



# **The Edinburgh Geologist**

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### ***Cover Illustration***

A very large rock slope failure in the Lochaber Cluster: Sgurr Eilde Mor Mamores from Binnein Mor across a glacial breach-col. Photograph by David Jarman. For more information see the article by David Jarman on the Glen Almond Rock Slope Failures.

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### ***Editor***

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The Edinburgh Geological Society was founded in 1834 with the twin aims of stimulating public interest in geology and advancing geological knowledge. We organise a programme of lectures and excursions and also publish leaflets and excursion guides. For more information about the Society and membership, please visit [www.edinburghgeolsoc.org](http://www.edinburghgeolsoc.org).

# Inspired by Stone

*A first editorial by Robert Gatliff*

One of the hardest things in life is to follow someone who has had a remarkably long run of sustained excellence. Phil Stone (along with Bob McIntosh) has had an eleven-year stint as editor and the feedback from members shows how much his style and the content are enjoyed by our readership. I am so pleased the Society have rewarded Phil with the status of Distinguished Member of the Society. Thank you, Phil and Bob, for all your hard work, and I'll do my best!

I've enjoyed putting this edition together—and have started on the next—so Phil does not need to come to my rescue just yet – but readers, do let me know if my standards slip too much, and if there is subject you would like included, I'll see what I can do.

One of my first tries at getting a contribution was to approach the Royal Parks for an article on the engineering geology analysis of Salisbury Crags and the closure of the Radical Road. Has Health and Safety gone mad or have they done a thorough geotechnical examination? The display boards about Hutton are away from the cliff face and the surrounding area at least could be

reassessed to allow access. Alas, still no response from the authorities which leads me to believe that there may not have been a professional analysis. I live in hope that the barricades will be moved before too long.

The first article in this edition is by David Jarman, who gave one of the EGS lectures earlier this year. David spoke about Rock Slope Failures (RSF) in the Highlands. Perhaps I should have asked him to look at Salisbury Crags instead! I am ashamed to say my knowledge of the RSFs in Scotland was almost non-existent and I found his talk very stimulating. His analysis of their occurrence in clusters in areas with increased erosion by ice leading to locally greater forces associated with isostatic rebound demonstrated that there is a lot more evidence of isostatic rebound than raised beaches! I am delighted that he has provided the remarkable pictures from his lecture for the website. David tells me he betrayed his 'first love' at school and Cambridge by going over to the dark side as a development, transport and environmental planner. Luckily for us, he returned to geomorphology as a 'gentleman scientist', essentially self-taught but "greatly indebted to

many in BGS and academia, who must despair at his imaginings, prolixity, neologisms, and lack of any time, budget or teaching pressures”.

I was not expecting an EG article on the pandemic, but Roy Thompson, a geophysicist at the University of Edinburgh, has applied an established petroleum geology technique to look at the spread of the pandemic. Roy submitted this in June and as you read it a few months later, he will have some extra data which you can read on his blog. I will leave the reader to interpret how he rates the Government response to the virus!

Our third author, Lord Ian Duncan of Springbank has ventured to the dark side, and he is still there! But what a career path to take! Does anyone know the previous geologist to hold a role in Government? Ian studied geology at St Andrew's before completing a PhD in palaeontology at Bristol and joining BP. He was elected as a MEP and more recently, after narrowly failing to get elected to Westminster, he was ennobled, and served as a minister until the beginning of this year. He is now a deputy speaker in the House of Lords, where he is encouraging their lordships in the use of IT and enjoying their extensive knowledge and wisdom. Angus Miller, Hugh Lockhart and I had a long chat with Ian about the ambitions of the new Scottish

Geological Trust (see <https://www.scottishgeologytrust.org/>) to promote geology in Scotland and encourage more teaching in schools, and try to reverse the downward trend in applicants for Earth Science university training. He is very supportive and gave us some excellent advice on getting the whole geosciences community on board, and he agreed to help with links to government both in Edinburgh and at Westminster.

Our new President, Tom Challands is also a palaeontologist who studied at Bristol. You can read his plans for EGS in the fourth article, and I wish him well, and look forward to a dynamic future for our Society.

I would like to invite readers to consider submitting short articles, pictures, or letters to the editor. I have included a song submitted by George Strachan. The two book reviews are well worth reading: You will enjoy Bruce's humour and Danny may persuade you to buy Professor Ballantyne's book on Scottish geomorphology and learn more about the development of our scenery.

Like many of you, I am waiting to get out on field trips. We can look forward to the proposed Scottish Geology Festival in Sept/Oct, and hope that EGS will be able to run a series of early autumn field trips, if at all possible.

# Rock slope failure — the Glen Almond Perthshire cluster

*By David Jarman, Mountain Landform Research, Ross-shire*

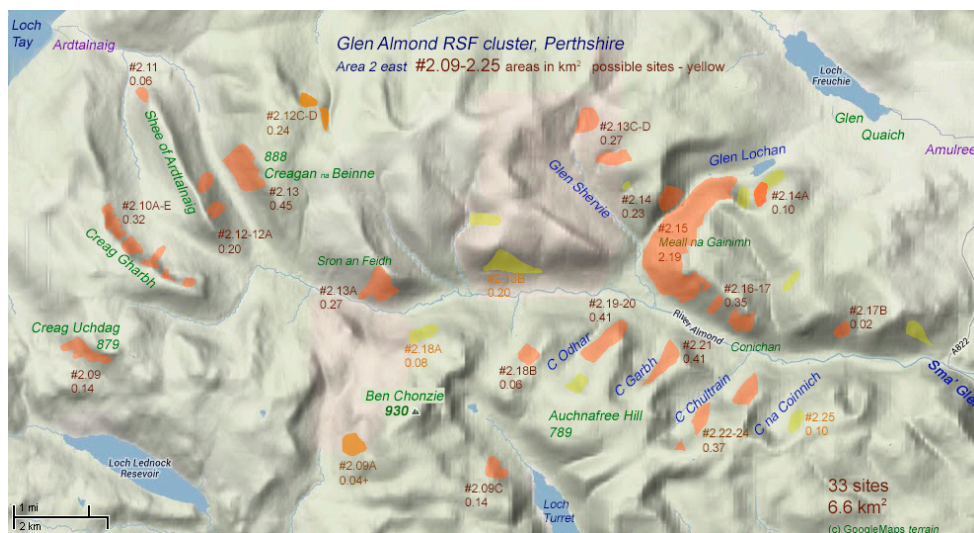
With limited words, it is impossible to introduce a subject as recondite as Rock Slope Failure (RSF) to anyone new to it, so we will assume you know the essentials, either from perfect recall of my March 2020 presentation on RSF in the Scottish Mountains, or from diligently reading the review paper by Jarman and Harrison in *Geomorphology* 2019!

Back in 2006, my first overview identified seven clusters of montane RSFs in the Highlands, most of them written up or at least mapped out in Quaternary Research Association Field Guides. Five are in a chain along the main Highland divide up the west coast, one is on the main Grampian divide straddling Drumochter (Ericht–Gaick), and only one is on a secondary divide (Forth–Earn) around Ben Ledi and Ben Vorlich. Since then, an eighth has come to light, in an unexpected out-of-the-way location in relatively subdued relief, in Glen Almond north of Crieff.

The only previous comprehensive search for Highland RSFs was the unpublished 1984 PhD of Graham

Holmes at Edinburgh, at the prompting of Brian Sissons (available online and still highly pertinent). Working from old air photos, Holmes identified the several major RSFs on the Tay–Earn divide, but none down Glen Almond. I then stumbled upon a remarkably extensive RSF complex on the flanks of the Glen Lochan breach/overflow ravine (Auchnafree–Glen Quaich), but only became aware of the prevalence of RSF along the main glen walls when scanning improved Google Earth imagery in winter 2012. Most have now been field checked, and several more have been discovered. By curious coincidence, Maarten Krabbendam and Tom Bradwell identified those in the mid-outer glen independently at the same time while mapping the BGS Pitlochry Sheet. Happily we concur almost 100%!

The Glen Almond cluster extends from the top of Sma' Glen to the impressive twin breaches isolating the Shee of Ardtalnaig, into Glen Turret and across Craig Uchdag to the south, and just over into the head of the Quaich to the north (Figure 1).



**Figure 1** Location map: Glen Almond RSF cluster, Perthshire

It comprises 33 RSFs, with average size of 0.20 km<sup>2</sup> being the Highlands average. It affects 6.6 km<sup>2</sup> or 5.9% of the land area - the second-highest cluster density after Glen Roy–Lochy, which is also in more plateau than mountain terrain. In the core of Glen Almond, 12 RSFs affect a remarkable 17.2% of surface area, second only to Glen Roy itself. There are seven ‘large RSFs’ exceeding 0.25 km<sup>2</sup>, the Beinn na Gainimh complex which occupies the entire south flank of the Glen Lochan gap being one of only four in the Highlands over 2 km<sup>2</sup>.

Although available relief is modest, 300–500 m, it supports the full diversity of RSF modes, from typical Highlands short-

travel rockslides to more disintegrated (quasi-) rock avalanches, and at the other end of the spectrum, subtle rock slope deformations. These are often characterised by anticarps, neat little uphill-facing scarplets which snake along glensides. In Coire Chultrain opposite Conichan, anticarps up to 3–4 m high extend over 400 m, creating conical ‘sithean’ knolls as seen from the glen.

The most dramatic RSFs are the rock avalanches, although here these are all ‘sub-cataclastic’ retained on the mid-lower slopes, rather than running out into the valley floor. They are mostly confined to the Ardtalnaig breaches, plus a notable assemblage on the SW flank of Creag Uchdag above the



**Figure 2** *Conichan—the most prominent RSF within Glen Almond displays a large wedge-shaped rockslide that has descended some 50 m, progressively disintegrating and now metastable, with basal springs above the slopefoot. The cavity is retrogressing to isolate Conichan Castle (top right). A linked secondary wedge midslope has only travelled a short way, but the core slipmass has ruptured spectacularly into large extruding blocks.*

Turret-Tay col, where rocky debris drapes resemble sticky lava flows.

Above Conichan in mid-Glen Almond, a large and deep-seated RSF combines all three modes, with a clear-cut upper rockslide having moved out of wedge cavities, evolving into a disintegrated mass that clings to the midslope, with incipient

retrogression invading the summit ridge—in effect, slope deformation that will eventually isolate the spur end as a miniature Pap of Glencoe.

### **Explaining the Glen Almond RSF cluster**

This large RSF cluster appears spatially quite anomalous, with negligible incidence in the adjacent Glens



**Figure 3** *Beinn na Gainimh—just one sector of this 2.19 km<sup>2</sup> complex, rim-slips progressing to flow-slumps on a vast scale, closing in the breach-trough floor of Glen Lochan; view from Meall nam Fuaran, with Meall Mor RSF background left.*

Quaich and Lednock (although the latter is largely in granite, which is unconducive to RSF unless tectonised). It is absent from the whole length of the Tay valley, and its Tummel-Garry-Lochay tributaries, and along Loch Earn, and from most of Glen Lyon, until the head, where it is intense in the Orchy breaches. There are several important RSFs around Ben Lawers, but in corrie not glen contexts. There is a dense pocket in a deep fluvial valley north side of Beinn a'

Ghlo. To the west, RSF is absent until Glen Ample and Glen Ogle, where it becomes equally intense. To the east, it is very sparse in Glen Shee and Glen Isla, but a dense concentration occurs in Glen Clova (which numerically could constitute a cluster, but average size is small—QRA Field Guide, 2019), bracketed by sparsity in Glens Prosen and North Esk.

There is nothing obviously unusual about the geology or structure



**Figure 4** *Coire Chultrain—slope deformation with large-scale antiscarp development, the ribbon pool suggesting long consolidation.*

of Glen Almond which might predispose it to RSF, as BGS colleagues concur. It is comprised of Dalradian metasediments of the Southern Highland Group, predominantly semipelitic schists on the north side and psammitic schists on the south, of relatively low-grade metamorphism. The slippery micaceous pelites used to be thought conducive to RSF, as did favourable inclination of the foliation surface, but here neither influence incidence. Thus the north trough wall between Auchnafree and Conichan, which displays almost continuous deep-seated rockslides for 3 km, straddles this lithological boundary with blithe disregard. Nor is any major fault mapped here, and in any case Glen

Almond is not (unlike Glen Ample) on the Caledonide strike.

Across the Highlands, there is a marked association between RSF and glacial breaches in the main divides, attributed to excessive rebound stresses after concentrated erosion in bedrock (CEB) of possibly hundreds of metres depth in the last glacial cycles (see 2019 paper). Here, the twin breaches at Shee of Ardtalnaig may be relatively recent, responding to shifts in ice dispersal patterns. If they fed Loch Tay and Ben Lawers ice through into Glen Almond, greatly augmenting its effective catchment, that could have provoked rapid late-stage enlargement of the trough for some distance down-stream. Some

of this augmenting ice could in turn have been discharged by diffluence via Glen Turret and especially Glen Lochan, provoking their cutting or deepening. RSF diminishes lower down the main glen, with further diffluence probable ENE via Amulree; Sma' Glen itself displays no extant RSF, strangely given its steep-sided raw character, possibly suggesting discharge was impeded across the Highland Boundary.

Glen Almond could thus exemplify the CEB:RSF hypothesis as associated with late-stage glacial breaching, at Ardtalnaig and also Glen Lochan (the V-form of which suggests glacifluvial meltwater incision, but is substantially attributable to RSF toe-bulging on both sides). It bears comparison here

with RSF concentrations at Orchy–Lyon, Loch Ericht and Gaick Pass, and nearby, the extraordinary and overlooked large RSF on Beinn Dearg in a breach off Glen Artney. However, breaching is not proposed as the sole driver of RSF in the Highlands, with concentrations such as Glen Ample, Beinn a' Ghlo, and Glen Clova requiring other explanations. Proximity to the Highland Boundary Fault (and Loch Tay Fault) might even be considered for some, although impossible to vindicate, as our paper debates.

To see the slides from David's lecture, and the details of access to the Glen Almond RSFs please visit: <https://www.edinburghgeolsoc.org/publications/the-edinburgh-geologist/>



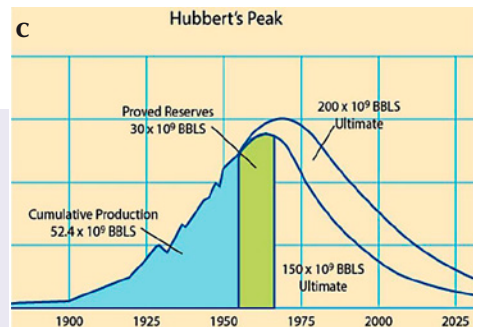
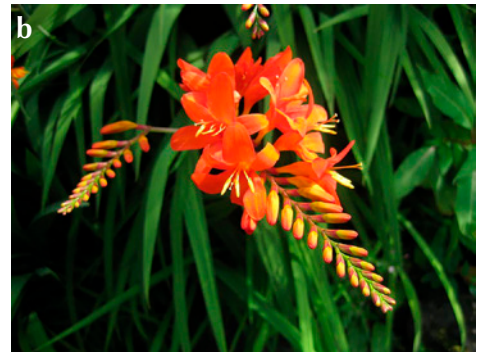
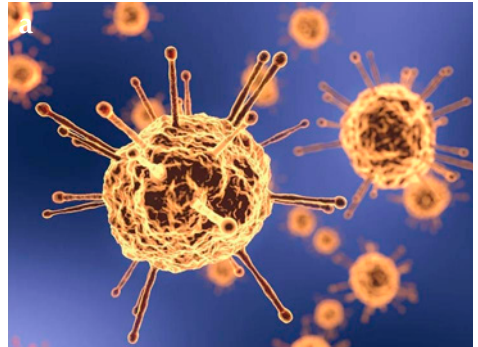
**Figure 5** *Shee of Ardtalnaig—Bual a' Chlaidheimh, the Sword Cut.*

# Peak oil, flowering curves and the COVID-19 pandemic

By Professor Roy Thompson, University of Edinburgh

Negative oil prices, the unusual sight of vivid blue skies, the best air quality in decades, gorgeous spring flowers, reduced traffic, reduced traffic noise, what's not to like about the coronavirus lockdown? Well, maybe the highest mortality rate since World War II. "What on earth have these disparate phenomena got to do with geology?" I hear you ask. The article aims to show how a consistent geo-mathematical methodology can be used advantageously in studying many dissimilar phenomena (Fig 1).

More specifically the article describes the pioneering geo-statistical work of the visionary, oil-company polymath, Marion King-Hubbert (1949, 1956, 1981 and 1982). I find it fascinating that Hubbert's maths, in addition to its classic application—of predicting the timing of peak oil and quantifying the total amount of recoverable



**Figure 1** What do (a) the COVID-19 pandemic, (b) the opening of Montbretia flowers, and (c) the prediction that oil production would peak by the early 1970s, have in common?

fuels—also performs remarkably well in a wide range of other situations, including modelling the deaths and infections resulting from the COVID-19 pandemic, and in charting the patterns of opening of flowers in the spring.

Briefly the ‘peak-oil’ story effectively began at about 10 am on March 8, 1956, when King-Hubbert first ‘went public’ with his bold prediction—that, contrary to conventional geological wisdom, oil production (Lower 48 States, onshore USA) would reach its zenith by the early 1970s and then quickly decline. He chose a conference of the American Petroleum Institute (API), the oil industry’s main lobbying outlet, to set out his new geo-mathematical forecasting rules, to describe his “reappraisal of the whole energy picture”, and to make his controversial forecast for US production. Quite an agenda for a speaker faced by an audience of some 500 hearty oilmen in a plush venue in down-town San Antonio, Texas, especially as, at the time, America was a supremely confident exporter of petroleum.

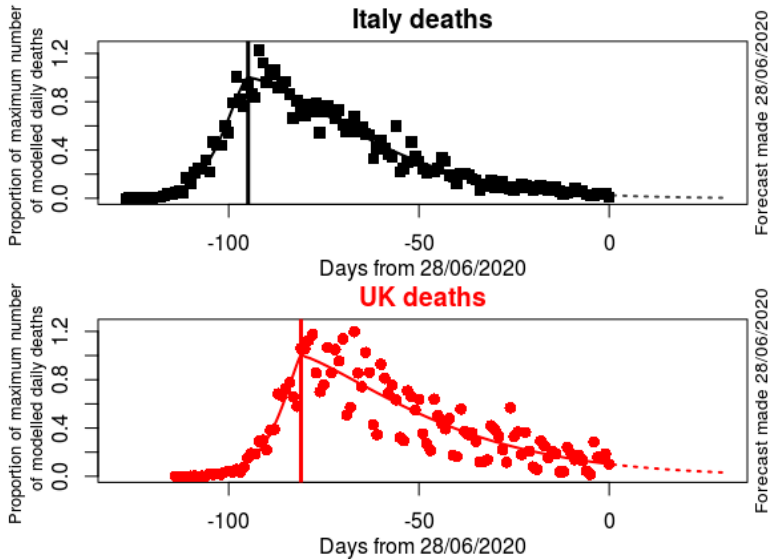
### **Geo-statistical curve fitting**

During the COVID-19 lockdown in Scotland (began 23 March 2020) I posted a series of blog pages about the epidemic and how it was likely to progress. To achieve my forecasts

I employed Hubbert’s curve-fitting approach. I was already familiar with Hubbert’s maths, having previously used it in order to delve into the rapidly declining state of UK oil and gas reserves (Thompson, 2017b), but had generalised the underlying equation slightly (see the flowering curve approach of Clark & Thompson (2011) and Box 1 for further details).

Fig 2 shows an example of Hubbert’s geo-maths when used to model both Italian and UK deaths trajectories (daily deaths as reported in the database of the European Centre for Disease prevention and Control, ECDC) and to project the future course of the epidemics (dashed lines). The trajectories of the two countries can be seen to have been exhibiting remarkable similarities in general shape, duration and skewness, and to resemble typical curves of oil discovery and production. The maths showed that for any officials formulating UK policy response, Italy was supplying an honest, down-to-Earth foretaste of what was about to befall the UK.

In addition to forecasting ‘peak oil’ Hubbert also devised a method to estimate the important economic and geological indicator of ultimate recoverable resource (URR). His neat methodology is often referred to as Hubbert linearization. Fig 3 shows

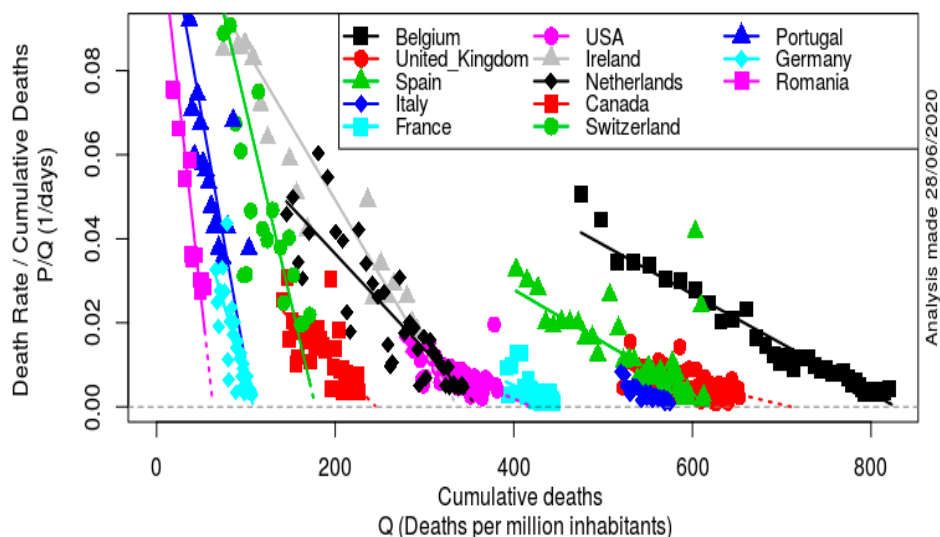


**Figure 2** Comparison of curve fitting of Italian and UK deaths trajectories. Dashed lines: forecasts using skew-normal model. Note the low quality of the UK data, largely caused by under reporting on Saturdays and Sundays and on bank holidays but also by confounding effects associated with a step change in recording procedures in England, brought in for April 29th onwards, when the count included deaths with COVID-19 in all settings for the first time. Nevertheless the trajectories of the two countries remain remarkably similar in general shape, duration and skewness. Italy, on average, was 15 days ahead. Conclusion, from analyses made on 09/05 and again on 28/06/2020: watch Italy if you want advance warning of how the UK epidemic is likely to progress.

the results of applying this facet of Hubbert's work to COVID-19 deaths as recorded in countries from around the world with high numbers of deaths. The key finding was that expected deaths (per capita) varied widely. The intercepts of the coloured diagonal lines with the horizontal axis quantify the ultimate totals.

Fig 3 is an update to a very similar plot drawn and posted on my blog on April 7th, and yet as late as May 15th the UK government was still claiming it was far too early to compare between countries. They chose to maintain that any such comparison while the crisis was still unfolding was 'premature'. In my view, Hubbert's

### Hubbert analysis of COVID-19 per capita deaths



**Figure 3** *Hubbert-type predictions of final (per capita) death tolls. Countries ranked (see legend) by total numbers of per capita deaths (as estimated on 28th June). All data points are daily. For example the black square in the extreme lower right corner represents the most recent day, for which data was available at the time the diagram was drawn, in Belgium. Hubbert showed that a plot of  $Q$  vs  $P/Q$  can be used in a straight-line extrapolation (dashed lines) to determine recoverable oil-reserves, or in this example, ultimate deaths. Some of the data sets (e.g. Netherlands and UK) are rather scattered, others have occasionally unusually high values (e.g. Portugal, Canada, USA and Spain). Nevertheless reasonable projections forward can still be made by employing a robust least-squares line-fitting procedure.*

maths were way ahead of the game and already demonstrating distinct between-country differences in late March — i.e. demonstrating the disastrously tardy way in which Britain had allowed the infection to spread, to swamp the NHS and in turn to overburden our care

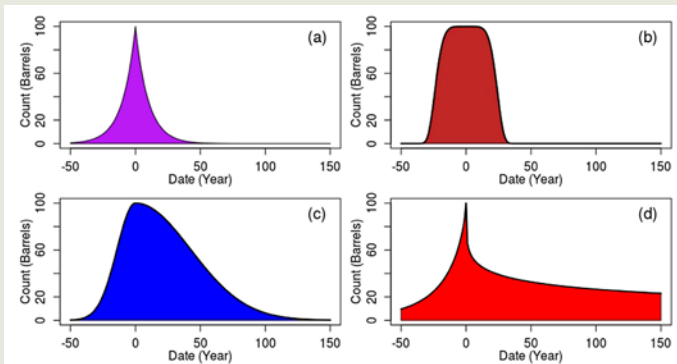
homes. The stringency of the social distancing that countries chose to adopt, the firmness and rapidity with which travel restrictions were put in place, the rigorous implementation of public-health measures used to prevent viral transfer to vulnerable sections of the community (e.g.

### Box 1 Generalised epsilon-skew curves

The equation I have been using to make forecasts of oil reserves (barrels), or COVID-19 deaths, or counts of open flowers as based on previous behaviour (x) is:

$$y = k * \exp(-\text{abs}(((x-\mu)/(\text{sig}*(1+\text{sign}(x-\mu)*\text{eps})))) \wedge (\text{gam}*(1+\text{sign}(x-\mu)*\text{eta})))$$

The response (y) is a function of six parameters (k, mu, sig, eps, gam, and eta). These are respectively the peak value (k), date of the peak (mu), spread i.e. width of peak (sig), skewness (eps), a flat-topped parameter (gam), and an excess kurtosis parameter—a measure of the fatness of the tails (eta). The classic symmetry of the bell-shaped curve (e.g. Fig 1c) occurs when eps=0, gam=2 and eta=0. Clark and Thompson (2011) developed the equation to model springtime flowering. Pleasingly, as it allows a smooth transition between all four types of curves sketched below, as well as fitting symmetrical curves, it is highly suited to maximum likelihood optimisation and to studying a wide range of phenomena.



**Four curves illustrating a range of generalised epsilon-skew fits. (a) cusped, (b) round-shouldered, (c) skewed, (d) fat-tailed, skewed and cusped.**

isolation of Covid patients in hospital settings and care homes) and the effectiveness of temperature testing at major airports were all likely to be

critical policy-response interventions (Hale et al., 2020). Governments that chose to take no, or tardy, actions or had not prepared in the wake of the

traumatic experiences of countries afflicted by the 2015 outbreak of Middle East Respiratory Syndrome, or MERS, ended up with high numbers of deaths on their hands (e.g. Hubbert intersections at the right-hand side of Fig 3) as their health services were overcome and unable to function efficiently. Countries that acted swiftly (intersections towards the left-hand side) had far fewer deaths, returned more easily to free internal movement and achieved a rebounding economy more speedily. Tellingly many of these nations had female leaders (Taub, 2020).

Why should Hubbertian lines (Fig 3) decline so linearly? Why should oil production and epidemics follow similar trajectories? A useful analogy can be drawn with an ecological model. Imagine a piece of newly derelict ground starting to fill up with weeds. In the beginning the weeds are so far apart they are not competing with each other and so the number of plants can grow rapidly. Then as the weeds become more numerous the rate at which new plants materialise starts to be constrained and to depend on the area of unoccupied space remaining. Eventually the previously open ground is fully occupied. In the oil-energy analogy the rate of new discoveries primarily depends on the geology. Fundamentally, to first order, it is controlled by the volume of rock

(specifically — porous rock capable of trapping hydrocarbons) remaining to be explored. Oil production follows discovery, but typically with a ten-year development gap. What rates of oil discovery, weed increase, and daily deaths during viral infections all have in common is their dependence on the fractions of the ultimate totals (barrels of oil, gaps between weeds, susceptible people) which remain untouched. Hubbert (1949, 1982) explained how the straight-line trends, of Fig 3, are to be expected for typical population growth, or decline, because in technical terms the logistic function is a good approximation for the cumulative normal.

Hubbert, to my mind, although a maverick was a genius, a visionary, an oracle. It is often claimed that the advent of “fracking” and cheap gas, which today is being won from North American black shales, has undermined Hubbert’s predictions (see Box 2). But I would point out that Hubbert, in the mid-1950s, had been the first person to explain correctly how the then-new engineering technique, known today as hydraulic ‘fracking’, actually worked. It is true that fracking, made possible by the development of horizontal drilling, has revived the fortunes of oil and gas production in the USA and Canada. Nevertheless it will be interesting to see if fracking,

post COVID-19 and its by-product of negative oil prices, survives as a major producer. As hinted at in Box 2, it is often claimed (e.g. Helm, 2011 and 2017) that “the Earth’s crust is absolutely *riddled* with carbon”, and that economic behaviour (e.g. commodity super-cycles) dominates over geology when it comes to the oil price; and hence the world is

nowhere close to running out of cheap fossil fuels. That is not what Hubbert believed and neither do I.

For references and further details see: <https://www.edinburghgeolsoc.org/publications/the-edinburgh-geologist/> and <https://blogs.ed.ac.uk/roythompson/2020/04/26/glimmer-of-hope-recap-of-posts-i-to-xv/>

### **Box 2 Super basins and peak oil**

The timing and magnitude of peak oil, despite being of enormous significance for future economic growth and for the well-being and lifestyle of billions of people, continue to remain contentious and to be very poorly known.

A wide range of well-reasoned estimates of the volume of ultimate recoverable oil and gas have been generated. Starting at the low end, Hubbert’s most recent (1982, 1985) logistic-curve-based evaluation of 2.1 trillion barrels of oil has been confirmed by Campbell’s (2015) reworking of 2.0 trillion of conventional oil. Both authors argue for similar quantities of total recoverable gas. Their overall judgement is that, in broad terms, only 1/3<sup>rd</sup> of oil and a somewhat higher fraction of gas remains for development. Similarly Sandra (2005, 2020), in a detailed, well-argued report, uses Hubbert’s approach, when production data are available, and reservoir modelling when not, to arrive at a URR of 2.3 trillion boe for conventional and unconventional gas alone. In contrast, at the high end, Li (2011) employs geological arguments to conclude that 7.3 trillion barrels of conventional and non-conventional oil are producible from the 1000 million km<sup>2</sup> of sedimentary rocks on Earth. He suggests we are barely 1/5<sup>th</sup> of the way into the ‘Oil Age’.

The modern concept of super basins (Fryklund and Stark, 2016) provides a fresh way of looking at future energy potential from fossil fuels. Sedimentary basins with 5 billion barrels of oil produced, 5 billion yet to be produced,

multiple plays, at least one prolific source rock and extensive existing infrastructure are classified as super basins. The world's top four super basins (Central Arabia, W. Siberian, Rub Al Khali and Zagros) dominate world oil production today. These four embrace the world's most prolific fields (> 65 billion recoverable barrels of oil, past and future): Ghawar, Burgan, Gachsaran and the Mesopotamian Foredeep Basin; but intriguingly they do not contain any of the world's top individual wells (>100 000 barrels per day) located in Mexico, California and Oklahoma. Forecasting global reserves using super basins as a basis for a Hubbert-type analysis is an attractive proposition because of the intermediate geological scale between wells & fields and the whole planet. Furthermore the definition of super basins ensures reasonably low lifting costs.

The ever-optimistic American Association of Petroleum Geologists is especially keen on the concept of super basins (Sternbach, 2020). It foresees that the associated paradigm shift will lead to a resurgence of exploration and to an energy renaissance that will lead to a more abundant and affordable energy supply. Technologically the programme will be led by recent improvements in seismic imaging, particularly in deep-water basins, and by the industrial production successes already demonstrated for the black shales in the emerging Permian (W. Texas) super basin.

A word of caution, especially relevant in this era of COVID-19 induced sufferings: energy balance modelling shows that total oil and gas production is closely interconnected to global warming. Production of even the lowest total reserve would lead to global temperatures well above the Paris Agreement's temperature threshold of +1.5oC (See Thompson, 2017a and Additional material). Production of the high-end reserves would in the absence of mitigation technologies lead, by 2150, to 7–8 degrees of warming: a geohistorical, ice-free state not experienced since the Eocene (Burke et al., 2018), some 40–50 million years ago, when sea levels were (roughly) 100m higher than today.

## Geologist in politics: Yes Minister!

*By Lord Ian Duncan of Springbank, House of Lords*



Back before the lockdown, which seems like a lifetime ago, I was being shadowed by a group of science undergraduates, part of a scheme to improve the political awareness. There aren't many folks in government who hold a science degree. When I left office the number of ministers holding a PhD in a science was halved. I was describing some of the day-to-day challenges faced by ministers and happened to mention that sometimes there were just too many Sir Humphreys in the room. I could tell from the blank stares that Sir Humphrey was a stranger to the group.

As a youngster, I was addicted to 'Yes, Minister,' and its successor, 'Yes, Prime Minister.' When people ask what has driven my career, the

answer is two-fold: finding a lump of limestone riddled with fossils (no mean feat given my home town was built entirely of Old Red Sandstone; it was glacial debris) and watching the interplay between Sir Humphrey Appleby the über bureaucrat and Jim Hacker MP, the naïve politician, never quite getting his way. Both fascinated me. (I was a slightly odd child).

It came as something of a shock to realise that it's forty years since Sir Humphrey first graced our screens. (As I realised at the time, probably before the undergraduates' parents were born, let alone the undergraduates).

The undergraduates had joined me to increase their understanding of government. However, it is often politicians who need to increase their understanding of science. Indeed, more scientists are desperately needed in politics (and the upper echelons of the civil service).

It brought to mind a 'Yes, Minister,' episode in which Jim Hacker is confronted by an MP worried about a chemical factory opening

in her constituency. The reason for the unease: the plant will produce metadioxin, an inert compound, which unfortunately sounds a lot like dioxin, a toxic compound responsible for a series of environmental disasters. The dialogue continues:

Local MP: *'What I insist upon knowing is the actual difference between dioxin and metadioxin'*

Sir Humphrey: *'It's very simple. Metadioxin is an inert compound of dioxin.'*

Minister: *'I think I follow that but, er, could you, er, just explain that a little more clearly?'*

Sir Humphrey: *'In what sense?'*

Local MP: *'What does inert mean?'*

Sir Humphrey: *'Well... inert means that... it's not...ert'*

The discussion continues in a similar vein. Reading it cold it must seem highly improbable at best. And yet, and yet, it isn't. The truth is that there are precious few scientists, or individuals with a scientific background anywhere near politics or the senior civil service. There are no holders of a science degree to be found in the cabinets of the Welsh or Scottish Governments.

A single mathematician serves in Northern Ireland. The UK Cabinet has three cabinet members with a scientific background (out of 22). A cursory examination of the Permanent Secretaries serving in UK Government—the Sir Humphreys of this world—uncovered only a single holder of a science degree.

Does it matter? There is no denying that those senior politicians and civil servants are, on the whole, clever people. Almost all possess degrees from some of the most prestigious universities in the land. The fact that their last experience of hands on science was cranking up the Van de Graaff generator or dissecting a runner bean shouldn't really matter. Or should it?

Of late many of the greatest challenges facing the country are intertwined with science: pandemics; climate change; environmental degradation; the coming energy revolution; pollution; GMOs. Planning for the future will depend upon an understanding of demographics; nature-based solution to global challenges an understanding of ecology, biology botany; food security an appreciation of agronomy, hydrology, biology.

Geology too will be at the heart of a whole range of debates, not least questions around the future

of energy, our dependence upon rare earth elements, general mineral exploration, disposal of waste, infrastructure planning, natural disaster aversion.

Politicians and senior civil servants can always rely upon advice from scientists. My old department, Business Energy & Industrial Strategy, was awash with scientists at junior grades. However, receiving advice and understanding it are not the same thing. A scientific background and appreciation of scientific concepts and constructs are all valuable commodities. It's why scientists regularly climb to senior levels in a whole range of corporate endeavours. And yet, In the UK only a single scientist has ever become Prime Minister. I will leave you to work out her name. Rarely do scientists fill the ranks of the very senior civil service.

There is clearly a need for more folks with a scientific background close to the levers of power. Why do so few individuals with a scientific background seek political careers. It begs the final question: have you ever entertained the thought of standing for election? If the answer is no, and I suspect it may well be, then we may have to accept the rule of lawyers and historians, English graduates and moral philosophers,

PPE-ers and economists. But if you have an interest, an itch, a concern at the way things are going, then now could well be your moment. There has never been a greater need for scientists at the heart of politics.

### Editors note

One of my tutors at Oxford was Lord Oxburgh, who is also a geologist in the House of Lords, but a quick search on the internet revealed few geologists in politics. One of the first in the UK was Sir James Hall of Dunglass, FRS, RRSE (17 January 1761–23 June 1832), who lived in Edinburgh, although he was an MP for the rotten borough of Mitchell in Cornwall (1807–1812).

Sospeter Mwijarubi Muhongo, MP is a Tanzanian geologist and a member of the Tanzanian Parliament, where he has served as the Minister of Energy and Minerals. In the USA, Colin Powell, Secretary of State to George W Bush, and Bruce Babbitt, Secretary of Interior to Bill Clinton are also recorded as geologists.

The most powerful geologist in the World was Wen Jiabao, who was Chinese Premier from 2003–2013. Earlier in his career he was Chief of the Gansu Provincial Geological Bureau and later Vice-minister of Geology and Mineral Resources before going on to greater things.

## An introduction to the new President of EGS

*By Tom Challands, Edinburgh Geological Society President, 2020–2022*



Sitting in a small cottage in the Adelaide hills, 10124 miles from Edinburgh, the circumstances to be taking on the presidency of the Edinburgh Geological Society could not be more extraordinary. As the world tackles the coronavirus pandemic, we have all seen our lives change in ways that nobody could have foreseen. This has affected our home lives, our work lives and how we are all able to engage with our passion for geology. Coronavirus has resulted in prolonging my time in Australia but I also feel that there is a

silver lining to every cloud and that the necessary changes we are having to make can be to our society's advantage in the long-run. Our new reliance on web-based meetings and presentations has inspired some very creative ways of presenting information such that it is suddenly accessible to a larger audience than ever before. With our society's aim **of stimulating public interest in geology and the advancement of geological knowledge these new platforms are an exciting opportunity for us. Still, nothing beats getting your hands on real rock.**

I am extremely fortunate to work in a discipline that, generally speaking, grasps the public's imagination. Besides this I am also extremely lucky to be working in Scotland, specifically Edinburgh, where the shores of the Firth of Forth abound with Carboniferous fossil sites of global importance. Furthermore, Edinburgh, and Scotland more widely has a rich history of palaeoichthyology—the study of fossil fishes and my area of expertise. I have been lucky enough to work on specimens

of fossil fish from the Orcadian basin that Hugh Miller collected (Challands 2014). I have also been privileged to have been involved in the recent TW:eed project on the evolution of early tetrapods during Romer's Gap lead by the late Jenny Clack and working with members of BGS Scotland group, National Museums Scotland friends and colleagues from institutions all over the world. The very first fossil fish ever to be described was from Scotland—*Dipterus valenciennesi* Sedgwick and Murchison 1828, and it is this legacy of nearly 200 years (and still going strong) of fossil fishing in Scotland that demonstrates that we truly live in a world class country for palaeontology and geology more generally.

I have come full-circle from completing my undergraduate degree in geology at the Grant Institute, University of Edinburgh in 2002 to now working here as a researcher in the evolution of sensory systems in early vertebrates. Immediately following my undergraduate degree I moved to Bristol to undertake their masters degree in palaeobiology where I cut my teeth on researching the geochemistry of vertebrate fossils from the Lower Jurassic fissure fills of south Wales working with Pam Gill and Mike Benton. I stayed with the University of Bristol for a further

year holding the illustrious job title of 'Bristol Dinosaur Education Officer' as part of their very successful outreach project. Having learnt a great deal about scientific outreach and public engagement from my time in Bristol, I was eager to get back into research and was lucky enough to be selected for a PhD with case funding from the BGS at Durham University on geosphere and biosphere interactions in the Ordovician of the Welsh Basin. As most PhDs are, it was a highly illuminating experience but made the more so by working alongside BGS mapping geologists. I was able to help build a biostratigraphy for the Upper Ordovician in a geochemical stratigraphical framework as well as model the expression of climate changes in the Welsh Basin during the Upper Ordovician.

Not content with jumping through the standard academic hoops and heading into a postdoc, I joined Total E&P UK as a research geologist for two years working on geostatistical methods for modelling fluvial systems based on field data. An invaluable insight and experience working in industry I almost felt that it was too easy—I didn't have to apply for funding and I was given datasets to work with rather than collecting the data myself! Having met and worked with many wonderful colleagues I

decided to try and make the move back into academia albeit by the circuitous route of becoming a rock climbing instructor and mountain leader and setting up my own company in providing such activities with a geological and scientific angle to them.

It was during this time that I started working on fossil fish inspired and encouraged by Al McGowan and the spectacular finds of Ken Shaw who had noticed fossil fish in the pavements of Edinburgh. Together with support from various bodies and institutions we launched the Save the fishes! pavement fish project from which a small but significant expertise of Devonian and Carboniferous fish has blossomed in Edinburgh. During this time I was invited to take part in sampling the Permo-Triassic boundary for fish in Svalbard and was subsequently taken on to teach in the School of Geosciences. Having since gained funding and support to undertake further research, my current research interests largely concern using the fossil record as a source of inspiration to solve engineering problems—palaeobioinspiration. This is such an exciting new area of palaeontology being interdisciplinary science in its best and purest form. I now work with engineers and have met a greater diversity of researchers in a

broader variety of fields than I ever could have from a more traditional palaeontological route of classifying organisms and documenting their patterns of evolution.

2013 was a very exciting time to join the School of Geosciences at the University of Edinburgh as palaeontology really began to flourish again following in the footsteps of Euan Clarkson and Sue Rigby. My notorious dinosaur-loving colleague Stephen Brusatte and I both joined the School in the same year and since then, with the hard work of Dick Kroon, Rachel Wood and colleagues we now proudly offer the UK's only MScR in Palaeontology and Geobiology. My position also involves managing the vertebrate side of our new palaeontology laboratory in the Grant Institute where we are lucky enough to be engaged in a programme preparing some spectacular finds from the Jurassic of the Hebrides and the north east of Scotland. The Isle of Skye and other Scottish sites that expose Jurassic rocks are revealing themselves as a hotbed of vertebrate fossils. Following our 2014 discovery of a 'dinosaur disco' on Skye more and more dinosaur footprint sites are becoming apparent. But there is a whole terrestrial and aquatic ecosystem preserved in the Jurassic of the Hebrides and it is now apparent

that these areas will provide a great deal of fascinating work for both researchers and students for years to come.

Edinburgh Geological Society has been extremely supportive of students working on Skye and I think this is a key attribute to what makes our society work so well. A geological society offers so much more than simply a lecture and field trip schedule. It was through my geological society 'alma mater', the Cumberland Geological Society that as a teenager I was encouraged to pursue palaeontology and geology not just as a career but a passion. Though we do not see too many youngsters at our lectures this is something I feel we do very well through the enthusiasm of our members, the many public outreach activities that we engage in and our support of student research and fieldwork in particular. Our members night in particular and our journal, The Scottish Journal of Geology, provide a platform for students to present their work

In his inaugural presidential introduction for The Edinburgh Geologist Bob Gatliff stated a wish for the society to raise the profile of Scottish Geology. Through support of conferences such as the forthcoming Geologist's Association meeting,

being integral in the formation of the Scottish Geology Trust and funding of some excellent field work and research projects (among many other initiatives) I believe Bob's vision is being realised. This is, however, an ongoing task and we should always be striving to demonstrate that Scottish geology and geoscience is world class. Keeping a finger on the pulse of all things geological, be it policy, industry, science or art is something that as a group we are capable of. Transmitting this information to our members but also to a broader public is also our responsibility as a society.

I also believe that we can raise our own profile as a society. We are a diverse society whose membership comprises interested amateurs to university professors and everyone in between and this is certainly something to celebrate. For the latter group, publishing their scientific work is part of their job but for many others the prospect of publishing a scientific paper based on their own geological observations or activities is considered the preserve of academics alone. Nonsense. Given the great range of expertise we have on publishing geological research I would like think that we can encourage our members to publish their work. This does not need to be limited to scientific work

as the hugely successful Hugh Miller Writing Competition has shown but could also involve geopoetry, art and outreach.

For all the geological activities that we engage in we can be under no doubt that in the short- to medium-term our activities may very well be affected by social restrictions and how we operate may change. But this needn't be for the worse. The sudden rise of zoom as a remote meeting tool (other platforms are available) has shown that we can operate efficiently together remotely. For EGS this approach will allow us to stream all of our lectures to a global audience as well as upload them to our website so that anyone may be able to view them at their leisure. But such digital interactions are not for everyone and it would be a great shame indeed if this became the norm for meetings and lectures. Face to face interactions with other members, the public and invited speakers is key to learning and we are, after all, a learned society.

Finally, before coronavirus, I had a chat after a lecture about what we could do in our Society that we currently do not do. One idea raised was an annual dinner and ceilidh. Once we see our lives returning to what can be considered the new normal, I would love for us all to be

able to celebrate the occasion with such an event.

Tom Challands  
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## Reference

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*Tom and his son at the golden spike section for the Ediacaran Period and global warming following global ice house conditions. Trezona, near Brachina Gorge, Flinders Ranges, South Australia. Below the spike is the Elatina Formation tillite and above the Nuccalenna Formation dolomite. Scotland has contemporary deposits on Islay of the Port Askaig tillite and the Bonahaven Dolomite Formation respectively.*

# The Gn-neiss song

By George Strachan

On Wester Ross's rough terrain  
Some students hunched in pelting rain  
Before a craggy rock they stood  
And tried to name it, but in vain.  
That's convoluted bedding in sandstone!  
Na, na! It's a coarse-grained granite  
Fae Aiberdeen, withoot a doot!  
What tosh! It's muscovite biotite garnet  
    staurolite schist.  
At which the rock responded through the mist –

I'm a Gn-neiss. I'm a Gn-neiss.  
I'm the Gn-nicest bit of gn-eiss past Achnasheen.  
I'm a Gn-neiss, take my advice.  
A better Gn-neiss there's never ever been.  
Not a sandstone, nor a schist, not a granite  
    through the mist;  
But a super-duper ancient block,  
A stupendous metamorphosed rock,  
A three billion year old chunk of Scourie Gneiss.

A post graduate was mapping for his thesis,  
When a crag some metres high he did espy.  
He sketched the outcrop well and inserted  
    strike and dips,  
Then hammered off a chunk to micro-analyse.  
"Ouch!" cried out the crag on being hit.  
"How dare you whack me for to get a bit  
Of rock to cut and polish for the stage,  
(Not Eden Court, you dumb cluck!).  
It's for viewing under polarising light".

I'm a Gn-neiss. Another Gn-neiss.  
I wish I could gn-nash my teeth at you.  
I'm a Gn-neiss, a most noble Gn-neiss.  
How dare you hammer me till I'm black and blue!  
My ancestry's archaean and my sister's Laxfordian;  
Far superior to Grenvillian or Nagssugtoquidian.  
As for Caledonian, Silurian and Devonian! Ugh!  
I'm the best-est, oldest rock that's ever been!  
The best-est, oldest rock that's ever been!  
*(sing softly)*



Braigh Horrisdale in South Gairloch.

In muggy August weather when the wind had  
dropped to zilch  
And the midges from the heather rose a cloud,  
A muckle rounded boulder loomed through  
the midgy mist  
And was spotted by a very keen rock hound.  
He noted its position perched up upon three  
stones  
And remarked it was erratic, but what rock he  
did not know.  
A gabbro brought from Skye, or a granite from  
nearby?  
When the boulder's high-pitched voice sang  
sweet and low.

I'm a Gn-neiss. An Augen Gn-neiss.  
If you look, you'll see me flutter my eyes at you.  
I'm a Gn-neiss, an Inchbae Augen Gn-neiss.  
And Erratic an Augen Gneiss as you can view.  
A glacier plucked me up and carried me all  
this way,  
To dump me on Ben Wyvis untidily.  
I'm a Gn-neiss, a most erratic Gn-neiss,  
The finest Augen Gn-neiss there's ever been.  
The finest Augen Gn-neiss there's ever been.  
*(sing softly)*

But our intrepid bloke had more than had  
enough  
Of midgies in his nose, his eyes, his throat;  
And with a mighty ARGGHHH he shot off  
down the hill  
To shelter in his car from fiendish hoards.  
And so our story ends about our Gneiss Gn-neiss.  
Yet still comes this refrain from Ross-shire's  
stately hills –

I'm a Gn-neiss. The best-est Gn-neiss.  
*(sing softly)*  
I'm the Gn-nicest bit of Gn-eiss by Loch Maree.  
I'm a Gn-neiss, take my advice.  
Tectonic forces have contorted me.  
I'm twisted out of shape and amphibolitisied,  
And migmatised — not stigmatised — till fully  
crystallized.  
Just remember I'm a gneiss; an aristocratic  
gneiss,  
The most archaic Gn-neiss in all the Gl-lobe.  
The most archaic Gn-neiss in all the Gl-lobe.  
*(sing very softly)*  
The most archaic Gn-neiss in all the Gl-lobe.  
*(sing very very softly)*

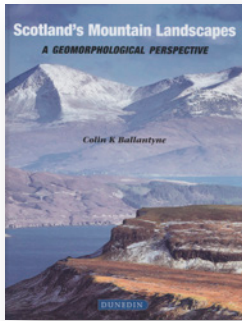
*(To be sung to the 'Gnu Song', with apologies  
to Flanders & Swan)*



Half way up Ben Wyvis

## Book reviews

**Scotland's Mountain Landscapes — a geomorphological perspective** by Colin K Ballantyne, Dunedin Academic Press, Edinburgh. 2019. ISBN 9781780460796



On a spontaneous visit to Edinburgh, revisiting happy haunts and friends from my days living in the city, I discovered by chance that Emeritus Professor Colin Ballantyne of the university I had once hoped to go to was giving a talk on the Ice Age in Scotland. At the end of a riveting talk, in which he revealed that while at St Andrews he had climbed many more Munros than I had managed, he mentioned a book he had just written. This book turned out to be much more than supporting material for the talk he had just given on Scotland's Ice Age but a comprehensive and impressive account of the

geomorphology of Scotland's mountain landscapes.

In his splendidly illustrated book, the author aims to 'steer a middle course' with a text that is neither so research orientated that it appeals only to a small audience of experts, nor so popular that the science is trivialised. This he achieves with great skill providing a text that is easy to read and highly informative with simple and clear diagrams.

The author is known for his expertise on the Ice Age in Scotland and the glacial landforms created at that time and it is this subject that takes up two of the fullest chapters of the book. The glacial and interglacial stages of Scotland are described with a fascinating focus on the extent and characteristics of the last Scottish Ice Sheet and mountain glaciers. Glacial landforms are described in erosional, depositional and ice-dammed lake categories (the parallel roads of Glen Roy). There follows an account of the surrounding landscapes (periglacial landforms) and descriptions of wind, river and landslide modifiers to the glacial landscapes (chapters on landslides, aeolian and fluvial landforms).

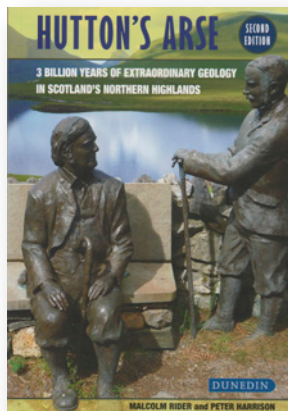
There are two substantial chapters at the beginning of the book on the geological evolution of Scotland. A useful 'primer' on basic principles of geology is followed by descriptions of the five terranes the author defines in Scotland: the Hebridean, Northern Highlands, Grampian Highlands, Midland Valley and Southern Uplands terranes. For each terrane an account is given of its geological evolution and the relationship between large- and small-scale bedrock structure and landforms.

Some readers may be slightly startled by the red lettering used for the main headings but I find it gives the book a crisp appearance which cannot be faulted in its overall presentation and the clarity of the figures and photographs.

In addition to valuable indexes, readers will find the description of nine key sites in the last chapter of the book a particular benefit of this most attractive book.

Danny Clark-Lowes

**Hutton's Arse: 3 billion years of extraordinary geology in Scotland's northern Highlands (second edition)** by Malcolm Rider and Peter Harrison, Dunedin Academic Press, Edinburgh. 2019. Paperback. 226pp. ISBN 9781780460406



Although aware of this book for many years and interested in the Northern Highlands of Scotland as a tourist and as a leader of field excursions, I had avoided this book entirely due to its title which I found gratuitous and cynically chosen to attract attention.

It is indeed a bit of a 'marmite' book, some excellent prose and beautiful evocation of the Highlands, combined with good story-telling but interspersed with variably successful 'humorous' asides frankly-expressed personal views and rants, for example against wind farms.

I was sold on reading on by the introduction which was pacy, passionate and good prose. It echoed my own delight in highland scenery, solving geological puzzles and understanding the evolution of ideas, particularly geological ideas.

The book takes the form of a series of guided walks through highland scenery during which the story of an idea or a place, or normally both is set out. These include for example the Torridonian at Stoer and Clachtol near Lochinver, the Moine thrust around Skiag Bridge, Loch Assynt, Conival and Knockan Cliff. The Devonian fish beds at Achanarras, The isle of Rhum, The Quirang on Skye, Gruinard Bay and Loch Maree, The Scourie dykes and Laxford front, and of course Siccar Point. Along the way topics as diverse as future climate, evolution of vertebrates, crustal formation, the origin of life, and the life of a volcano are addressed as the reader and authors wind their way up the glens and bens of the highlands, in an informal, conversational, and sometimes appropriately breathless style.

This is not a textbook, nor an authoritative field guide but a book designed to encourage, through its patent enthusiasm, the reader to visit the places described in the book.

And for me it does this very well.

There are a few errors here and there, and there is the one aberrant section on the Precambrian which is distinctly wobbly (unfortunately in Chapter 1 but if you do notice this please don't let it put you off! Read on, the writing gets more confident and secure straight away. I particularly enjoyed the chapter on the Orcadian lake fish beds and High Miller. I learnt a lot from the chapter on ice ages and recent climate change in the highlands, I now am even more sure that I need to get to Rhum and see the layered gabbros. This book worked for me!

The historical development of knowledge of the highlands underpins all the writing. Numerous known and less well-known historical hero and villain figures in highland geology are introduced in a breezy style. Hutton himself doesn't make an appearance until the last chapter in which he helps expand the scope of the book to the planetary. His saddle-soreness, the origin of the title is well and truly behind him by then. One is tempted to say "Hutton's Arse? A cracking good read!" But there you go. Have I fallen into the publicist's trap? Good book, doubtful title.

Bruce Levell

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