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Cover Illustration
A granite glacial erratic on a limestone pavement in Strath Suardal, Skye. Limestones of the Durness Group form magnificent limestone pavements in the Strath Suardal/Torrin/Camas Malag area in Skye. The rounded hills in the background are the famous granite Red Hills, they are part of the Palaeogene Skye Igneous Centre.

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Editors
Phil Stone  Bob McIntosh
psto@bgs.ac.uk  rpm@bgs.ac.uk

British Geological Survey
Murchison House
West Mains Road
Edinburgh EH9 3LA

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Another Edinburgh Geologist—there must be another anniversary to celebrate. This time it’s the 175th birthday of the British Geological Survey, founded in 1835 as the Geological Survey of Great Britain. To be honest, the Scottish connection is a bit weak, as the Survey’s early work was done in England and it was about 20 years before geological investigations started north of the border.

The establishment of the Geological Survey was largely the result of lobbying by Henry Thomas De la Beche, a prominent gentleman geologist of the period and an influential figure in scientific circles. De la Beche became the first director, and indeed for the first four years was the only geologist on the staff! He had been previously engaged in compiling a geological map of Devon and simply continued with that project in his new official role. Slowly the number of geologists employed increased, and the mapping progressed northward. The first Scottish maps to be produced (at a scale of 6 inches to the mile) were for the Lothians, with work then extending into Fife and Berwickshire. The first 1 inch to 1 mile map, for Edinburgh, appeared in 1859 with an accompanying memoir published in 1861.

De la Beche had died in 1855 and had been succeeded as director by Roderick Impey Murchison. Under Murchison’s leadership there was a substantial increase in staff numbers and in 1867 the Scottish section acquired a separate identity with Archibald Geikie as Director. For the first time a headquarters office was established in Edinburgh. All previous work had been carried out by staff officially based in London, though in practice most geologists seldom went there and remained in ‘field accommodation’ throughout the year. The Survey’s first Edinburgh office was in Argyll Square, in a building housing the Science and Art Museum. This was demolished in 1869, and Argyll Square disappeared,
when the new ‘Chambers Street’ Museum was built on the site, and for the next ten years the Survey office was in No. 1 India Buildings, which happily is still with us.

From India Buildings, geological work was first focussed on southern Scotland but from 1875 attention turned north and in 1883 the Survey began tackling the complex geology of the north-west Highlands. This mapping was destined to become a classic of geological investigation. Murchison, Nicol (Professor at Aberdeen University) and Lapworth (Professor at Birmingham University) had proposed different solutions to the ‘Highland Controversy’ and Geikie, who had become Director of the Survey in 1882, saw its resolution as a means of hastening completion of the geological mapping of Scotland. Some of the Survey geologists involved in the work, for example Ben Peach and John Horne, went on to become much celebrated figures in Scottish geology, but of course there were other contributors whose efforts are less well known. Amongst them was Henry Moubray Cadell, and in this issue of *Edinburgh Geologist* John Mendum provides an account of his work in the Highlands, and of his prescient experiments on thrust deformation.

The field mapping techniques used in those days continued to serve geologists well for the next hundred years or so, with a basic kit of hand-lens, hammer, compass-clinometer, map-case and notebook. I’m pretty sure that if Peach, Horne and Cadell could have been resurrected to assist with geological mapping in the mid-20th century, they would have found no particular differences from the process as they knew it. Aerial photographs would probably have excited them, but would likely have caused no particular interpretational difficulties. Structural analysis using stereographic projections might have needed a bit of explanation but if any other maths needed doing they were probably familiar enough with slide rules and logarithms. So it was when I began my first post-graduate field work in the early 1970s. Then, in 1972, the world changed. In that year Hewlett-Packard launched the HP-35, the first commercial electronic calculator. It was about the size of a large telephone directory and cost about £350, which for me at the time was about 3 months salary! Since then, just about every aspect of our lives has been revolutionised by computers, and geological mapping has been no exception.

Today’s field geologist will locate themselves with a Global Positioning
made available. Sounds great, but it also means that the geologist will effectively be electronically tagged and tracked. Stop moving for 10 minutes and expect an automated ‘are you all right’ enquiry. Of course, that may not be necessary, because pulse and breathing rate will be constantly monitored to ensure compliance with health and safety regulations. One thing will not change though: the visceral thrill of finding that fossil or working out that complicated structure. On the other hand, read John Mendum’s article and ask yourself what Henry Cadell might have achieved with a computer.

A last word on greywacke
Fellows of the Edinburgh Geological Society prove to be a pretty abstemious lot, with not one admitting to sampling a bottle of greywacke. Maybe you were put off by the knowledge that in official circles ‘greywacke’ is no longer regarded as a politically correct lithological descriptor. It has been around a long time though, with its original German form of grauewacke first being applied in 1789 to hard, dark-coloured, Carboniferous sandstone from the Harz Mountains. Although when you see it you immediately know what it is, greywacke has always
resisted formal definition. Even the spelling is disputed, with graywacke being preferred in North America. Archibald Geikie provided one of the early attempts at definition in his 1882, *Textbook of Geology*: “… a compact aggregate of rounded or subangular grains of quartz, feldspar, slate or other minerals or rocks cemented by a paste … grey, as its name denotes, is the prevailing colour … The rock is distinguished from ordinary sandstone by its darker hue, its hardness, the variety of its component grains, and above all by the compact cement in which the grains are embedded.”

Subsequent attempts to modernise the definition in more precise terms were less than successful and we ended up with a vague consensus of a class of ‘wacke’ sandstones defined by their matrix content being between 15% and 75%. Sandstones with less than 15% matrix were arenites, whilst anything with more than 75% matrix was a mudstone. Different definitions fiddled with the matrix proportions and added various descriptions of the grain content to give us lithic greywacke and feldspathic greywacke, but also arkosic wacke and quartz wacke. Progressively the ‘grey’ became a bit redundant and is now dropped from most formal definitions. Old habits die hard though so I’m sure that ‘greywacke’ will be with us, informally, for a while yet. But I wonder if the New Zealand viticulturists realise that officially their wine is wacke. Curiously, in 1882, Geikie had a very different definition of wacke: “A dirty green to brownish-black clay arising as end-product of in situ decomposition of basalt.” That doesn’t sound very appealing.

**What else?**

Though not admitting to drinking the stuff, Angus Harkness was clearly concerned that we might get the false impression that New Zealand was entirely made up of wacke/greywacke. Accordingly, he draws our attention to the country’s varied geological delights with a review of a recently published account of ‘New Zealand Geoscience into the 21st Century’—and whilst down under he does the same for Australia. Then, picking up on the themes of fieldwork and sandstone, Sandy Stewart shares some reminiscences of 40 years research on the Torridonian. So far, so factual, so we finish with a foray into some geologically inspired fiction. Read on.
Henry Moubray Cadell: a geological and industrial innovator

By John Mendum

Many characters served in the Geological Survey in Scotland during its early years, some well known, but others less so. One of the latter, who perhaps deserves a more celebrated reputation, was Henry Moubray Cadell—a geologist best known for carrying out early experiments to try and explain the geometry and mechanisms of thrusting in layered rocks.

H M Cadell posing with his experimental ‘squeeze box’ at The Grange, Bo’ness (25th January 1887). BGS image P612832.
Henry Moubray Cadell was born in 1860, the eldest of the seven children of Henry Cadell of Grange and his second wife, Jessie Gray McFarlane: his paternal grandmother’s name was Isabella Moubray. The family name was originally spelt Caddell, but in the 18th century a d was dropped. However, it is still pronounced with emphasis on the first syllable; thus Cadell rhymes with paddle! Henry Cadell of Grange was a mining consultant and industrialist who had acquired considerable geological knowledge of the Lothian coalfields. Indeed, in the 1850’s he had provided Archibald Geikie with geological information about the Bo’ness area that was incorporated into the initial survey map and memoir for Edinburgh and the Lothians. He favoured and fostered economic development of the hinterland to the River Forth and managed the Bridgeness Coal Company that held interests in coal mining, iron foundries, iron ore mining, salt pans, timber, agriculture and pottery manufacture. The wealth of the large Cadell family was based mainly on industrial enterprises that started initially with iron-ore smelting at Cockenzie and continued with the establishment of the Carron Iron Works in 1759. In the late 18th and early 19th century the Cadells of Grange were the senior branch of the family and owned considerable estates in Linlithgowshire and Stirlingshire and several collieries.

H M Cadell attended Edinburgh University (1878–1881), where he studied geology under Archibald Geikie. On graduating he continued his studies for a further year at the Clausthal Royal Mining Academy in Germany and in 1883 he joined the Geological Survey in Scotland. The previous year Geikie had been appointed as Director-General of the Geological Survey (based in London) and the survey was recruiting staff to work in the Highlands, by then the largest part of the British Isles that remained geologically unsurveyed. Cadell was one of several new recruits assigned to the Highland mapping programme that commenced in north-west Sutherland. This work had been stimulated by the discovery of large-scale thrust planes and mylonites in the Loch Eriboll area by Charles Lapworth in August, 1882. Lapworth’s interpretation resolved a long-standing geological problem concerning the relationship of the metamorphosed Moine rocks and the underlying non-metamorphosed Cambrian sedimentary strata that lay to the west. His model proposed that the Moine succession (‘Eastern Schists’) had been thrust westwards.
for many kilometers over the Cambro-Ordovician strata and underlying Lewisian gneisses along a gentle, easterly dipping dislocation, now known as the Moine Thrust. Lapworth’s conclusions contradicted the previous interpretation of Murchison, staunchly supported by Geikie, which had postulated that the easterly dipping structural succession was in normal stratigraphical order. James Nicol had strongly disputed the Murchison interpretation, arguing that the Moine rocks were juxtaposed against the Cambro-Ordovician rocks along a steeply dipping fault. Both protagonists had died before the problem was resolved.

In fact, the Eriboll area forms part of a c. 200 kilometre-long, structurally complicated belt, termed the Moine Thrust Belt. This belt separates the mostly Moine Supergroup rocks to the east, part of the Caledonide Orogenic Belt, from the Foreland Lewisian basement gneisses and Torridonian and Cambro-Ordovician cover rocks to the west. The Moine rocks, originally mostly sandstones and shales deposited in Neoproterozoic times around 1000 Ma ago, have experienced several episodes of deformation and metamorphism. In contrast, the protoliths of the Foreland Lewisian gneisses were mainly tonalites and granodiorites with significant gabbro bodies and dolerite sheets and dykes, mostly intruded at deep crustal levels between c. 3000 Ma and c. 2800 Ma. The gneisses show evidence of a complex Archaean and Proterozoic structural and metamorphic history, but are unconformably overlain by Meso- and Neoproterozoic (Torridonian) and Cambro-Ordovician successions. These distinctive sedimentary cover rocks, the red-brown arkosic sandstones and subsidiary shales and conglomerates of the Torridonian succession, and the white, grey and brown Cambro-Ordovician quartzites, dolomitic mudstones and limestones were not deformed or metamorphosed during the Caledonian Orogeny except where they lie within the Moine Thrust Belt.

Cadell carried out his first geological mapping in the autumn of 1883, covering some 20 sq. miles of Dalradian rocks north of Kenmore on Sheet 55 (Blair Atholl), probably mentored by J.S Grant Wilson. The following year he was posted to the Durness-Eriboll area of Sutherland where he joined an expanding team led by Benjamin Peach whose remit was to make detailed maps of the area. Geikie believed that if the survey geologists could resolve the complex structural and metamorphic
pattern of the Moine Thrust Belt, this ‘solution’ could be applied to the remainder of the Highlands, speeding up the mapping considerably. Cadell appears to have rapidly become an efficient and reliable field geologist, adept at recognizing thrusts and folds and their effects on the Cambro–Ordovician succession. He worked in Sutherland for three summers (1884–1886), where his youth, training, innate abilities, and outlook made him a good choice to traverse the remote, wild, mountain country centred on Foinaven and Arkle. Although focused primarily on the complexities of the Moine Thrust Belt, Cadell also mapped eastwards into the Moine succession and westwards across the Foreland Torridonian and Lewisian rocks. Fieldwork took place in the summers and late autumn times to avoid the spring snows and the main shooting season. In the spring and early autumn periods Cadell mapped Dalradian rocks of the Southern Highlands between Arrochar and Helensburgh (Argyllshire and Dumbartonshire) on Sheet 38 (Ben Lomond). In the winters of 1885 and 1886 he collected borehole and quarry information in the Lothians and looked at local sections in order to update the Edinburgh map to keep pace with coal and oil-shale exploitation. This involved accurate computation of cross sections and prediction of the 3D geometry of coal seams and oil shale horizons. This Lothian work was continued after Cadell left the survey, with detailed 6 inch-scale map updates in 1891 and again in 1901. It culminated in his papers describing the geology of the Oil Shalefields (1900, 1901) and in the Geological Survey Memoir on the Oil Shales of the Lothians, published in 1906.

In the summers of 1884 and 1885 Cadell made numerous traverses across the northern flanks of Foinaven and along the upper parts of Strath Dionard. He realised that the Cambrian quartzites here form a large massif due to stacking by a series of low angle faults termed ‘slide planes’ and marked ‘S.P’ on field maps (note that Geikie later coined the term ‘thrust’). A ‘Great Slide Plane’ (‘G.S.P’.), now known as the Moine Thrust, was shown capping the subsidiary thrust structures below. For the Survey’s 1885 Annual Report Cadell wrote “The most conspicuous feature of the geological structure is the extraordinary exaggeration in the apparent thickness of the quartzites by the action of multitudes of reversed faults or thrusts, nearly parallel to the planes of bedding. A series of beds not more than 500 or 600 feet thick are thus made
to appear when measured across the strike in the usual way, like a continuous series of beds, over 4000 feet in thickness”. The Foinaven–Arkle area is now considered a type-area for the thrust duplex—a fundamental component of thrust belts. Modern interpretations still rely heavily on this mapping, done almost a century earlier. Cadell had found thrusting on a massive scale and his notebooks, maps and writings suggest that he understood both the 3D geometry and mechanical implications of the mapped structures. Like Peach, Cadell filled his field notebooks with sketches and paintings of landscapes and geological features—many of these relate to the thrust belt in Sutherland. Interestingly, the detailed landscape sketches in pencil or ink wash are largely objective with some emphasis of the bedrock and superficial features. Such sketches are followed by more detailed sections and annotated geological sketches from the same area, seemingly done after the initial landscape assessment. Perhaps the landscape sketches played a role in geological interpretation and planning of the field traverses? In contrast, Cadell’s watercolour paintings are more subjective and portray a less detailed view of some of the more attractive Highland landscapes.

Cadell mapped a wide variety of Highland areas, both topographically and geologically. For example, in July 1888 he mapped the Ben More

Watercolour painting—Loch Dionard in dull weather (18th June, 1885). Imbricated Cambrian quartzites form the prominent southeast dipping features on Creag Urbhard (left) beyond Loch Dionard. BGS image P612739.
Coigach area in Wester Ross, a daunting mountain with relatively simple geology. In contrast, in autumn 1887 he mapped the Lochindorb area of Nairnshire and Elginshire—topographically less challenging, but geologically complex. Geikie recorded in the Summaries of Progress that the Highland weather was particularly bad in the 1880’s; indeed, he cited the bad weather and difficult conditions as the main causes of debilitating illnesses (inflammation, sciatica), that affected several of the staff. Cadell’s youth and apparently robust health made him a prime candidate to map wild and remote mountainous areas in such conditions. Following Cadell’s resignation, Geikie, in the Summary of Progress for 1888, referred to him as ‘a most efficient surveyor in the difficult region of the Northwest Highlands’. However, Cadell’s yearly totals for area mapped and miles of boundary traced show that he did not map in particular detail, when compared with Peach and Horne.

Pencil sketch of Ben Hope and Loch Hope, made prior to field mapping of the area. Looking south-east from the Creagan Road (29th September 1886). BGS image P612777.
Such figures show Clough as a supremely detailed surveyor, whether mapping Lewisian or Dalradian rocks, or even Jurassic rocks in Yorkshire. Cadell’s talents ranged more widely and he was perhaps more interested in geological problems, processes and mechanisms.

Cadell’s interest in the geometry and mechanisms of thrusting and their tectonic significance was demonstrated as early as 1885 when he carried out ‘squeeze box’ experiments that compressed wet sand and plaster of Paris layers to try to recreate thrust geometries similar to those mapped in Sutherland. He was familiar with earlier work by Hall, Favre, Daubrée and Pfaff, and in 1886 and 1887 he refined his method and materials, settling finally on clay, foundry loam (sand) and plaster of Paris. He obtained sufficiently good results to merit a series of formal photographs that were used to illustrate his lecture on ‘Experimental Researches in Mountain Building’, read to the Royal Society of Edinburgh, on 20th February, 1888 and incorporated in a paper published later that year. Cadell recognized that the thrust structures were clearly a product of horizontal compression and in his notebooks he discussed how the Earth could accommodate such folding and thrusting. He stated ‘There are insuperable objections to a liquid earth with a solid shell but the existence of a layer of semi-fused matter will not interfere with its substantial solidity’. He suggested that ‘ocean beds’ were the likely areas to undergo most contraction. Musing on causes he stated ‘Like apples and old people’s faces may the earth not become wrinkled from other causes besides the loss of heat.’ The experimental work

*Early experiment compressing wet sand, ochre, and Plaster of Paris to generate thrust stacking (February, 1885). Abstracted from BGS image P612789.*
was summarized and reproduced in the 1907 Northwest Highlands Memoir. Cadell’s Royal Society paper still has relevance today and the thrust and fold geometries that he obtained closely resemble those seen in many thrust belts.

Henry Moubray Cadell’s career in the Geological Survey officially ended in 1888, when following the death of his father on the 8th January, he resigned to run the family’s affairs. Nevertheless, he subsequently carried out limited surveying and other related work in the Lothians, in addition to his duties as chairman of the Bridgeness Coal Company that controlled a variety of mining, manufacturing and agricultural enterprises. He went on to develop the family mines in West Lothian and was heavily involved in numerous land reclamation schemes along the shores of the Firth of Forth. In August 1889 Cadell married Elinor Simson, the eldest daughter of David Simson (Bengal Civil Service), and they subsequently had 8 children (7 girls, 1 boy). In the following years he also travelled widely to many parts of the world – Norway, 1889; USA, 1891; Switzerland, 1894; Australia and New Zealand, 1895–6; Russia (Caucasus, Volga, Black Sea), 1897; India and Burma, 1899; Egypt, 1902–3; Mexico, 1906; Bavaria, 1909; Canada and Alaska, 1913; England, 1915; Spitzbergen, 1920–21. In the course of these trips he recorded geological and geographical information that formed the subjects of numerous papers and lectures to learned societies. He also applied this wider experience to several Scottish problems, e.g. the nature and origins of the Forth river system. Cadell showed great interest in solutions relevant to land improvement, mining, and land reclamation that were reflected in his ongoing works on the Grange Estate and in the Forth estuary. He was patently a successful businessman and by the early 1900’s he realized that Grange House, Bo’ness (built 1564) was inadequate for his accommodation needs. At first he commissioned Hyppolyte J Blanc to submit designs for its extension, but ultimately he decided to build a more substantial property nearby at Bridgeness. The new Grange House and garden (now part of the Nightingale Grange Nursing Home) were designed and built by the architects J N Scott and A Lorne Campbell between 1904 and 1909, and the old Grange House was demolished in 1906.

Cadell was a man who retained a great sense of duty throughout his life. He was a patron of the arts, a founder member of the Royal
Scottish Geographical Society and a member of the Institute of Mining Engineers. He held posts in both the Royal Society of Edinburgh and the Edinburgh Geological Society. He was a Justice of the Peace, a Commissioner of Income Tax, and served for over 40 years on West Lothian County Council, becoming its convener between 1924 and 1930. He also rose to the rank of Lieutenant-Colonel in the volunteer Forth Division of the Royal Engineers. In recognition of services to industry and science, Edinburgh University awarded him an honorary doctorate in 1932, particularly for fostering the development of coalfields beneath the Forth. Cadell also found time to write popular books on geology and landscape together with an array of scientific papers. His books included The Geology and Scenery of Sutherland (1896), The Story of the Forth (1913) and The Rocks of West Lothian (1925). His papers ranged more widely, from studies of the local Carboniferous geology and the glacial and post-glacial phenomena in the Midland Valley, to those linked to reclamation and industrial development, notably of the Forth estuary. Other papers dealt with Scottish coal, oil shale and mineral mining areas, but he also described mining areas in Germany (salt), India (coal), the Yukon (gold), New Zealand (gold) and Spitzbergen (coal).

Cadell died suddenly on 10th April, 1934, and was survived by his wife Elinor (1868–1943), herself a JP and recipient of an MBE, and by their eight children. He is described in his obituary in the Scottish Geographical Magazine, written by Robert Campbell, as ‘decided in his opinions, yet generous and kindly in disposition, gifted with a keen sense of humour, able to write a topical song and also to sing it’. He was renowned for his clear writing and his artistic and draughting abilities. Murray Macgregor’s obituary in the Transactions of the Edinburgh Geological Society stressed Cadell’s dedication to public service and his busy and varied role in both public and private organizations. He cited his sincerity and devotion as the prime elements of his character. It seems likely that Cadell would have pursued wider and more detailed geological studies had his other duties permitted. Despite his onerous responsibilities he maintained his zeal for geological investigation throughout his life, ranging from field mapping to problem solving, theoretical discussion, and most notably, for the practical application of geology.

But was Cadell engaged in a fued with his colleages? And just what was that elephant doing on Suilven? Find
out in the next issue of *Edinburgh Geologist*.

**Selected Bibliography**


A personal view of Torridonian research, 1956–2000

By A D Stewart

Just over fifty years ago I started research at Liverpool University on the ‘Torridonian’ metasediments of Colonsay and Oronsay. The project had been suggested to me by Dr Derek Flinn and involved a reinvestigation of the multiple deformation history of the rocks, already known in outline from the pioneering work of W B Wright, published in 1908. Consequently, one warm summer day in 1956 I found myself at Oronsay House, in Argyll, staring at a sparkling sea, and wondering where I was going to sleep. I was billeted by the tenant’s kindly wife, Flora MacNeil, in a disused boat house called Seal Cottage, on the eastern coast of the island. The following seemingly endless days were separated by brief, luminous nights, interrupted by the wailing of seals. The sediments were thought to be Torridonian only because they appeared to unconformably overlie high-grade gneisses. They were lithologically quite different to the Torridonian farther north. When I finished mapping the adjacent island of Colonsay three years later the relationship of the metasediments to the type Torridonian was still a mystery, and I resolved to go north and spend a fortnight looking at the real thing. This was August of 1960. My path was fortunately smoothed by those who had preceded me, especially those who wrote the north-west highlands memoir of 1907.

I started from Stromeferry railway station on a pleasant summer day with a small tent, food for a week, a hammer, notebook, camera, and Njal’s Saga for wet days. I walked south along the railway and camped on the coast facing Plockton with the aim of seeing the inverted unconformity at Fernaig. I then walked north and camped first at Loch Carron, and then in a birch wood near Balgy River on Loch Torridon. I crossed the loch by the old ferry from Shieldaig to Alligin and camped at Upper Diabaig, Red Point and Gairloch. The last camp was in a wood near the Loch Maree Hotel, where after a stormy night I was more than pleased to catch the mail bus back to the railway at Achnasheen. I took with me the notion that the Torridonian was a geological treasure to which I was going to have to
return. In fact, I returned every summer until 2000. For the first fifteen years I camped in secluded spots, though always within reach of my short wheel-base Land Rover. Only once did it seem necessary to ask for permission to camp, in a field at Stoer. The reply was negative. I was directed instead to rocky, heather covered ground near a road and when I objected was told ‘Well, that’s where the tinkers camp, and if it’s good enough for them it’s good enough for you’!

In 1963 I moved to Reading, where research on the Torridonian was under way. Prof. Perce Allen at the recently established Sedimentology Research Laboratory in the University of Reading had decided to make the Torridonian the main research thrust of the laboratory and soon had five doctoral students working on it. I was lucky to be invited to join the team as a post-doctoral fellow.

One of the first things I looked at was the splendid section of cyclothems at Cailleach Head, near Scoraig, about which I had heard, indirectly, from Prof. John Hemingway. Four of us made a brief but memorable trip north to see the section in 1964. On arriving at Badluchrach we found no regular ferry across Little Loch Broom to the peninsula, but were fortunate to find a local fisherman who explained how to attract the attention of the ferryman, who lived on the other side of the loch, at Scoraig. We were to wait until the following morning at about 5.30 am and then light three large fires along the length of the stone jetty. We spent the night on the concrete floor of a store room at the jetty, got up at dawn, collected driftwood and dry seaweed and did as instructed. Nothing happened until Alan Bush, the ferryman, got up for his breakfast at 8.00 am, noticed a group of disconsolate individuals on the jetty, and came over an hour later to enquire if they needed his services. The friendly fisherman, we learned, was celebrated for his practical jokes. The day we spent on the headland left us little wiser as to the nature of the cyclicity. This only emerged years later after I had logged the entire 300 m thick cliff section on a scale of 1:100.

The years 1965 and 1966 were particularly fruitful. Dick Selley at Imperial College produced a key publication showing that the Applecross Formation was deposited by braided rivers. Shortly afterwards George Williams at Reading produced the first version of a classic sedimentological study of the Applecross Formation at Cape Wrath, showing that the braided...
streams there lay on a giant alluvial fan, with a radius of about 50 km and an apex on the Minch fault. In 1965 the Reading school showed that the Torridonian was not a single conformable succession but, rather, two successions separated by an angular unconformity. Dave Lawson, who was a Reading research student mapping at Gairloch, had already found a spectacular sandstone boulder conglomerate resting on an erosion surface, apparently within the Torridonian succession. I vividly recall the day in 1965 when we were at Enard Bay, picking our way across the slippery boulders at low tide towards the sandstone conglomerate near the bothy, when he cried excitedly ‘Good Heavens, that’s the same conglomerate I have at Rubh Reidh’. In a matter of days we had identified the conglomerate at Badluchrach and Achiltibuie. In all cases it had been wrongly identified by the Geological Survey as Triassic. Later the same year it became clear that at Enard Bay the erosion surface beneath the conglomerate was actually an angular unconformity. The facies of the Enard Bay area had already been carefully mapped by Andrew Gracie, another Reading student, but the stratigraphical significance and correlation of the rocks had been almost entirely overlooked, as had the angular nature of the unconformity between the Stoer and Torridon Groups. Indeed, a shortcoming of research at Reading at this time was an emphasis on sedimentology to the almost total exclusion of stratigraphy and structure.

In 1966 it occurred to me that an investigation of the palaeomagnetism of the Torridonian might be fruitful. The inspiration came from Ted Irving’s earlier work on these sediments, published in 1957. Lacking any practical knowledge of palaeomagnetic techniques I approached Ted for help and we devised a joint project. Ted and I first sampled the sections spanning the Stoer—Torridon unconformity. Later the same summer I systematically sampled the Stoer type section. The first measurements were made the following year in Ted’s laboratory at the Dominion Observatory in Ottawa and finished in 1972 during a second trip to Canada.

The research had its origin in 1951 when Keith Runcorn at Cambridge decided to investigate the palaeomagnetism of ancient rocks to determine what kind of magnetic field, if any, the Earth had in the distant past. Advised by Professor T C Phemister at Aberdeen, he selected the Torridonian as a
suitable sequence. The initial aim was to seek evidence of the magnetic secular variation well known from recent times. The work was started by Ted Irving, then one of Runcorn’s research students, at a locality near Alligin. The secular variation proved elusive, but the stable magnetisation demonstrated something totally unexpected, namely that the direction of magnetisation in the Torridonian was quite different to that of today. Since continental drift was not then generally accepted this result was hard to explain. Ted Irving continued sampling during 1952 and 1953 and found another major shift in the direction of magnetisation in the Torridon Group at Achiltibuie, then thought to belong to the Diabaig Formation. These sediments later turned out to be part of the much older Stoer Group. Quite soon the palaeomagnetic results from British rocks were sufficient for Creer to plot the first apparent polar wandering path, which included the ‘upper’ and ‘lower’ Torridonian, i.e. the Stoer and Torridon Groups. This was in 1954. Twenty years later, in 1974, Ted and I were able to show from the palaeomagnetism that the Stoer and Torridon Groups were deposited in relatively low latitudes on the ancient continent of Laurentia at about the same time as the sediments and lavas of the Keweenawan rift sequence. My initiation into Torridonian geochemistry happened in 1980 when, by chance, I met Nigel Donnellan outside Ullapool Youth Hostel. Nigel had been a geology student at Reading, and was then working at Sheffield on the geochemistry of a set of rocks from the Torridonian which he had been given by his doctoral supervisor, Prof. John Tarney. What he told me about Torridonian geochemistry while we stood on Ullapool sea-front was absolutely fascinating, even though it was apparent that he knew little about the stratigraphic setting of his samples. In 1985 I took his splendid analytical data with me during a sabbatical at Oxford, thinking, in my innocence, that with its help I would be able in a few weeks to deduce something interesting about the geochemistry of the Torridonian. The questions the data provoked, however, took me ten years to resolve and generated a long series of geochemical papers.

All these papers were produced after I had retired from university teaching in Reading. For years I had contemplated constructing a completely different life while I still had the strength, and in 1987, aged 54 years, started farming land which I already owned in Italy. I had no intention of continuing with geology, but nevertheless felt an unexpected urge to write about the
Torridonian. All the geochemical papers mentioned above were written in the spare time left after working the fields.

On 14 September 1999, during a fateful conversation with Dr John Mendum of the Geological Survey in Edinburgh, I suddenly decided that I had to write a comprehensive memoir on the Torridonian. The description of the rocks and their field relations had already been compiled, piecemeal, over the preceding thirty years and it remained to write a synthesis. The synthesis was completed in 2001 and published by the Geological Society of London in 2002\(^1\). When I finished writing it I was mildly surprised to find that my desire to continue research on these old rocks had gone, and concluded that the moment had come to leave the field to others.

I still like to imagine my favorite sections at Bay of Stoer, to hear the eider ducks softly cooing on a calm summer day at Enard Bay, detect the scent of the bog myrtle, and see the magic landscape surrounding Loch an Doire Dhuibh, with its caves, cascades and birch woods, haunt of the roe deer. Strangely, though, when occasionally I dream of the Torridonian, these are not the things that appear but, instead, looming outcrops of Diabaig breccia and pebbly Applecross which I have never seen before!

As stated in its introduction, this beautifully produced book really does provide an authoritative summary of 21st century geosciences as applied to New Zealand. It celebrates the 50th anniversary of the founding of the Geological Society of New Zealand. The easy accessibility of the geosciences, from the text maps, diagrams and pictures is excellent despite covering some complex ideas. This book will also, as is its stated intention, enlighten policy makers and the public and assist in reaching informed decisions before committing to courses of action which may have far reaching consequences. That aim, which is restated by the chief editor, may explain why this book is so gloriously a colourfully clear but heavyweight review, both literally and metaphorically. In this book the amateur geologist and geotourist has a wonderful review provided for them, whilst New Zealand has shown that it is possible to produce an understandable briefing document on geohazards. Unfortunately it has not been exported to the UK in bulk so the price is in $nz. In view of their success with wine I have hope for this book!

The methods of presentation as well as content are worthy of review. Chapters are divided into sections of two or more pages generally by two or more authors. After an introduction to the chapter, sections, up to ten per chapter, are clearly written and well illustrated, largely with photographs. The chapter titles themselves, whilst pithy and occasionally witty, are rarely informative. Instead it is the subtitles of the chapters that provide a useful summary of their contents, as follows:
1. Providing expert advice and commentary
2. Mapping as a key to understanding geology in 4D
3. The measurement and ordering of geological time
4. Discovering New Zealand’s basement
5. Understanding the Pacific-Australian plate boundary through Zealandia
6. Plate tectonic evolution of Zealandia
7. Post Gondwana volcanic activity in Zealandia
8. Geological hazards in the New Zealand region
9. Discovering the undersea continent
10. Ancient lifeforms— the past explaining the present
11. Paeleoclimatic fluctuations across Zealandia
12. Natural economic resources of New Zealand
13. Geoscience in New Zealand past present and future

There follows a bibliography of recommended reading (largely NZ publications for a general readership), useful Web sites, details of authors, graphic credits, a glossary and an index.

Despite a modest and valid disclaimer that this is not a comprehensive textbook, and though the 122 contributors range widely in approach and sometimes in the depth of their treatment, the result is a consensus document of consistency and quality. It may be helpful to give three examples that held my attention better than some alternative, more weighty and wordy monographs and textbooks:

1. As a possible cause for the disproportionate mantle thickening under the middle of the Southern Alps, a massive Rayleigh–Taylor instability is described; this may be due to a 2% density difference in two immiscible fluids. The potential for uplift of the Southern Alps is chillingly calculated to compare to that of the Himalaya.

2. On earthquakes, I have been searching for more evidence of about 10 metre wavelength disturbances; this book has pictorial evidence.

3. The Dun Mountain ophiolite belt is shown photographically as a dun, brown, range of hills and mapped. I find it interesting that this belt breaks off from the main fault and traverses the southern end of the South Island.
In Conclusion, this is an excellent heavyweight summary of 21st century geosciences as applied to New Zealand, ideally suited to the amateur geologist. For geotourists it would be a good souvenir as well as scientific introduction, because the photographs are superb. I shall continue to read this book. It is readily and efficiently available by post, though that is a costly service.

Living on islands with 36 mm per year displacement parallel to the Alpine fault and a mean displacement perpendicular to the alpine fault of 10 mm per year has, rightly, concentrated the minds of local geologists wonderfully. This book deserves to succeed.

By Angus Harkness


This book is a summary of geology as well as a summary of Australian geology. Australia is built up in time and space, block by block, in a book with a smoothly readable, well illustrated text. The book is concise but jargon is minimised. Unavoidable technical terms are defined and explained in a priming chapter, Chapter 2, which also provides the contexts of the terms. The sources are well referenced and usable for literature searches. The index has been adequate for me although only four pages long. As in the scientific literature, abbreviations are defined at first use.

The contents are best defined, in my opinion, by the Chapter headings used by the author and deriving from his own insight and overall grasp of the subject. There is a clarity here that will save readers much time and effort. The contents are, by chapter headings:

1. An Australian Perspective
2. The Earth: a Geology Primer
3. Building the Core of Precambrian Rocks
4. Warm Times: Tropical Corals and Arid Lands
5. Icehouse: Carboniferous and Permian Glaciation
6. Mesozoic Warming: the Great Inland Plains and Seas
7. Birth of Modern Australia: Flowering Plants, Mammals and Deserts
8. The History and Evolution of Life on Earth
9. Eastern Highlands and Volcanoes Barely Extinct
10. Building the Continental Shelf and Coastlines
11. Great Barrier Reef
12. Planets, Moons, Meteorites and Impact Craters
13. A Geological Perspective on Climate Change
14. Cycles in a Continental Journey

Sources and References

Acknowledgements of figure Sources are then followed by the index. Economic geology is specifically excluded.

Some additional explanation might be helpful. Chapters 2, 11 and 12 contain good general geology text which gives a broad view in the midst of much topographical detail. There are two new chapters in this second edition; Chapter 8, the history and evolution of life on earth, and Chapter 13, a geological perspective on climate change, both 22 pages long. Chapter 8 concentrates on the great increase in the forms of life in the Cambrian. Cyanobacteria and algae are in Chapter 3 on the Precambrian rocks and extinctions are in Chapter 14 on cycles—tectonic, climatic, and biological. The Australian fossil record is remarkably complete and for the most part occurs on one tectonic plate. The separation of the West Australian plant flora by desert is an interesting exception.

Both new chapters show science at work and make a fundamental point that geological dating makes a major contribution to scientific understanding. The geological timeframe shows the flow of change. That data is shown in telling numerically format, and so its impact is not lost in discursive text. A series of models for climate change are examined and modified; cycle lengths in time and numerical mean temperature changes are given. The conclusion is clear. Human produced greenhouse gases are the only mechanism that account for these climatic changes.

Though the above chapter headings provide a framework and summary, it is advisable to try to suggest why this book is successful. For me it replaces the classic text, The Face of Australia, by C F Laseron (1954) published by Angus & Robertson. However, for some the Laseron book might be a useful introduction (of 244 pages) to this book by Johnson.
Book reviews (of 360 pages). In neither book are you cast adrift in a sea of technical terms. In the newer book the reader is guided by more diagrams, maps and pictures which are also better placed; in many cases this is achieved by careful page layout. For example, silicate structures are clearer as diagrams, whilst the linear pattern of Precambrian glacial sediments is well shown, sweeping through central Australia, as a black and white map. The varying tectonic geography is well shown as a series of coloured maps. For meteorite craters, the ages and diameters are shown as a table alongside a map of the sites of the craters which makes for some interesting comparisons. Fossil pictures or diagrams have their legends in large margins and in this section are a series of maps with relevant legends in which ages are given precedence over names, for example: 509 Ma Cambrian, 467Ma Ordovician, 414 Ma Silurian. As an amateur, I find this easier.

There are boxes which show self contained complete stories. As reference book summaries they are good, for example on granite emplacement, but they break visual continuity. Despite this, and overall, modern book design has been well used to enhance the availability of information. Additionally, in this second edition, more space has sensibly been used to improve the readability of the text. This book is a well integrated, even text by a single author supported by a good editorial team. Moreover, clarity was not achieved by avoiding problem areas. Only a humble author would list the five major extinctions of life in his closing pages.

In conclusion, if you are likely to be drawn to Australia, you might consider buying this book. I find it re-readable. For those who need an introduction to general geology this book could also be helpful since an overall presentation of basic facts is here available. On Australia, the amateur geologist can be enjoyably and well briefed.

By Angus Harkness

An alternative view of New Zealand Geology

"These islands; the remnant peaks of a lost continent, roof of an old world, molten droppings from earth's bowels, gone cold; ribbed with rock, resisting the sea's corrosion for an age, and an age to come."

A R D Fairburn (1904–1957) from 'Dominion'
Some Geological Fiction . . .
reviewed by Phil Stone

Now by geological fiction I don’t mean that fossilised flying saucer dug out of a coal mine in Virginia in the 1950s and kept under wraps ever since by the CIA. Rather, this is a look at a couple of excellent books that came out in 2009 and which both weave their respective plots around 19th century geological themes. Both were written by women, and derive some of their literary tension from the difficulties encountered by intelligent, scientifically-inclined women in pursuing their interests in male-dominated society. However, there is a striking difference in the way the books’ heroines deal with those difficulties.


Rebecca Stott is perhaps better known for her non-fiction works, such as Darwin and the Barnacle (2003), but here presents a racy tale of deceit and double-dealing in the Parisian underworld of 1815, shortly after Napoleon’s defeat and surrender at Waterloo. We join Daniel Conner, a medical student travelling from Edinburgh University to Paris with letters of introduction and rare fossil corals for Baron Georges Cuvier from Professor Robert Jameson. If that set of circumstances is not enough to arouse your interest, there is the most wonderful geological simile in the first sentence of chapter one.

Daniel wakes up on the top of the stagecoach just outside Paris to hear “… a woman’s voice, speaking in French, deep and roughly textured, like limestone.”

The femme fatale proves to be a proto-Darwinian savante emotionally ravaged by the horrors of the French Revolution, to which had been lost her family fossil collection. Now she aims to rebuild that collection...
through a talent for burglary, and as a result is of great interest to the Parisian police. Daniel is robbed by her, then seduced both physically and intellectually as the star-crossed lovers argue the merits of the transmutation of species and explore the heretical evolutionary theories of Lamark and Geoffroy. Daniel is drawn ever deeper into police duplicity and criminal escapades, culminating in an audacious raid on Cuvier’s museum in the Jardin des Plantes, where Jameson’s introduction has established him as an ideal ‘inside-man’.

The story moves along at a cracking pace, beautifully crafted and with enough contemporary references to establish a strong sense of time and location. An interesting device in this respect is a parallel account of Napoleon’s journey from prisoner-of-war to political exile in St Helena, the emotions of which mirror Daniel’s scientific journey from the comfortable, unquestioning mainstream to a disturbing anarchic uncertainty. And how does our heroine cope with the masculine establishment? She dresses as a man, lights up a cigar and blags her way in.

I enjoyed the story almost to the last, but then found the sort-of-happy ending a bit contrived and highly improbable. But at least it has a good geological setting as the dénouement develops in the quarry tunnels beneath Paris, with fossils and the dip of the strata used as navigation aids. Daniel survives it all, though returns home a changed man racked with doubt and regret, eventually re-living his Parisian experiences through the catalyst of Darwin’s Origin of Species. When he finally marries it is to a woman who lends him her copy of Cuvier’s Le Règne Animal, just arrived from Paris.

And here’s a nice coincidence. We get the impression of about ten years passing between Daniel’s departure from Paris in 1815 and his marriage. In 1825, the eminent English geologist William Buckland married a woman to whom he was attracted when she sat opposite him in a stagecoach reading a volume of Cuvier. And Buckland features prominently in our next book—as does Baron Cuvier.


Tracy Chevalier is a much admired writer of historical fiction, but in this account of the relationship between Mary Anning and Elizabeth Philpot is
perhaps more constrained than usual by the well established circumstances of her subjects. Mary Anning is now celebrated as an extraordinarily successful fossil collector, discovering ichthyosaurs, plesiosaurs and other ‘remarkable creatures’ in the cliffs around Lyme Regis in the early part of the 19th century; and thereby scraping a living from their sale to wealthy gentlemen. Elizabeth Philpot, perhaps now less well known than Mary, was no less remarkable a palaeontologist and was better placed socially and financially to pursue her interest in fossil fish. These two ‘remarkable creatures’ were brought together in Lyme Regis by a shared interest in fossil collecting and the differences in their background—class, age, religion—act as a counterpoint to their scientific discussions around the age of the Earth, extinctions, and just how their fossils fitted into the greater scheme of things.

The story is developed, alternately, from the perspectives of Mary and Elizabeth. Its important facts are preserved but to help things along the time scale of events is compressed somewhat, and a few incidents experienced by characters who do not feature in this fictionalised account are reallocated to the main players. But if it’s biography that you want I recommend Shelley Emling’s 2009 book ‘The Fossil Hunter’. In ‘Remarkable Creatures’ you get the main thread of the Anning-Philpot story embellished with the imagined thoughts, emotions, squabbles and scientific arguments between the two ladies and the gentlemen geologists who took possession of their finds—amongst others, William Buckland, William Conybeare and Henry De la Beche, all stalwarts of the newly established Geological Society of London. It is all very well done, and I had to keep reminding myself that I was reading a work of fiction.

Now I don’t read very much romantic fiction, so I found the imagined
flirtations between Mary and the likes of William Buckland a little hard to swallow. After all, Buckland was better known for living with a hyena and eating mice. But that device allows the tension to build between Elizabeth, concerned for Mary’s ‘good name’, and Mary, resenting the intrusion into her private life. In parallel with this, Elizabeth finds herself slipping into the unwanted role of Mary’s scientific champion, culminating in a raid on the men-only Geological Society meeting (24 February 1824) convened to debate Cuvier’s accusation that Mary’s plesiosaur was a forgery. No disguises and cigars for Elizabeth though. She dragoons a male relative into attendance, applies moral blackmail to Buckland and Conybeare, and then sits in the corridor outside the meeting room to listen to their successful defence. Though we must remember that this is fiction, her seething resentment of the patronage and prejudice of the male establishment seems highly probable. Mary is portrayed as more reconciled to her lot, particularly once she had transferred her religious affiliations from her family’s non-conformism to Elizabeth’s Anglican persuasion; an odd move given her circumstances.

This kind of book needs a happy ending, so the increasingly estranged relationship between Mary and Elizabeth allows one in the form of their reconciliation. Contented fossil collecting is resumed in each other’s company. In real life there was no happy ending for Mary Anning. She died of breast cancer in 1847, aged 47 and unmarried. Elizabeth Philpot died in 1857 at the age of 78 and her splendid collection of fossil fish passed to the Oxford University Museum of Natural History.

The book is great—if you like this kind of book. I wasn’t too sure about it, but am delighted by what it will do for geology. On the cover of the paperback version (2010) there is a very telling quotation from a review in the Financial Times. I think it’s a fair bet that the FT’s reviewer will be pretty bright, probably a doyenne of the literary scene, yet she happily writes (my italics): ‘These women, neither of whom I had heard of before, become vivid and engrossing.’ Most of Tracy Chevalier’s readers will be in the same situation. They will all be much enlightened as to the joys and challenges of palaeontology, and maybe some will be tempted into London’s Natural History Museum to gaze at the awesome wall display of ichthyosaurs and plesiosaurs, many now properly acknowledged as having been discovered by Mary Anning. Perhaps a few will make it
to Lyme Regis to look up at the cliffs in wonder. For my part, when next in Oxford I shall check out Elizabeth Philpot’s fish.

**Floating Stones** by Ann Lingard. Published online at: http://www.onlineoriginals.com/showitem.asp?itemID=299.

For an assessment of this third work of fiction I here appeal for assistance. Is there a literary-minded technophile out there who can check out this e-book and report back for the rest of us? It is a story built around a geological field excursion to Sutherland, so sounds like it should be on familiar territory—though some of the romantic activities described may not be! Apparently Richard Fortey advised on the geological content so that should be ok. Just to whet your appetite, here’s the beginning of what would be on the flyleaf, if there was one.

“Set in Scotland, this is a modern story of the love of two very different men for local artist and potter Anna, creator of the ‘floating stones’ of the title. Oxford geologist Stephen Rhodes and his students Kat and Max set up temporary homes in the rugged beauty of Sutherland for a summer of scientific fieldwork. As a result they are brought into intimate contact with both the landscape and its inhabitants.” This leads into “… a four sided relationship whose complexity only gradually becomes clear. For Stephen, the summer becomes the story of his conflicting desires … etc. etc.” Go on. Give it a try.

**Quotable geology**

One final thought whilst on this foray into the realms of fiction. I was much taken by Rebecca Stott’s ‘voice like limestone’ simile and began to wonder about all the other magnificent geological quotes that must be buried in our literature. Maybe you have a favourite too. If so, or if you spot a good one, let’s hear it. As a starter I offer the following from *Wuthering Heights*:

‘My love for Heathcliff resembles the eternal rocks beneath—a source of little visible delight, but necessary.’ Emily Brontë, 1847.
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