground or in quarries. Although regarded as socially progressive when introduced, this effectively blocked women from obtaining jobs in economic geology.

2. Most areas of geoscience involve fieldwork, and there were ongoing debates about the 'moral' aspects of a woman working outside by herself or in company For example, Daphne Suggate was keen to study geology at university in 1940, but was talked out of it, being told that she would never be allowed to do fieldwork (interview with SN, 1999).

Kolbl-Ebert and Turner (2017) have recently published a worldwide review of women in geoscience for the International Commission on the History of the Geological Sciences (INHIGEO) which provides a useful reference with which to compare experience in New Zealand. They raise several points that are relevant to this paper:

- Paleontology was one of the first areas of geoscience in which women could find employment;
- The earliest women geoscientists were often supported by a male relative or mentor;
- Women were sometimes employed as 'computers', undertaking lengthy or tedious computations in the days before the invention of electronic calculators.

Within New Zealand, most geoscientists were employed in the Department of Scientific and Industrial Research (DSIR). The Geological Survey, a branch of DSIR, included both geological and geophysical work until 1951 when Geophysics Division split off as a separate branch (Burton 1965; Hatherton 1980). In a major reorganisation of government science in 1992, DSIR was disbanded, and both geological and geophysical work was incorporated in the Institute of Geological & Nuclear Science, now known as GNS Science.

In order to limit the scope of this project, I have deliberately focussed on women working in positions designated as scientists rather than research assistants or technicians. As the project progressed, however, it became clear that the proportion of women employed as science support staff is approximately the same as those designated scientists. In contrast, there is a higher proportion of women employed in clerical roles or as librarians.

Nineteenth and early twentieth century

In their worldwide survey, Kölbl-Ebert & Turner (2017) outline the impediments to women obtaining university qualifications and employment in geoscience in the nineteenth and early twentieth centuries. They document a few exceptional women who had successful careers, as well as some who worked as unpaid research assistants and/or amanuenses to their husbands, brothers or other male geologists. So far I have been unable to find any similar examples in New Zealand – the small local geoscience community appears to have been entirely male prior to World War 2.

The New Zealand Geological Survey was reorganised in 1905 under the direction of J.M. Bell, with a strong emphasis on field mapping, and this tradition was maintained for the next 35 years. Geologists were expected to be in the field for at least six months every year, and worked in large field parties including surveyors, field hands and a camp cook. It was an entirely male environment akin to the army. Funding for fieldwork was reduced in the depression years of the late 1920s and early 1930s, with much smaller field parties, often limited to a single geologist and a student assistant. Doris Fyfe accompanied her husband Horace as cook and housekeeper during fieldwork for the Murchison and Kaikoura subdivisions, and was the first of many geological wives who provided unpaid support over the years.

Most universities in the UK and USA did not provide a supportive environment for women to study geoscience subjects, but there were exceptions. Newnham College at Cambridge contained a small geological teaching and research group under Gertrude Elles and Ethel Wood. In the late 1920s Elles supervised the PhD research work of Robin Allan (later professor of geology at Canterbury University), and a few years later Dorothy Hill (later professor of geology at the University of Queensland).

Within New Zealand each of the university colleges had a small geology department, generally only a single lecturer apart from Otago where geology was taught in association with the School of Mines. Although male students predominated, there were generally several women in first year classes as geology was regarded as a good background subject for geography teachers. Photographs in the University of Auckland centenary booklet (Brothers 1983) show both men and women on field trips. Mrs Bartrum (wife of the professor) regularly joined the excursions as a chaperone.

I can find only a single example of a woman who completed an undergraduate degree in geology before the war. Rose Bonner (later Mrs Wilson) started taking university classes at Auckland in 1925 while working as a pupil-teacher. She chose geology because the early evening classes could be fitted into her working day. When her final year results were announced in 1929 she was awarded a Senior Scholarship so she could study for a masters degree. Although Professor Bartrum encouraged her to take up the scholarship, she decided that she needed to earn her living, and embarked on a career as a science teacher (Mason 2010).

The DSIR did not employ any women as scientists until the late 1930s – it is unclear if this was official policy or simply an unstated understanding. Ruth Mason graduated with a degree in botany, but found that she could not get a job. Her father, a cabinet minister, worked behind the scenes, and thereafter applications from women were not automatically rejected (Hancock 2019).

A scan of the Bibliography of New Zealand Geology up to 1950 (Adkin & Collins 1967) illustrates the almost complete absence of research publications by women authors. I can find only two such papers, both undertaken overseas:

1. While studying at the University of Stockholm, botanist Lucy Cranwell undertook pollen analysis of cores from Southland, previously collected by Dr Carl Caldenius, the first work on Holocene vegetation changes in New Zealand (Cranwell & von Post 1936, Cranwell 1938).
2. In 1936 Danish seismologist Inge Lehmann used data from the 1929 Murchison (Buller) earthquake to infer that the Earth had a solid core (Kölbl-Ebert 2001).

The impact of World War 2

The outbreak of war in 1939 caused major changes in employment within New Zealand. As men were sent overseas for military service, opportunities for women opened up in what were previously thought to be male-only occupations. Until that time no women had been employed in the Geological Survey, but a small number of women were progressively employed in clerical positions and as technical assistants and cartographers. Although there was a critical shortage of geologists and geophysicists to aid the wartime search for strategic minerals (Burton 1965, p 79-80), no women were appointed to the scientific staff during this period, presumably because there was no-one available with appropriate training or experience.

Elsewhere in DSIR, the Director-General, Dr Ernest Marsden actively recruited young male scientists with a background in physics and mathematics to work on wartime projects ranging from the development of radar to munitions manufacture. He also employed two notable women geoscientists. With a degree in mathematics, Jean Bullen worked as a secondary school teacher. Her older brother, Edward Bullen was a seismologist with an international reputation, who would have been known to Marsden. Jean was recruited to fill a vacancy in the Magnetic Observatory in Christchurch (Fig 1). During the war years she travelled widely around New Zealand, making magnetic observations to provide accurate data for navigation. She later became a foundation member of Geophysics Division.

English-born Elizabeth Caldwell (Alexander) studied at Newnham College, Cambridge under Gertrude Elles, and was a contemporary of Dorothy Hill while they both completed PhDs in geology in the early 1930s. Married to New Zealand physicist Norman Alexander, the couple moved to Singapore where Elizabeth undertook research on tropical weathering, but at the outbreak of war she was co-opted into military research on radio direction finding (radar). In late 1941 she was sent to New Zealand to pick up urgently need equipment, but was stranded here after the invasion of Singapore in February 1942. Because of her expertise, Marsden recruited her to run New Zealand's Radio Development Laboratory where secret work on radar was being undertaken (Fig 1). A natural leader, Elizabeth Alexander ran her unit effectively for the next four years until she was reunited with her husband and returned to Singapore in 1946 (Harris 2017, 2019). Her departure was a loss for New Zealand as she would have been a role model as a science leader.


Fig 1. The first two women geoscientists employed by DSIR during World War 2. Left: Jean Bullen (source, North Shore Advertiser). Right: Elizabeth Alexander (source, Mary Harris). When appointed, Elizabeth was faced with the problem of what to wear to work. She chose a military look.

Until the 1960s, women's salaries were less than those paid to men, based on the argument that a man would be supporting a family. For example, in 1943 Elizabeth Alexander (who had three dependent children) was initially employed on an annual salary of £350. This compares with geologist Colin Hutton, also with a Cambridge PhD (a few years later than Elizabeth) who was on a salary of £515, but with considerably less responsibility.

Post-war pioneers, 1946-59

The Geological Survey expanded rapidly after the war under new Director Mont Ongley, with demands for coal, hydro-electric development and geothermal energy. Ongley actively recruited new staff, including a group of young British geologists, who were entirely male. Jean Luke was a pioneer who had completed an MA in geography with a thesis on land-use in the Wanganui area. Initially employed as a technician at Rotorua, she moved to Wellington so that she could take advanced geology papers at Victoria, and was then reclassified as a scientist. Jean worked on groundwater exploration, and recalled that Ongley was supportive of the few women staff, but she encountered problems in 1952 when Ongley retired and was replaced by Grange. He vetoed a proposal for her to undertake a groundwater project for a dairy company, saying that it would be an insult to send a woman to meet the manager (Jean Luke, interview with SN, 2001). Thereafter she was confined to the office where she worked as a scientific editor.

Three of the earliest appointments of women scientists within the Geological Survey were as paleontologists. All came from a similar background, with a BSc in biological sciences. Shona Bell (employed 1948-50) worked on fossil leaves in an attempt to aid the dating of late Cretaceous and early Cenozoic coal measures. She married geologist Tom Grant-Taylor, and resigned as was expected in those days. Heather Leed (employed 1947-53) worked on fossil corals, including the first identification of Permian corals in Northland, and also resigned when she was married. Anne Boreham (employed 1957-63) worked on Tertiary mollusca, and married micropaleontologist George Scott.

An account of the 1952 Geological Survey conference in the Weekly News of 14 May 1952 included a paragraph on 'Women in Geology' mentioning Jean Luke, Heather Leed and Mabel Rice (DSIR science editor) (Fig 2). The writer clearly did not place much importance on their work as the following paragraph notes "the fascinating and useful work of the band of highly-qualified men" who made up the Geological Survey (Johnston & Nathan 2017).

After the war a small number of women studied geology at university to advanced levels. Hope MacDonald (later Hope Sanderson) started at Auckland University College in 1945, completing her BSc in geology, and was encouraged by Professor Bartrum to undertake an MSc on the petrography of the Jurassic conglomerates at Kawhia. Her MSc in 1951 was the first postgraduate degree in geology by a woman at a New Zealand university. She later worked as a technician in the Geology Department for several years before travelling overseas (Sanderson 2010; Black 2017). Inspired by the example of Hope MacDonald, Heather Halcrow (later Heather Nicholson) undertook a field-based MSc thesis, mapping the whole of Waiheke Island, which she later published (Halcrow 1956; Nicholson 1999).

Fig.2: Three woman scientists at the 1952 Geological Survey Conference. From left, Mabel Rice (scientific editor, Heather Leed (paleontologist), and Jean Luke (assistant geologist). Source: *Weekly News*, 14 May 1952.

Fig. 3: Two leading women geoscientists. Left, Joan Wiffen with the humerus of a new species of elasmosaur she described, Turangisaurus keysi (Source, GNS Science, VML 4462). Right, Alva Challis with her microscope (Source, S. Nathan collection).

Although a small number of women geoscience graduates were looking for work in the 1950s, none were recruited as scientists within the Geological Survey or Geophysics Division. Alva Challis (Figure 3), who had trained in the UK as a radiographer, joined the Petrology Section of the Geological Survey in 1958 as a technician. She studied part-time at Victoria University, completing a master's thesis on the geology of the Mt Lookout area in Marlborough. Harold Wellman was one of her supervisors, whom she remembered treating her like an honorary man. But when it came time for him to visit her in the field, she was startled to find that he was accompanied by Professor Bob Clark, who had previously shown little interest in her work, but was presumably there as a chaperone (Nathan 2005, pp 167-168).

During this period and subsequent years, several women acted as unpaid research assistants to their geologist husbands. Joan Wellman regularly accompanied Harold in the field, collecting fossils, compiling maps and acting as driver and navigator (Nathan 2005). Similarly, Peg Fleming worked closely with Charles in his geological and biological activities (McEwen 2005, Fleming 2014), and Daphne Suggate worked as a field assistant with Pat (Suggate 1999). Although they contributed substantially to many projects, none were included as co-authors in published papers or reports.

Increasing opportunities in the 1960s

One of the most significant changes in the 1960s was the employment of women in teaching positions in the universities who were able to act as role models to their students. Jane Soons was appointed as a lecturer in physical geography at Canterbury University in 1960, and the following year Dawn Rodley (subsequently Dawn Beck) was appointed assistant lecturer in paleontology at Canterbury. Later appointments included Philippa Black (geology, Auckland) and Alexa Cameron and Jocelyn Campbell (geology, Canterbury).

Alva Challis was awarded a post-graduate scholarship to study at Cambridge and completed her PhD in 1963 on the petrology of ultramafic rocks from New Zealand – the first geoscience doctorate by a New Zealand woman. Using the newly developed electron microprobe she discovered and described the microscopic mineral wairauite. On return to New Zealand in 1963 she married her former lecturer, Ross Lauder. They worked at different organisations, and social conventions had changed, so she was not pressured to resign, change her name, and give up her scientific work as had happened in earlier generations. In 1965, the centenary year of the Geological Survey, Alva Challis was the only woman scientist employed in that organisation, and this was not to change for several years.

Fig. 4: Two of the first women geologists to undertake projects involving extensive fieldwork. Heather Nicholson (neé Halcrow)(left) mapped Waiheke Island for her MSc thesis in 1953., and Jocelyn Campbell (neé Adamson) mapped a rugged, bush-covered area near Lake Rotoiti for her MSc thesis in 1964.
Photo: Simon Nathan, taken at the 2005 Geological Society of New Zealand conference.

Traditionally postgraduate research to PhD level was undertaken overseas, but from the 1950s onwards such work could be undertaken within New Zealand. Dawn Seed completed her PhD in 1964 on the mineralogy and environment of New Zealand glauconites (Canterbury), and in 1967 Philippa Black completed her PhD on the Paritutu and Cuvier plutons in Coromandel (Auckland). These research degrees were significant because they clearly demonstrated that there was no longer a shortage of well qualified women geoscientists within New Zealand.

Some aspects of geophysical analysis involve considerable routine work and calculation, and from the early 1960s onwards young women technicians were employed in Geophysics Division. Within the Seismological Observatory they undertook the work of identifying earthquakes from paper records and making preliminary estimates of epicentres for the annual New Zealand Seismological Record. Major or complex earthquakes were calculated by more experienced male seismologists after the technicians had done the background work (Chris Locke, pers. comm. 2019). Another group of primarily female technicians worked on the 1:250,000 gravity survey of New Zealand supervised by Ian Reilly who considered that young women were more conscientious and productive than young men. He involved his staff in all aspects of the project, including planning, fieldwork and data reduction as well as including them as co-authors of the published maps (Christine Whiteford, pers. comm 2019). Although this worked well, concerns were expressed by some older staff about the safety of young women undertaking fieldwork (T. Hurst, pers comm 2019). Margaret Cowan was the sole woman geophysicist classified as a scientist during this period, preparing several papers on aspects of gravity analysis.

Although several women had been employed as paleontologists within the Geological Survey after the war as noted in the preceding section, there was a subtle change about 1960. Although there was a major expansion in the paleontology group, no women were appointed to scientific positions for over 30 years although there were women applicants. All of the approximately 15 appointments during this period were male. It is hard to escape the conclusion that those making recruitment decisions felt that women were likely to leave after a few years, so they were not seriously considered.

Revolutionary times, 1970 to 1992

The 1970s was a period of considerable change in the geosciences, with the recognition that plate tectonics provided an explanation for past and present crustal movements. Tanya Atwater, a young American geologist was a prominent advocate of plate tectonics, with her well-publicised work on sea-floor spreading and the crustal evolution of western North America, providing a powerful demonstration that a woman was involved in major scientific discoveries.

From the 1970s a small number of younger women graduates were appointed to a variety of geoscience positions: Julie Palmer was a geologist with Petrocorp, the government-owned exploration company; Sarah Beanland was appointed to the Earth Deformation group within the Geological Survey; Margot Syms and Helen Anderson were employed by Geophysics Division; and Diane Seward undertook fission track dating at the Institute of Nuclear Sciences. Although it was becoming accepted that women could undertake scientific work, all found difficulties as they worked in isolation, and found that they were constantly under scrutiny.

Apart from Julie Palmer, it proved almost impossible for women to get employment in economic geology within New Zealand. The prohibition against women working in mines and quarries was still in force, and not effectively repealed until the 1990s. A small number of graduates, including Nola Walker from Otago, left for Australia where they were able to obtain employment in mineral exploration. The School of Mines (originally at Otago, but moved to Auckland in 1987) had traditionally been wholly male, but a few women enrolled in the late 1980s. One of these, Marianne Rogers, found that it was almost impossible to get underground practical experience – the local mine manager at Huntly where she was employed claimed that it would cause trouble with the unions if she was allowed to go underground - so she moved to Australia where she gained her Mine Manager's certificate (Priestley 1991).

Joan Wiffen was a keen amateur geologist. In December 1972 she visited Mangahouanga Stream in Hawkes Bay where fossil reptile bones had previously been noted. She was astounded that no one was working on these fossils and spent the next 35 years extracting and describing them. She found a range of fossil reptiles, including plesiosaurs and mosasaurs, and discovered the New Zealand's first dinosaur bone in 1979. She published her work in local and international journals, and became a recognised expert on Cretaceous reptiles (Martin 1993, Nathan 2018). Joan was a outlier compared to other women geoscientists mentioned in this paper as she had no university education – perhaps an advantage as she might otherwise have been discouraged by the difficulties of vertebrate paleontology. Her achievements are remarkable because she was largely self-taught, and driven by determination to collect and describe her unique fossils.

The late 1980s were marked by a major reorganisation of government departments, with a substantial number of redundancies within DSIR, eventually leading to the formation of the Institute of Geological & Nuclear Sciences (now GNS Science) in 1992. Although there had been some progress in employing women in previous decades, the final report of DSIR Geology & Geophysics (formed by the amalgamation of the Geological Survey and Geophysics Division in 1990) in 1992 listed only 5 women scientists compared to 126 men.

Into the 21st century, 1992-2020

The 1993 New Zealand Official Yearbook, marking the centenary of womens' suffrage, optimistically stated (p 292) that, "Life as a woman scientist looks more promising in 1993. The restructuring of government science over the last five years has left all scientists feeling very insecure and has removed the security of long-term employment. We believe that women can complete well in this new environment. While women tend not to be strong negotiators, employment contracts can offer increased flexibility in working arrangements. With the predicted shortage of scientists worldwide in the next decade, opportunities can only increase for women in science" (Fleming & Davenport 1993). What the statement did not mention was that the majority of redundancies in the preceding years had been of older men, thus opening some opportunities for younger women.

The period from 1993 onwards has certainly seen a gradual increase in the number and proportion of women in geoscience. In part this has been due to gradual social acceptance as has happened in other conservative professions such as engineering and law, but an additional influence has been the provision in Section 17 of the Crown Research Institute Act (and similar legislation covering other government bodies and universities) that every annual report must include details of the impact of their equal opportunities programmes, thus putting pressure on management to demonstrate progress. For GNS Science the change can be seen in the following figures showing the increasing percentage of women scientists:

1992:	4%
2005:	17%
2019:	38%

An article compiled by the present writer in GSNZ Newsletter 129 (November 1999, pages 8-16)), under the heading "Geological Herstories", included contributions by 23 women geoscientists, and was a striking demonstration of the employment possibilities that had opened up since the 1980s.

An analysis of women academic staff in university geoscience departments in 1998 showed that while women made up just under 20%, they dominated in junior positions, and several were working part-time or on short-term contracts (Nathan 1999). For example, Daphne Lee was employed initially on short-term contracts because Otago University would not recognise permanent part-time positions. Over the succeeding 20 years the proportion of women in senior positions has slowly increased. In 2020 women make up at least 50% of almost all geoscience classes, so there will be no shortage of qualified women geoscientists in the future.

The McKay Hammer, the major award by the Geoscience Society of New Zealand for research excellence, had always been awarded to male geoscientists until 2014. The winners for the next four years were all women (Julie Rowland 2015, Helen Bostock 2016, Daphne Lee 2017, and Laura Wallace 2018).

Although women gradually made progress within geoscience, it was as individual scientists rather than in senior administrative or management roles. Before the 1990s there was a reluctance from senior management for women to be in charge of men, but this gradually changed so that the following landmark appointments can be noted:

- In the 1990s Philippa Black and Jane Soons were both appointed administrative head of their respective departments;
- Julie Palmer was the first woman president of the Geological Society of New Zealand in 2002-03
- Helen Anderson was Chief Executive of the Ministry for Research, Science & Technology from 2003-10, and has subsequently held senior governance roles in a number of organisations;
- Nicola Crauford has been Chair of the Board of Directors of GNS Science since 2015.

Women in Antarctic geoscience

Although New Zealand has played an important role in exploring the geology of the Ross Sea and Transantarctic Mountains, this was traditionally a male-only area. During the International Geophysical Year (1957-58) there was a period of concentrated geophysical work at Scott Base. Jean Bullen spent considerable time preparing instrumentation for upper atmosphere observations, but to her great disappointment she was not able to visit Scott Base and make any observations herself. Her role was restricted to preparing the instruments, training the male observers how to use the equipment, and later interpreting the results.

Despite the restriction on women working in Antarctica, Dawn Rodley was selected for a Victoria University geological party in 1958, but the US Navy (which provided transport to and from Antarctica) refused to accept her. This prohibition continued until 1969 when they agreed to allow an all-woman party from Ohio State University's Institute of Polar Studies to work in the Dry Valleys. This party included Eileen McSaveney, who subsequently settled in New Zealand (McSaveney 2020). A Victoria University party the following year included Rosemary Askin, a paleontologist who later returned to Antarctica several times.

Margaret Bradshaw first visited Antarctica in 1975 to collect rocks and fossils for the new Antarctic Hall at Canterbury Museum. She subsequently organised nine return trips to Antarctica, collecting fossils from the Devonian Period from different areas.

Despite initial reluctance to allow women to visit Antarctica, they are now routinely included in field parties and research programmes.

Conclusions

Before World War 2 there were no women employed in the geosciences in New Zealand. Changes in social attitudes during and after the war meant that women were able to enter a wider range of professions, but it took several decades before there were many women with Tertiary qualifications in geology, geophysics and physical geography. By 1990 there were a small number of women employed in most areas of geoscience, but they often worked in isolation, with little or no management responsibility.

In the first two decades of the 21st century there has been a steady increase in the number of women employed in geoscience, and a few have achieved positions with significant responsibility. Apart from changing social attitudes, a major factor in the increasing employment of women is the requirement that public sector organisations report regularly on the effectiveness of their equal opportunity plans, encouraging managers to takes this more seriously.

As the proportion of women students in most university geoscience courses is now at or above 50%, it is likely that the proportion of women employed in geoscience will continue to increase.

APPENDIX: Biographical notes on pioneering women geoscientists in New Zealand

The following list contains biographical data on fifteen women who were pioneers in different aspects of New Zealand geoscience in the twentieth century. It has been arranged in chronological order. There is remarkably little written information about women geoscientists. Although the five volumes of the Dictionary of New Zealand Biography, published between 1990 and 2000, contain entries on 40 male geoscientists, it includes no women; an online entry about Joan Wiffen was added in 2018. It is hoped that this compilation may lead to further documentation of New Zealand's women geoscientists.

Jean Bullen (1918-2002)

Having completed a BA in mathematics and philosophy, Jean trained and worked as a teacher. Her career changed dramatically in 1942 when she was recruited for wartime service in the DSIR Magnetic Survey. She travelled widely around New Zealand making magnetic observations to provide accurate magnetic declination data for a new series of topographic maps then being produced. After the war she was transferred to Western Samoa for two years as assistant director of the Geophysical Observatory in Apia. When she returned to New Zealand she joined the Christchurch Geophysical Observatory, specialising in upper atmosphere research. She was highly involved in planning and interpretation of data collected during the International Geophysical Year (1957-58), and published several papers. She retired early in 1968 to look after her elderly parents. After their deaths she returned to teaching in the late 1970s.
Source: North Shore Times Advertiser, 22 January 2002, p 5.

Elizabeth Alexander, neé Caldwell (1908-58)

After spending her early years in India, Elizabeth was sent to the UK as a 'colonial orphan' for her education. She obtained entrance to Newnham College, Cambridge where she intended to study natural sciences but later changed to geology, in which she was one of the earliest women to complete a PhD. At Cambridge she met and married New Zealand physicist Norman Alexander, and in 1935 they moved to Singapore. Elizabeth's early research was on local geology and tropical weathering, but at the outbreak of war in Europe she began work for the Royal Navy at Singapore naval base on radio direction finding, the term used as a cover for the new technology of radar. In January 1940 she was ordered to take her three children to the safety of New Zealand and return with urgently-needed equipment, but was stranded here after the fall of Singapore in February. Because of her expertise, Marsden recruited her to set up a new Operational Research Section in New Zealand's Radio Development Laboratory where secret work on radar was being undertaken – the first woman scientist in a management position in New Zealand. She returned to Singapore with her husband in 1946, and they subsequently moved to Nigeria where she died in 1958. Her research on tropical weathering was published posthumously.
Source: Harris (2017 & 2019).

Jean Luke (1921-2016)

Jean studied at Canterbury University College, and was one of the first women to complete an MA in geography (with a thesis on land-use around her home town of Wanganui). She obtained a job as a technician at the Rotorua office of the Geological Survey in 1946, assisting in fieldwork and measuring temperatures in boreholes. She transferred to Wellington so that she could take advanced university papers in geology, and was subsequently reclassified as a scientist. Initially she worked on groundwater investigations but, to her regret, was moved to scientific editing where she was responsible for the production of many NZ Geological Survey monographs in the 1950s and 1960s. In 1969 she was seconded to the Geological Survey of Iran where she worked as a scientific editor for a decade until she retired and returned to New Zealand.
Source: Interview with SN, 2001.

Joan Wiffen, neé Pedersen (1922-2009)

Joan spent her childhood in rural parts of the King Country and Hawkes Bay. Her education was partly by correspondence and partly at local primary schools, finishing when she was aged 12. During World War 2 she joined the Woman's Auxiliary Air Force, where her abilities were quickly recognised, and she was trained and worked as a radar plotter. In 1953 she married Pont Wiffen, and worked on their small landholding. In the 1960s the Wiffens became keen amateur geologists. Joan heard of a remote locality in inland Hawkes Bay where reptile bones had been discovered. In December 1972 they visited Mangahouanga Stream and saw the fossils. Joan was astounded that this locality was almost unknown, and extracting and

working on the fossils was to be the focus of her life for the next 35 years. By patient and painstaking work she extracted plesiosaur and mosasaur fossils, taught herself the fundamentals of vertebrate paleontology, and described the fossils with the aid of overseas experts. In 1979 she found the first dinosaur bone from New Zealand, and subsequently found fragments of other dinosaurs. From the 1980s onwards she was recognised as the expert on New Zealand's Cretaceous reptiles. She was awarded an honorary doctorate by Massey University in 1994 and a CBE in 1995.
Sources: Wiffen (1991), Martin (1993), Nathan (2018).

Hope Sanderson, neé MacDonald (1925-2016)
Hope was raised on a farm near Colville, at the tip of the Coromandel Peninsula. Studying for a BSc at Auckland, she decided to major in geology. She enrolled for an MSc, and for her thesis undertook a petrographic study of the Jurassic conglomerates at Kawhia – the first woman to undertake geological postgraduate study in New Zealand. She subsequently worked as a technician for almost five years in the Geology Department, and prepared her thesis for publication (MacDonald 1954). After travelling to the UK, she was offered a position undertaking petrographic work with the British Geological Survey. In 1964 she married Robin Sanderson, a fellow petrologist, and was forced to resign her position as was customary in those days.
Sources: Sanderson (2010), Black (2017)

Alva Challis (1930-2010)
Born in Wales, Alva studied radiography before emigrating to New Zealand with her family in 1952. Initially she worked as a radiographer in different hospitals before joining DSIR as a technician. Studying part-time at Victoria University, she completed a BA in geology and Russian before undertaking a masters thesis on the geology of the Mt Lookout area in Nelson. By this time she was working as a petrologist with the Geological Survey, and she was subsequently awarded a DSIR scholarship to undertake a PhD at Cambridge. She studied New Zealand ultramafic rocks, and discovered the new mineral Wairauite using the electron microprobe. On return to New Zealand she married her former lecturer, Ross Lauder, and they often worked together in the field, especially in the Longwood Range in Southland and the area around Lake Rotoroa in the Nelson Lakes district. With her background in radiography, she experimented with the use of X-rays in the analysis of rocks and minerals. Over the years she worked on a variety of petrological problems, including identification of unknown minerals, identification of drillhole cores, and possible contamination of samples collected by prospectors. She retired to live at Motueka in 1995.
Sources: Smale (1995), Watters (2011)

Jane Soons
Born in England, Jane won scholarships to her local grammar school and later to the University of Sheffield. In 1958 she was the first woman PhD graduate in geography at the University of Glasgow, and in 1960 was appointed lecturer in geography at the University of Canterbury – the only woman member of staff in her department for many years. Her research and that of her students focussed on the glacier-sculpted landscapes of the South Island and changing climates during the Quaternary period. In 1971 she became the first woman professor at the University of Canterbury, and was head of department from 1990 until her retirement in 1993. She served as president of the International Union of Quaternary Research, and was awarded an honorary DSc by the University of Glasgow in 2009.

Sources: Wikipedia, Hanson (2009)

Heather Nicholson, nee Halcrow (1931-2019)
Studying physical geography at school led Heather to enrol at Auckland University in 1949, graduating with a BSc in geology. She embarked on an MSc thesis on the geology of Waiheke Island, working alone and staying at local farmhouses. Although she was the first woman in New Zealand to undertake a major geological mapping project, she never felt that this was difficult or unusual. No jobs in geology were available when she graduated, so she took up a teaching career, eventually becoming head of science at Westlake Girls High School. In the 1970s she moved into craft work, writing the award-winning book, "The Loving Stitch: a history of knitting and spinning in New Zealand". She decided to revive her scientific career, undertaking a PhD on the history of greywacke rocks in New Zealand, and graduated in 2003, exactly 50 years after completing her MSc degree.
Sources: Nicholson (1999), Obituary in Dominion Post 30/7/2019

Philippa Black
After attending New Plymouth Girls' High School, Philippa enrolled at Auckland University, graduating MSc in 1964 with a thesis on the igneous and metamorphic rocks of Tokatoka in Northland. Subsequently she completed her PhD on the petrology of the Cuvier and Paritutu plutons in northern Coromandel. A post-doctoral fellowship from the NZ Federation of University Women allowed her to study in the US, and she was then appointed lecturer in geology at Auckland University. Her research in later years covered petrological aspects of rocks in Northland and New Caledonia as well as microscopic studies of New Zealand coals. In 1986 she was appointed professor, and was head of the Geology department for 15 years. After being elected a Fellow of the Royal Society of New Zealand, she became president of the society from 1993-97, the first woman to hold that position, and was awarded a CZNM for her services to science. Since retiring she has completed a PhD in history on the nickel mining industry in New Caledonia (Black 2015) and studied the properties of engineering aggregates. In 2013 she was elected Companion to the Institution of Professional Engineers (IPENZ).

Margaret Bradshaw
Despite discouragement from teachers, Margaret was keen to study geology, and was the first woman to be accepted in geology at Queen Mary College, University of London. She moved to New Zealand with her husband in 1976. Appointed curator of geology at Canterbury museum (and later deputy director) , she initially worked on Devonian strata in the South Island. She first visited Antarctica in 1975 to collect rocks and fossils for the museum's Antarctic display, and has returned nine times, studying Devonian fossils and sedimentation. From 1999 she became a Senior Research Fellow in Geological Sciences at the University of Canterbury. She was awarded a DSc from the University of London for her published work She served as president of the New Zealand Antarctic Society for ten years and was awarded a Polar Medal by the New Zealand government. She has also lectured on 11 Antarctic tour cruises.

Diane Seward
Diane studied for a BSc at the University of Wales and an MSc at McMaster University in Canada before moving to New Zealand with her husband. She completed a PhD at Victoria University in 1974 on tephras in the Wanganui basin, undertaking some of the earliest fission track dating in New Zealand. Subsequently she was employed at the Institute of Nuclear Sciences, DSIR, where she expanded her work on fission

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track dating to cover uplift of older rocks. After moving to ETH, Zurich, she worked on a number of projects involved with analysing tectonic uplift in China, the Himalayas and the European Alps, and has continued this work since returning to Victoria University.

Eileen McSaveney
At the State University of New York at Buffalo, Eileen was the sole woman in her undergraduate geology class. She subsequently studied at Ohio State University, completing a PhD on glaciofluvial gravels in Ohio. In 1969 she was invited to join an all-woman party in the dry valleys of Antarctica as a field assistant to the first group of women geoscientists to work in Antarctica. She returned in the 1971-72 summer to assist with fieldwork on Meserve Glacier in the Wright Valley (McSaveney 2020). Married to a New Zealand geologist, she moved to Christchurch with her husband, and taught evening classes on a variety of geoscience topics. Subsequently she worked as a freelance science writer, and was associate editor of the New Zealand Journal of Hydrology for many years. She has written several articles relating to geology and natural hazards for Te Ara, the online Encyclopedia of New Zealand.

Daphne Lee
Daphne was raised on a farm in Southland and studied geology at Otago University where she completed a PhD on fossil and living brachiopods. She was the first woman to be appointed to the academic staff of the Geology Department, University of Otago, and later appointed Associate Professor. She has supervised many post-graduate research students, and in recent years she has led a research group on the very rich fossil faunas and floras of maar deposits in Otago. She was awarded the McKay Hammer by the Geoscience Society of New Zealand in 2017 for her research. The recent campaign to save Foulden Maar is underpinned by the research done by Daphne and her group. She has had a long involvement with the Geological Society of New Zealand, both as secretary and convenor of its Geological Education special interest group.

Helen Anderson
After studying geophysics at Otago and Auckland Universities, Helen joined Geophysics Division, DSIR. She specialised in the seismology of large earthquakes, and completed a PhD at Cambridge University in 1985 on the seismotectonics of the western Mediterranean. From 1997-2003 she was Chief Science Advisor at the Ministry for Research, Science & Technology (MoRST), and from 2004-10 was Chief Executive of that organisation. She was awarded a QSO in 2010 for her services to science. Since then she has worked as an independent director, serving on the boards of Scion, Building Research Association (BRANZ), Antarctica New Zealand, NIWA, Fulbright New Zealand, and Dairy New Zealand. She was also Pro-Chancellor of Massey University, and is a Fellow of the Institute of Directors and a Companion of the Royal Society of New Zealand.

Julie Palmer
After graduating MSc from Victoria University, Julie was appointed as an exploration geologist to Petrocorp (later Fletcher Petroleum) where she became Regional Manager for SE Asia from 1989-92. After a period as an independent consultant, she was appointed lecturer in earth science at Massey University in 1994, and has remained there to the present day. Her research covers stratigraphy and sedimentology of the Wanganui and Taranaki basins. Julie has had a long involvement with the Geological Society of New Zealand, progressively as secretary, treasurer and the first woman president from 2002-03. ■

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ABILITY NOT GENDER:

NEW ZEALAND WOMEN GEOLOGISTS IN ANTARCTICA

Margaret Bradshaw: Christchurch

Over 100 years ago three women asked Shackleton if they could join his Antarctic expedition. History tells us they were not successful. Fortunately, things have changed.

The first woman to be officially part of the New Zealand Antarctic programme was **Pamela Young** in 1969. After being an ice widow for 4 summers in a row while her husband, Owen, studied penguins on Ross island, Pamela put her foot down and said, "Right, the next time - I'm coming with you!" She wrote a book about her experiences: ***Penguin Summer – or a rare bird in Antarctica*.** The couple cooked in the Cape Bird hut, but slept in a polar tent at both Cape Bird & Scott Base.

That same summer an American party of 4 women also went south and Pamela was able to join a specially arranged publicity trip

Pamela Young at Cape Bird

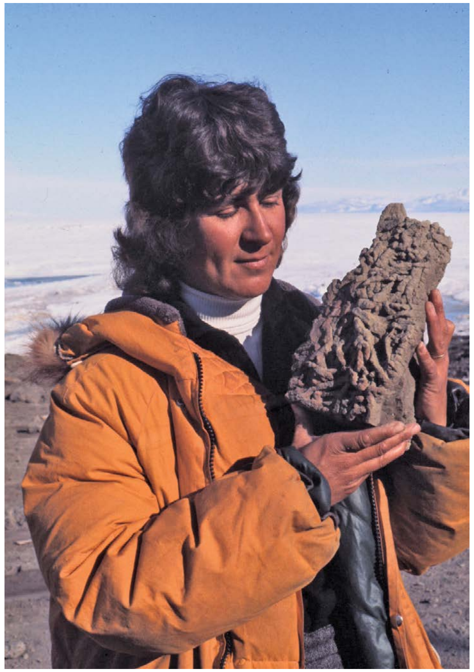
to the South Pole. **Eileen McSaveny**, a well-known earth scientist now residing in NZ, was also on that trip as part of the American team.

Pam (left) and Eileen McSaveny (second from right) at South Pole.

The first woman to go South in her own right in 1970 was **Rosemary Kyle** (nee Askin), an Honours student at Victoria University. She was a single woman in a 5-man party. Barry Kohn wrote - *"Having Rosemary in the group worked very well. She taught us all that temperament was more important than strength"*. After several more field seasons with NZARP, Rosemary continued her research in the US at Ohio State University and became a prominent Antarctic researcher specialising in plant fossils and pollen.

In 1975 **Margaret Bradshaw** went south to collect specimens for Canterbury Museum's new Antarctic Hall. **Sue West** was employed by Antarctic Division to accompany her Sue had a PhD on Antarctic rocks, but because of her sex, had never actually been allowed

Rosemary Kyle ▲



Margaret Bradshaw at Scott Base with a trace fossil she named ▲ *Heimdallia chatwini.*

down to Antarctica and worked on specimens collected by the men. When she heard New Zealand was sending women to Antarctica, Sue came to NZ at her own expense and helped Margaret collect rocks. A total of six women scientists went south that season, regarded by some as "the petticoat invasion". This was a major step for New Zealand, although the old base was not designed for them. Several wanigans were built outside the base to house the "invaders", and a large postbag cupboard was converted into a women's loo.

Despite encountering some anti-women attitudes at Scott Base, there were no problems in the field. For safety reasons Margaret & Sue were accompanied by two different "minders" for each of four localities, but at one other site were allowed to camp on their own for 2 days.

In 1976 **Margaret Bradshaw** returned to do research on the many interesting trace fossils she had seen the previous year. Her minder was **John Nankervis** (Nank), a well-known climber and very useful for scale. He was remarkably tolerant when she kicked him out of the tent so she could wash or change her clothes. In 1981 Margaret published a significant paper in NZJGG on the Devonian trace fossils in lower Beacon sediments.

Sue West appreciating the wolverine fur on her hood ▲

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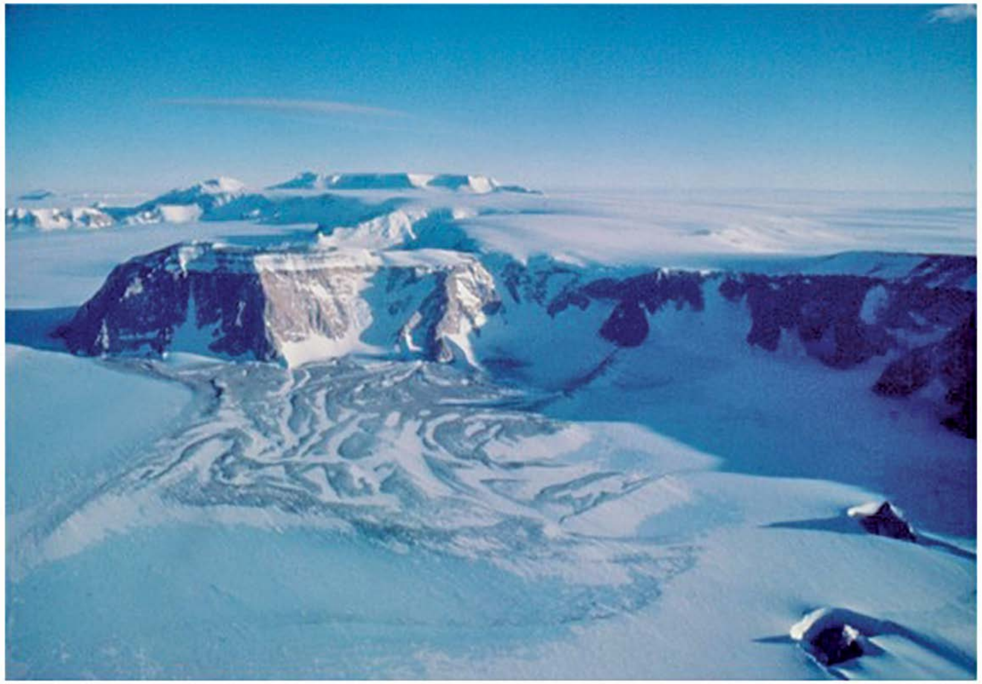
John Nankervis on the job ▲

John acting as scale ▼

Because Margaret was working on Devonian rocks and fossils in NZ, she was very keen to visit similar rocks in the Ohio Range, Antarctica in 1979-80. It was a deep field event that took a lot of organisation. She was the first woman to lead such a party and all eyes were watching her. With her were Americans **Lucy Force** and Karl Kellogg while New Zealander Graeme Ayres kept the group safe at a cold and windy location. There were several hurdles before getting into the field. The Scott Base leader didn't inform Margaret of meetings at McMurdo where weights were discussed, so she was never told that she needed to add the weight of the pallets to her calculations. Then on the Hercules put-in flight the Base Leader said that he would talk the pilots down to the landing site. In the noisy plane Margaret had to insist (politely) that it was the Event Leader who should talk them down and that she knew where they were going because she had spent a lot of time looking at aerial photos. As it happened, the

Lucy Force from the USGS ▼



The Ohio Range escarpment

weather was too cloudy and the landing was aborted with nothing to show after 7 hours of flying. The second try was also aborted due to a fault in the landing gear, but the third try made a successful landing on the polar plateau. The party then sledged to the edge of what was a fantastic and challenging escarpment) along which they measured 18 sections in the Devonian sediments at the bottom of the sequence. They were well balanced party, which helped when they were confined to tents during a 10 day storm. They had only one calm day – on all the rest they had cruel katabatic winds.

In 1983 **Margaret** returned to the Ohio R with a different 4-man party. With her was **Jane Newman** from Canterbury University who specialised in coal geology. Jane was used to being the only woman amongst a lot of men when she'd worked in the West Coast coal mines and came armed with a blue Plastic

Jane Newman well kitted for the persistent wind ▲

Potty that she found made life easier. On the C130 flight to Antarctica there was no toilet except for a drum with a funnel for the men at the back of the plane. But with a potty and the help of another woman to stand guard, you could hide behind the drum, use it, and pour it demurely into the drum. It promised to be a major improvement for women in the field, but the Ohio Range was so cold, the potty

Fraka Harmsen ▲

shattered the first time it was used. Margaret worked on the prolific Devonian trace fossils, Jonathon Aitchison on the post glacial sequence, and Jane to get more information on the high-quality coals there. Bill Atkinson kept the party safe.

In 1988-89 **Margaret Bradshaw** organised a group in the Darwin and Britannia Mountains to compare the abundant trace fossils reported there with those in the Dry Valleys Taylor Group. With her was **Fraka Harmsen**, a graduate of Victoria University, now teaching at California State University, Fresno. Fraka was a very happy person. She laughed at everything. You only had to look at her to start her off. Martin Kirkbride from Scotland, who was completing a PhD at Canterbury University, also joined us. Ray Waters, who worked for DOC, was the safety person and could do anything – cook bread in the field, mend the sledge, practice Yoga each morning & fashioned a mini-sledge for us to get a 60

L-R: Fraka, Martin, Ray ▼

Kg meteorite off a mountain. They made a very happy team (Fig. 12) and decided that many of the Darwin trace fossils were different from those in the Dry Valleys, including giant arthropod trackways. We also discovered a new horizon of fish fossils, the most Southerly outcrop yet found.

Fraka joined Margaret again in **1991/92** when she organised a group to specifically investigate new outcrops of the Aztec Siltstone in the Cook Mountains. Wonderful new outcrops were discovered, including one that was called "Fish Hotel" because all the beds were full of fish. With them was Australian Devonian fish expert John Long, who realised that these new outcrops were very important, and field support climber Brian Staite. The group worked north on a long traverse (over 700 km) through the Cook

The team back at Scott Base with large fish plates ▼

Mts to near Mt Crean, with a helicopter lift over the badly crevassed Mulock Glacier.

In **2004** a Canterbury University party, consisting of **Kari Bassett**, **Margaret Bradshaw** and MSc student **Jenny Savage**, worked on very coarse Devonian sediments in the northern part of the Devonian Basin from the MacKay Glacier South to Mt Cerberus. Duncan Ritchie acted as field assistant. He was still getting over jet lag after flying from

Jenny outside her tent ▲

Duncan, Jenny and Kari work on the conglomerate ▲

Greer Gilmer in the Olympus Range ▼

the UK. He had left behind his new wife but hadn't told her that he would be joining a party of three women in Antarctica. On this trip the group started working on the character and provenance of these rare early Beacon sediments, most of which contained rhyolitic clasts the same age as the granites on which they sat. We were able to recognise outcrops of Terra Cotta Siltstone resting directly on granite and correlated them with similar sediments in the Dry valleys that were well above basement.

In **2007** Canterbury University organised another field trip to study the Heimdall Erosion Surface in the northern part of the Dry Valleys, finding it overlain by a thin continuation of the northern conglomerate. A change in trace fossils above the erosion surface was also studied. M.Sc student Greer Gilmer joined forces with both Margaret and John Bradshaw, with further support from Post-Doc Robert Bolhar. Greer proved to be a very capable, strong and focused woman. She was often heard to say "I Don't do stress".

Heimdall Erosion Surface studies continued in 2008 and Greer Gilmer returned as field assistant to MSc student, Tim O'Toole, University of Canterbury. The study continued south though the Asgard Range to the Quartermain Range and south to Rotunda. Margaret and John Bradshaw were field supervisors. ■

L-R: Margaret, Greer, John and Tim and snow at the final helicopter pickup on the Rotunda▼

FEATURE ARTICLES

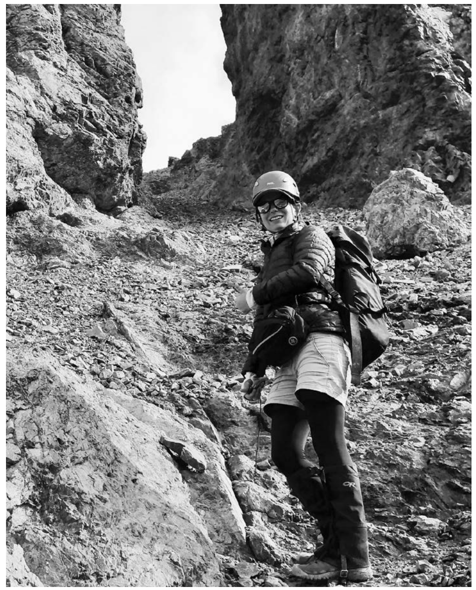
CAROLYN BOULTON

AN INTERVIEW WITH A ROCKSTAR 'FAULT HUNTER'

Janis J Russell: Christchurch

Carolyn Boulton possesses an intense drive, one she has had since she was quite young, to seek out the answers to hard questions. Today, she applies that drive to good effect in the geosciences. In addition, she readily conveys warmth, passion, and infectious enthusiasm for both geoscience and life, in general, in equal measure. These qualities, combined with her unshakeable confidence, characterise her as a formidable Early Career Researcher who has already achieved huge things in her fledgling career, thus far.

Amongst towering tors, spectacular fault rocks are exposed on the Liebig Fault. Studying these rocks will yield insights into the processes that accommodate deformation in greywacke sandstone and argillite, New Zealand's most common rock types.



She has been the recent recipient of two prestigious international awards from both sides of the Atlantic—The American Geophysical Union and The European Geosciences Union—and is the first New Zealander to have received either of them.

Although she feels fortunate to have done so, Carolyn is characteristically modest and quick to emphasise the support of the geoscience community. Adamant that these accolades are a reflection of the strength of New Zealand geoscience, she waxes lyrical about it: "It's great for our community to be elevated on an international stage, to say hey, we are training amazing graduates...it is a testament to our research programmes and our institutions".

Carolyn proudly highlights the quality of teaching at the universities she has attended, here, and thrusts them into comparison with top-notch teaching establishments around the world. This home-grown research excellence approach is something she is particularly excited about. "We can compete with Caltech, Berkeley and ETH Zurich— we don't have to go overseas, we can stay here and do *outstanding* degrees".

This talented researcher's interest in geoscience began as a child, during visits to rivers and lakes, where she became fascinated by the appearance of rocks, replete with various colours and textures, in water. Such visual appeal led her to pick up rocks deemed "pretty" or to use as or skimming stones. Sometime later, after becoming besotted with our Alpine Fault, and New

Zealand tectonics, Carolyn came to New Zealand to do a semester abroad and became totally hooked on our geology. She graduated from University of Otago prior to enrolling for a PhD at the University of Canterbury.

At UC, her research focussed on creating experimental earthquakes in the laboratory. However, as there were no facilities in New Zealand, she headed offshore as a recipient of a Claude McCarthy fellowship. This award allows PhD researchers to conduct research towards their degree that they can't do here. The young researcher was only back a week from that overseas stint when the Darfield earthquake struck in 2010, triggering a series of aftershocks that lasted for two years. She admits that it was hard to be studying earthquakes at the same time as living through them. "Even though I understand them, as a research topic, it doesn't stop my heart pounding when they occur. It is so much better in the lab than in real life as we have all the control in the lab and none of the control in real life... We can only control our response and prepare for them...".

> *"It's great for our community to be elevated on an international stage, to say hey, we are training amazing graduates...it is a testament to our research programmes and our institutions.*
> *We can compete with Caltech, Berkeley and ETH Zurich— we don't have to go overseas, we can stay here and do outstanding degrees."*

Her eagerness, to prepare people for the impact of natural hazards, has spilled over into her enthusiasm for communicating

Happiest surrounded by rocks, Carolyn's most recent field season was partly spent researching the Liebig Fault in the Gamack Range.

geoscience through discussions, activities and social media. She'll talk about it for hours, to anyone who will listen, and enjoys using hands on demonstrations to explain difficult ideas to people, including geology students, of all ages. According to Carolyn, one of the most fun activities for everyone is using Playdoh to make a plate boundary. More recently, she has started a public Instagram account, showing photos of her in the field, and will soon be involved in making some podcasts on natural hazard preparedness. It is another area she feels strongly about. "Not seeing them as something scary but just having something that's there and we can take measures to mitigate their effects on us. They don't have to be disasters".

Out in the field, Carolyn sees her main role as a "fault hunter". Her observations focus on fault zones during, and after, an earthquake where she looks for evidence

such as the presence of fluids (influential in causing earthquakes and facilitating slip), or degree of melt in the fault plane. She loves field work for that 'being there' feeling — Climbing hills or mountains to look out large expanses of landscape fuels her curiosity about how the landforms, in front of her, got to be that way as how they appear today isn't how they have always been.

In January, she was dropped in by helicopter to around 1500-1600m in the Southern Alps. There, perched on the edge of a cliff, at the point of greatest uplift from the tectonic collision of the Pacific and Australian plates, she is filled with awe and wonder at the interwoven processes which have created our landscape. "You can see the faults that have created the elevation, which is then interacting with the climate and glaciations, and depositing giant moraines, and scalloping out cirques. When you're up there, you get a real appreciation for the interaction of all these processes that shape our landscape. There is no danger of becoming complacent or being 'ho-hum' about the place that we live in".

And once the notion of landscape evolution through time captured her imagination there was no stopping Carolyn in her search for answers. "[It's] that time element of it, that what we see today used to be under the ocean and what we see in the high Southern Alps actually used to be in a subduction zone as part of the down-going plate off Gondwana. The deep, rich history of the rocks and the landscape in New Zealand is an endless source of fascination, curiosity and exploration. So just seeing the landscape and understanding its evolution means I'm always curious about it and will never stop wanting to know more about it". "That's the beauty of science", she insists. It is an iterative process whereby finding answers not only generates more questions but also invites learning to ask *better* questions.

> *"Working in geology, there is no danger of having an awe deficit!"*

Yet, although she enjoys the field work, Carolyn is adamant that field observations and lab measurements go hand in hand. The two are married together and then combined with other datasets including geophysical and seismological data. She believes that integrating disparate datasets allows us to gain a better big-picture understanding of how and why earthquakes happen.

In terms of her career progression, it has always been less about mapping out a career path and more about finding opportunities that will assist her to follow a personal curiosity journey of unanswered questions and indulging in her passion for geology. [I'm thinking] "Will someone give me the opportunity to do that? and then I say 'Yes' when they do".

Her modus operandi has certainly been a successful one as she has been fortunate to find funding for ongoing research. Current projects include publishing work stemming from her research on the Alpine Fault and the Hikurangi Subduction Zone (the largest and least understood in New Zealand). She's now working to understand processes that contribute to earthquakes in greywacke fault zones. These have been somewhat neglected because they're often considered "ugly" but, in fact, many recent earthquakes (e.g. Kaikōura & Darfield) have occurred in the greywacke rock that forms the backbone of many of our ranges in New Zealand. So, even though Carolyn's career path was unplanned, one has been forged from her approach, having recently been appointed as a lecturer at Victoria University, Wellington.

Perched on fractured greywacke sandstone at the junction of the Esk Fault and Torlesse Fault, Carolyn looks for information about processes that occur during and after earthquakes.

Carolyn responded with a laugh, when questioned about what she'd like her legacy to be, as she has only just begun to settle into her new role as a lecturer with all its additional opportunities and responsibilities. Upon further reflection, she decided that having a network of supportive people is crucial for a sense of belonging to a dynamic research community. She suggested that fostering a welcoming atmosphere and culture for students and researchers at every stage of their careers, regardless of background and circumstances, is a key role for the GSNZ to embrace. In fact, a key component of her 'legacy' would be to ensure that there is a place for everyone within geoscience.

> *"I want there to be a place for everyone is geoscience regardless of their gender, nationality, ethnicity or background...[we need] a very diverse research culture in New Zealand and overseas because with diversity comes innovation and, I think, progress."*

Carolyn describes coming to NZ when she was 19 years old because she wanted to see the Alpine Fault, as a major highlight. Being a part of New Zealand geological research, and its community, was an important component of it. But the opportunity to be taught by pioneering researchers, like Richard Norris, Alan Cooper and Rick Sibson was the icing on the cake. They inspired her to carry on in that field, for her PhD, and form part of the team for the Deep Fault Drilling project at Gaunt Creek, near Whataroa.

Having attended Margaret Bradshaw's talk at the GSNZ 2020 conference, in Christchurch, Carolyn acknowledges the hardships of those pioneering women who have gone before. In her view, there are still barriers in place today but they're primarily what she considers to be mental ones—an unconscious bias. She has encountered occasions where there is an uncomfortable dissonance between other people's perceptions of what a geologist could, or should, look like and herself. She clearly doesn't "look the part" by matching some outdated expectations of a geologist as a stereotypical six-foot-tall, deep-voiced, bearded man. It's the type of feedback that provides Carolyn with regular opportunities to confront and challenge this perception.

Furthermore, she reiterates the fact that women geoscientists are still under-represented in academia and Crown Research Institutes. She is keen to hold up examples, such as GNS's Laura Wallace, who have the ability to increase the visibility of women in the geosciences. She is keen to seek more change in this area. While the intellectual contribution of the aforementioned men to Carolyn's work was immense, looking back, she underscores the hugely supportive role that other women geoscientists, such as Daphne Lee at Otago and later Martha Savage at VUW, have played in her development as a young researcher. She recounts that she would have been lost if there had been *only* male professors in those early years. We should all feel somewhat indebted to these women, and others, who play such a pivotal role as advisors and mentors, in ensuring that young women are able to reach their full potential. The geoscience community in New Zealand is certainly stronger and richer because of it.

It may come as no surprise, that Carolyn's choice of geoscientist, from any time in history, to spend an evening with, would be an "amazing" woman. Tanya Atwater (b.1942) was "one of the first, most successful, female structural geologists in the world and was elected as a fellow of the AGU in 1978...within eight years of publishing her PhD". She wrote seminal papers on the evolution of North America and the San Andreas Fault and was a leading plate tectonics theorist in a male dominated discipline. "One of the things that I love about her is that she said that at first she disguised her passion for science because she thought that a real scientist is very staid, very analytical and very logical. But later she realised that her passion for science was her 'superhero quality', that being passionate is a *good* thing".

During those times when she isn't working on difficult questions in geoscience, she delights in her home life and "just doing normal things". She loves spending time shopping with her daughter, walking around the streets of Christchurch admiring its recovery progress, gardening, or hugging her aging German short-haired pointer about whom she asserts: "Everyone says 'my dog is the best dog' but my dog IS the best dog!". Once Covid-19 travel restrictions are lifted she is looking forward to a break, "Someplace like Rarotonga or New Caledonia and take my daughter swimming with sea turtles, and octopus, and all the diversity of life in and around a coral reef". She remains hopeful that we can get on top of climate change so that we don't lose those precious areas.

When asked how she fits everything in, Carolyn is all-at-once philosophical and pragmatic with a determination to find a work-life balance. Her brimming self-belief shines through at these times. "Being efficient and knowing when to stop...just saying hey, I have done a lot today, I have come up against a hard problem that I don't know how to solve. I'm going to go home and enjoy being with my family and I'm going to tackle this tomorrow. And tomorrow I'm going to be more awesome because I have done something I love, and given my brain a rest, and had a good night's sleep— future me is going to be way better". Her advice? "Don't neglect the other aspects of your life that make you happy". ■

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	July Issue	**June 15**
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