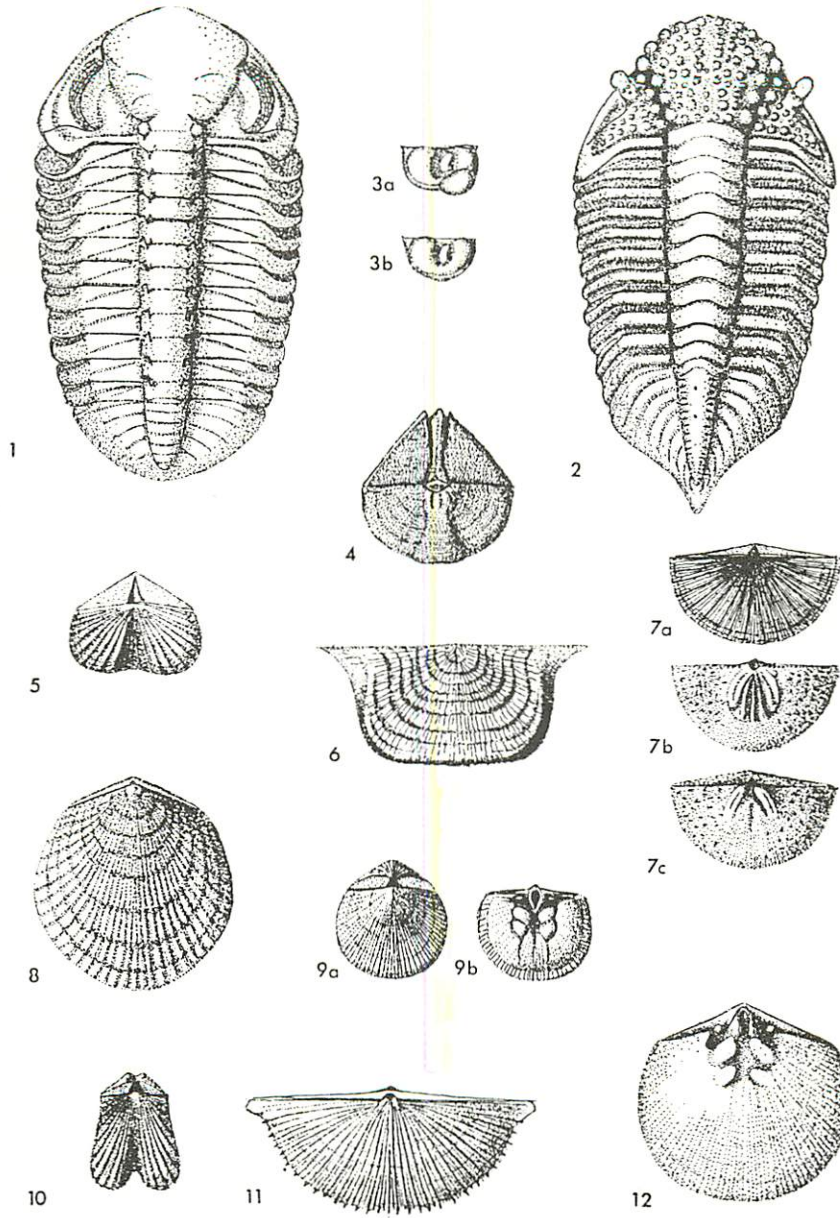

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Acknowledgements

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Cover Illustration: Silurian fossils from the North Esk inlier (drawn by Euan Clarkson)

1. *Acernaspis sufferta* (Lamont)
2. *Encrinurus expansus* Haswell
3. *Craspedobolbina (Mitrobeyrichia) impendens* (Haswell)
4. *Cyrtia exporrecta* Wahlenberg
5. *Skenidiodes lewisii* (Davidson)
6. *Leptaena* sp.
7. *Eoplectodonta penkillensis* (Reed)
8. *Atrypa reticularis* (Linnaeus)
9. *Visbyella* sp.
10. *Dicoeolosia verneuiliana* (Beecher)
11. *Coolinia applanata* (Salter)
12. *Dalejina polygramma pentlandica* (Davidson)

Editorial

Circumstances beyond our control have meant that this issue, No. 20, of the Edinburgh Geologist appears considerably later than we hoped when we wrote the editorial for No. 19. We trust however that the varied fare presented to you here will make up for the delay. There are accounts of expeditions to the Himalayas and to Sutherland, of the lives of two little-known Scottish geologists, and of research work at the Grant Institute.

Unfortunately both of us are now having to give up the editorship, but we are pleased that Margaret Ford has agreed to take over this job. Meanwhile may we urge our readers to put pen to paper with contributions for future issues, which can be sent to Margaret Ford, 59 Morningside Road, Edinburgh, EH10 4AZ or to the Society's Secretary at BGS, West Mains Road, Edinburgh EH9 3LA.

Frances Lindsay
Lizzie Davenport
May 1988.

A JOURNEY TO SHANGRI-LA: GEOLOGY IN THE NORTHWEST HIMALAYAS

Dr John Cater
Grant Institute of Geology, Edinburgh University

Like most geologists, I love mountains and have always dreamed of trekking across the Himalayas, backpack on shoulders, with my faithful pack-horse by my side. So I jumped at the chance when four final-year undergraduates suggested we mount an expedition to Zanskar, a remote, desolate Buddist Kingdom on the northern side of the High Himalaya range (Fig.1).

Several dog-eared telephone directories and many nights on a word processor later, we managed to put together a prospectus detailing our proposed trek and sent it to some 200 companies and trust-fund administrators, together with suitable begging letters. The Edinburgh Geological Scoiety, like many of our 'targets', was surprisingly generous and within a few months we obtained the 5,000 necessary to equip and transport the expedition. It wasn't too difficult to raise this money, and I'd certainly encourage anybody to have a go at putting their own expedition together (though our University status, my PhD and the patronage of Professor Sir Frederick Stewart, FRS, FRSE, gave us credibility that obviously helped).

Before describing our adventures, a word about who went. I was a sedimentologist working in Edinburgh with Euan Clarkson on Lower Carboniferous deltaic and coastal rocks; I've had field experience in S.E. Spain and Central Anatolia on a variety of sedimentary rock types. The expedition was led by Alexander Peckham, a giant, genial English-Raj type who'd lived in India and had experience of hill-walking in the Lesser Himalaya and spoke some Hindi. He could hail a rickshaw, haggle the driver down to a sane fare, and persuade him to go to our desired destination (rather than the hotel that sponsored the taxi!) more successfully than anyone else I met in India. The expedition was his idea. Then there was Ronan McElroy, a Scot of Irish extraction, with the sense of humour and love of wine, women and song to match. He was incredibly mentally and physically active throughout the trek, and is now doing a PhD at Cambridge University; also Iwan (Bob) Roberts, a welsh-speaking vegetarian (the Tibetans called him "the lama" – ascetic priest – because of this!) with a brilliant grasp of geology; and Martin Bond, a deceptively laid-back public school type who, like his namesake James, had hidden physical resources to cope with the harshest conditions we met.

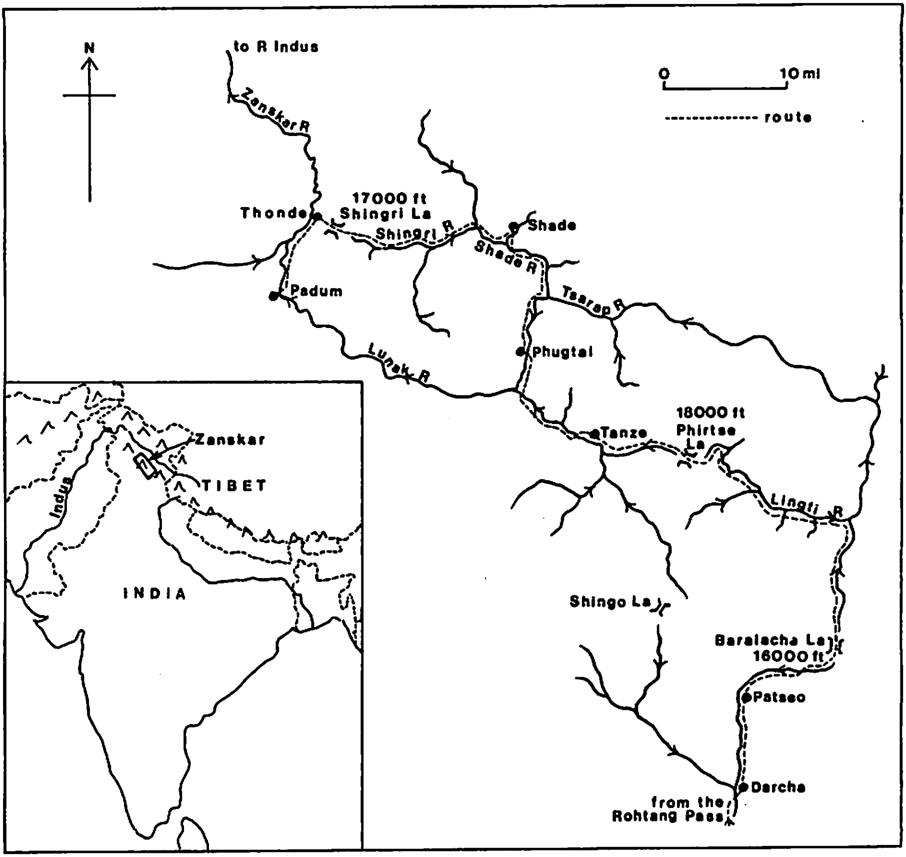

Figure 1 Zanskar expedition

Zanskar – the name means "Land of White Copper" – is described in Buddist writings as a place "where spirits gather". It is a "revealed land" created by the gods, according to Tibetan folklore; for the people are not Indian but a group of Tibetan Buddhists who settled there centuries before the British pushed their empire across the High Himalayas – they still have a King who is represented in the Indian Parliament. Geographically it is isolated from the world by passes over 13,000 feet – the gorge of the Zanskar River being virtually impassable –, shielded from the monsoon rains by the High Himalaya (up to 24,000 feet high), and dissected by juvenile river valleys that wind confusingly around, eventually joining the Indus in Buddhist Ladakh to the north. The valleys are arid, and with an elevation around 11,000 feet they reach –30°C in winter when they are blocked by ice and snow, and the people huddle indoors and leave the wilds to the wolves and the snow-leopards.

Geologically, it is part of India, to the South of the Indus – Zangpo suture line marking the position of an ancient ocean once separating India and Asia by over 2,000 miles. The closure of that ocean and collision of India with Tibet led to extreme crustal shortening and thickening of N. India and Tibet from the Eocene to the present. Among the pre-Eocene rocks are volcanics yielding the copper for which Zanskar was named. Recent glaciation of the narrow valleys led to the formation and later drainage of vast lakes, possibly originating the "revealed land" legend. We were mainly interested in describing the sedimentary evolution of N. India from the Ordovician to the Cretaceous, as revealed in the excellent exposures in Zanskar, and the details of the structural evolution of this part of the Himalayas during the Tertiary continental collision.

We flew to Dehli using cheap tickets provided by Kuwait Airways, and set off to the lush green Parbat Valley in the southern foothills of the Himalayas. There we spent a week trekking up to 9,000 feet to begin acclimatising and break in our boots (and feet!). Then we got a bus up the Beas River, the easterly extent of Alexander the Great's empire, to Manali, where we saw the Dalai Lama addressing Tibetan refugees on his birthday. We also got our first (and best) taste of Tibetan food. We bought our perishable supplies and piled them onto the crowded bus to cross the Rohtang Pass into Lahoul, a high land of mixed Buddhist and Hindu population. The bus stopped at Darcha, the "last homely house" where we gathered our supplies ready to set off. Then tragedy struck. Alex, the instigator of the whole trip, went down with a severe chest virus and was forced to return to Britain. We could only be thankful that it hadn't happened in a more remote area. We were determined to carry on, and at least it left a party of four, which made two teams of a pair each when mapping – rather than three, which it would have been if I hadn't joined the team virtually at the last moment. But is was a bitter blow, for all that.

We hired three ponies and the services of a Lahouli called Urgian, who cheerfully led his ponies, cooked, selected routes and camp-sites and made tea first thing in the morning – we'd expected to do most of this ourselves. He also taught us some Tibetan, and acted as interpreter in the settlements we found. When we finally abandoned him in Zanskar, we paid him a handsome bonus and gave him a Swiss Army knife in gratitude. His lessons in the use of yak-dung fires were invaluable, as our little paraffin stoves proved hopelessly inadequate.

We walked up the military "road" to the four-way Baralacha La (lapass) at 16,000 feet (Fig. 2). By this time, we'd spent so long at altitude that we had no great problems with breathing and stamina. We left the "road" and walked up the long valley of the Phirtse Chu, meeting yakherds and goatherds, the latter providing Urgian with a "treat" of a goat's head which he cooked with relish and we politely ate. Then we began mapping, an activity which Urgian regarded with tolerant amusement. He led us up to and across the 18,000 feet

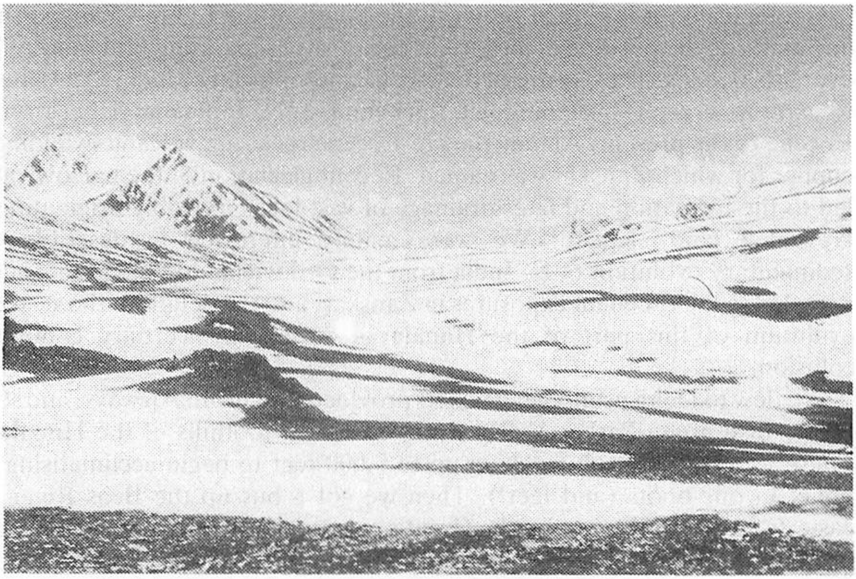

Figure 2 The Baralacha La at 16074 feet, crossing the High Himalaya

Phirtse La and into Zanskar itself. We followed the tourist route along the Zanskar (Lunak) river valley, beset by children begging for "bon bons" – most of the tourists are French – and plied with Tibetan barley beer (chang), with its severe high-altitude after-effects (the "changover"). We left Urgian and the horses at Phugtal and set off to do a detailed structural transect up the Tsarap River, which is crossed by bridges unsuitable for horses. We stayed one night at the spectacular Phugtal Gompa monastery (Fig. 3), where we saw ancient carved images of demons reflecting the old Bon religion and its influence on the more primitive forms of Buddhism. The Buddhists in this harsh region regard life as an atonement for past sins, and although they stop short of suicide, one wonders if they don't tempt fate with their use of bridges made of plaited twigs by which we had to cross the torrential Tsarap.

By the time we'd reached the abandoned monastery at Tantak we'd run out of food, so when we got to the village of Shade we bought supplies, plus bangles, Tibetan locks and even ammonites. (The locals are probably now mining the Jurassic shales there in preparation for the next visit by foreigners – I fear they'll be disappointed!). We also hired ponies for the crossing of the Shingri La (Fig. 4) – perhaps the beautiful Shade valley is the origin of the Shangri La legend? Or perhaps not.

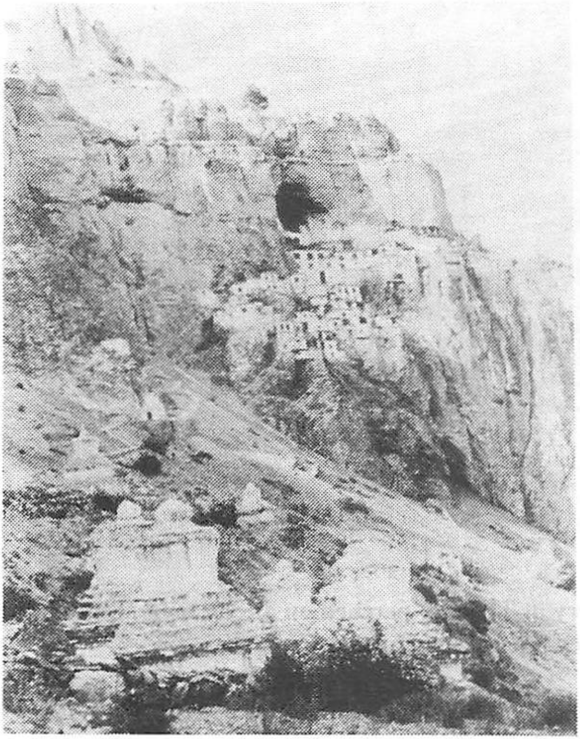

Figure 3
Buddhist monastery at Phugtal, built around a sacred cave 400 feet above the valley floor. Burial 'chortens' in the foreground.

Figure 4 Shingri La at 17000 feet looking east. Martin Bond, Ronan McElroy and local guide.

Figure 5 **Buddhist monastery at Thonde, perched on a crag several hundred feet above the valley floor of the Zanskar River.**

Figure 6 **Looking south from Thonde monastery along the Zanskar valley to the High Himalaya.**

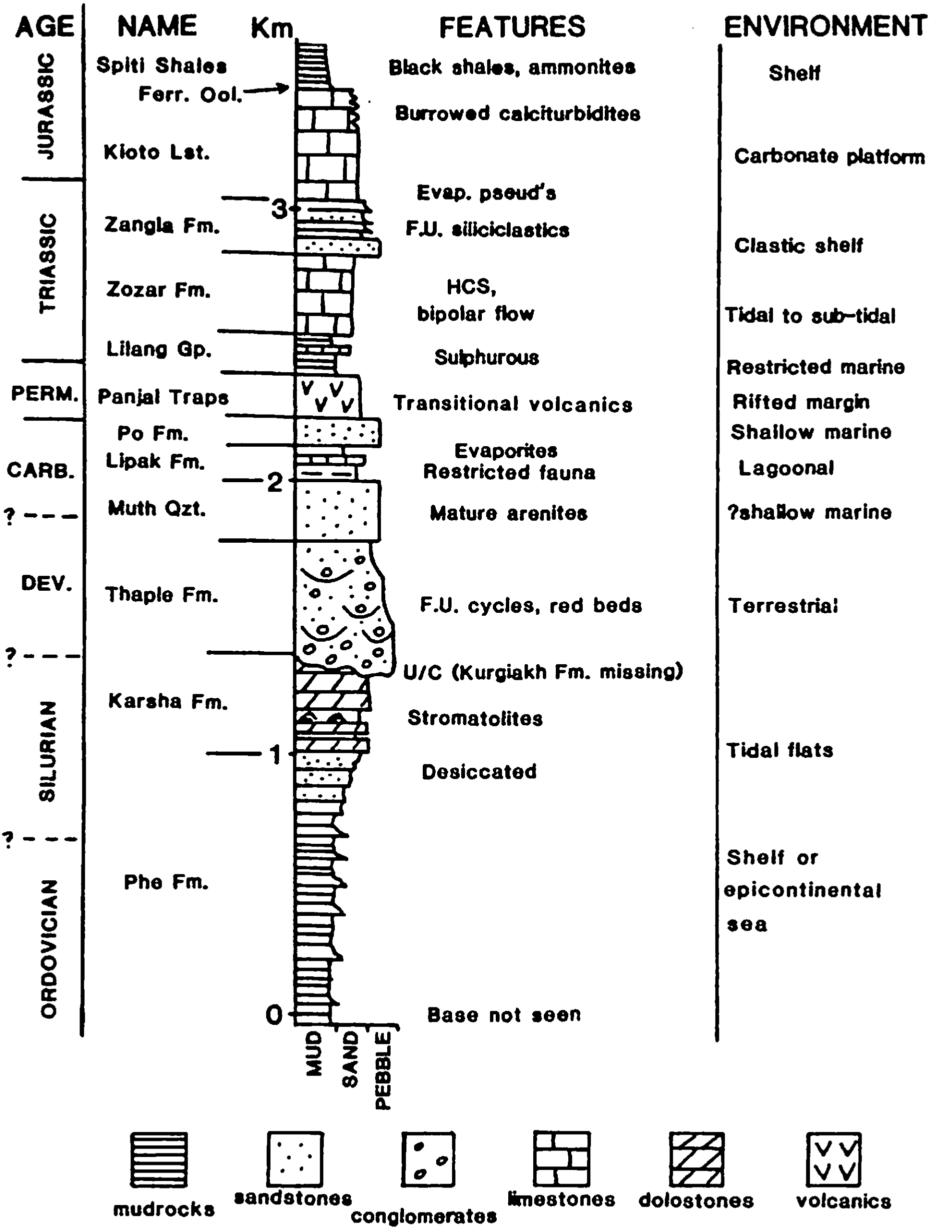

Figure 7 Stratigraphy.

We finished mapping before we reached the Shingri La, struggling up rugged terrain and crossing the Shingri Chu river 15 times in one day. Across the 17,000 foot Shingri La we reached the welcoming Thonde monastery (Fig. 5), with it's fine view of the "revealed land" of the Zanskar valley (Fig. 6). From there we walked to Padum, the capital (pop. 800), and got a bus home (Fig.1).

Geologically, the expedition was a great success. We produced a map of East Zankar – partially from interpretation of Landsat images – and structural cross-sections N – S across the area. These show how the rocks have thrust S over the High Himalayan Crystalline rocks, which then rose isostatically some 4 km in the Neogene and caused northward gravitational collapse of the thrust pile, buckling the "schuppen zones" of stacked minor thrusts into northward-verging folds and creating large flat (listric) normal faults. The sedimentology (Fig.7) reveals the evolution of the northern edge of India (then part of Gondwanaland on the south side of the Tethys ocean) as a shallow epicontinental sea in the Ordovician to Devonian, with continental and shallow marine deposits of Upper Palaeozoic age overlain by rift-related Permian volcanics recording the break- up of Gondwanaland. India then drifted north, gradually closing Tethys, and Zanskar was a leading-edge "passive margin", collecting shallow marine limestones and occasional clastic deposits until water-depth increased in the Jurassic and Cretaceous. We did not see younger rocks. Our studies augment those of West Zanskar, now underway by Leicester University, and we hope our results, when published, will convince our sponsors that we were value for money. We will certainly never forget "the land where spirits gather", and I hope I've communicated some of its wonder to you.

THE LIFE AND WORK OF JAMES BENNIE

Steven John Maddox
Grant Institute of Geology, University of Edinburgh

James Bennie was born in Glasgow on September 23rd, 1821. Although little is known of his childhood, it is apparent that his family were poor and as John Horne remarked in his obituary (Horne 1901), "he had to struggle with iron fortune." Bennie received little formal education, and is known to have spent a mere six months at school. At an early age, however, he became an apprentice hand-loom weaver, where his natural thirst for knowledge was awakened by his colleagues who as a profession were famous for their political activity, independence and intelligence. At the age of 26 in 1847, the onset of mechanisation within the weaving industry made many of the hand-loom weavers redundant and Bennie joined a Glasgow paper manufacturer. Here the dull routine and lack of intellectual stimulation drove him into the surrounding countryside, causing him to remark "the scenes passed on the way were often the chief attractions for my visits, the aspects of the hillsides and the bright sheets of Lochlibo at the head of the glen, which varied with the seasons, giving me much pleasure at the time, as well as in after recollection when I contrasted them with the hard and dry scenes of my daily life in Glasgow." (Bennie 1891,p.213).

Although at first the beauty of the natural surroundings were enough to occupy his mind, as his familiarity grew with the area his attention started to shift to the natural and man-made exposures of rocks which he often passed on his rambles. His first geological 'love affair', however, was with the Quaternary deposits of the Glasgow district which were often exposed in trenches dug for sewer excavation. Whilst walking between his home and workplace, Bennie would search the spoil heaps around the excavations, picking out fossils from the unconsolidated clays and carefully noting the pertinent features of the various successions of sedimentary rocks. He soon became a familiar sight to the slightly amused and bewildered workmen, and his activities served to underline the accessibility of geology to the amateur, and Bennie's own opportunism. Despite a lack of formal academic training, he sought to educate himself, and fired by the writings of Hugh Miller, attended a series of lectures delivered by Miller on the Quaternary deposits of Scotland at the City Hall, Glasgow. Miller's enthusiasm rubbed off on Bennie, who on Miller's suggestion visited the raised beach at Filleyside, a subject which later resulted in a publication. In 1856, Bennie wrote Miller regarding the geological specimens he had collected, but was gravely disappointed at not receiving a reply. Undeterred, he continued to self-educate himself, his isolation from the geological community causing him to suffer from periods of negative self-introspection, when he tried to come to terms with his aims in life which often conflicted with his underprivileged working class origins.

After the Glasgow Geological Society was founded in 1858, Bennie became a member one year later. Here, he met noted Quaternary workers such as Croll, Crosskey and Robertson and Carboniferous researchers such as Young and Armstrong. These influences enriched Bennie's life to such a degree that he often referred to the members of the society as "ancient Athenians, always famous for seeking after new things." (Bennie 1888, p.299). Bennie's meeting with James Croll was a fortuitous one, for Croll's interest was the Quaternary, and particularly the climatic and glacial activity. Croll's own work however, which included a book 'Climate and Time', and a paper on climatic changes during the Quaternary, was largely speculative, and lacked the sort of evidence which Bennie had painstakingly collected over a number of years. Co-operation between the two men resulted in the suggestion that the ice age was not merely characterised by continuous glaciation, but consisted of periods of glaciation punctuated by interglacials.

Whilst continuing to work on the Quaternary deposits around Glasgow, Bennie also become interested in the Carboniferous, and he is known to have collected fossils from Lower Carboniferous limestones and shales as early as 1851. Indeed, it was the shale spoil heaps in the limestone and sandstone quarries which probably first drew his attention, and after he had satisfied himself at having collected all the macrofossils, he set to work investigating the micro-faunas and floras. His magnificent eye for detail, patience and ingenuity aided him in this work, where he quickly pioneered methods of sample preparation, subjecting shales to a variety of techniques which would result in their disaggregation, so enabling him to carefully pick through them in order to separate out the fossils. After a while, the techniques he pioneered in his kitchen at home were so refined that he was able to extract and mount thousands of ostracods, foraminifera, spores and scorpion fragments, whilst attracting the attention of academic geologists eager to learn from this unassuming, self-effacing little man who almost single-handed invented the discipline of micropalaeontology.

James Bennie's work in Glasgow drew attention to his natural ability as a geologist, which had until this time been the pursuit of the idle rich and privileged. Almost all professional geologists in the Geological Survey or in academic posts originated from the middle and upper classes, and when Bennie was asked to join the Survey in 1868 as a fossil collector in Edinburgh, he broke this mould, forging a path for the working classes, as an unwitting champion of the masses. Although sad to leave his native Glasgow, he moved east buoyed up with a sense of sheer delight, that at last his achievements had been recognised, and that the love affair which had started many years ago during hard times in Glasgow should now result in a blissful union, consummated by the ecstasy of pursuing his pleasures full time. At 47 years of age, after 21 years of hard toil in a paper warehouse, James Bennie began work for the Survey, amazing his colleagues with his determination to investigate the Quaternary and Carboniferous in the east of Scotland with the same vigour he had shown as a much younger man in the west. As the number and significance of his discoveries grew, so did his publication output (for a nearly complete list of papers by Bennie, see Horne 1901) as well as public recognition. Many of the new species which he discovered were duly 'christened' bennei in his honour. Bennie was a modest, good natured man who viewed his new found fame with mild amusement. Although quiet and shy he had a sharp, yet kindly sense of humour, which was often exercised by gently 'sending up' his colleagues without them realising that they were the butt of Bennie's 'leg pulling'. This is revealed in his papers and in the few letters which survive, evidence of the correspondence he had with luminaries such as Archibald Geikie and Ben Peach. Letters to Peach are particularly good- humoured with references to John Horne's 'webfooted' expeditions to rainy Assynt, the letter ending with a hearty 'quack, quack, quack'.

Bennie spent his remaining years in Edinburgh working for the Survey where he still returned to work even after retirement. Before his death at the age of 79 in 1901, he had succeeded in unravelling many of the problems concerning Quaternary and Carboniferous geology in the Midland Valley of Scotland, and helped pioneer work in micropalaeontology, facies analysis and palaeoecology. Although largely forgotten today, this truly great Victorian who rose from the lower classes to hold his head up high amongst 'geological legends' such as Geikie and Peach and Horne, would probably like best to be remembered in the following lines, penned by Edward Greenly (1938, p.215) who came to work for the Survey in Edinburgh when Bennie was still in residence during 1894-5:

"One figure at the Survey had for us a peculiar charm. This was James Bennie, then engaged upon the flora and fauna of the later Pleistocene lakes. Day by day, a little man with silver hair walked in silence to a certain corner, took down certain trays, and worked for hours with lens and tweezers, speaking to nobody unless they spoke to him. "There's a true son of science" said Peach to us one day."

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ROBERT DUNLOP

Margaret Ford
59 Morningside Road, Edinburgh

A little known but enterprising Scot, Robert Dunlop was born on 27 February 1848 – a raw time of year. Cholera was sweeping through the Kilmarnock district, so his mother, Elizabeth (McKinnon) Dunlop journeyed to her father's house in Clins Vennel, Ayr, to ensure that her son would survive the first few months of his life. His father, Walter, toiled as an engineman for 17 shillings a week at Caprington colliery near Kilmarnock. Given the humble circumstances of his childhood, Robert's achievements were out of the ordinary, and speak for his character.

Robert's schooling (ruled by belt and bible?) lasted only four years, and he often missed a day running errands or doing the housework for his mother so that she could earn money as a "floorer" or flowerer doing embroidery for the local lace industry. By the age of eleven he too was helping to support his brothers and sisters by working on farms, for 8 farthings (about 1p) a day.

Boys were expected to enter the mine when they reached the age of 14, but his mother, and Robert himself, did not want this. Through a relative, Elizabeth saw to it that Robert was indentured as an apprentice iron moulder for seven years, at 12 shillings a week. She had shown him that his life was not predestined.

Walter meanwhile had fired his son's interest in geology. One day the boy found a fossil shell in a nearby limestone quarry. His father explained that it was "put there by the Deluge". This must have impressed him for he remembered it and was puzzled some years later when he found fossils which had come out of a coal pit 600 or 700 feet deep. His curiosity and wonder of nature had well and truly taken hold of him, and his interest did not wane, but strengthened to a passion (which is testified to by the massive collection he accrued).

Five and a half years into the apprenticeship (late 1867) Robert and the other apprentices had learned the trade well; so well that James Blackwood the master had the moulders locked out and took on more apprentices. Robert saw that the new boys couldn't work as well as he, yet they were being paid 4 shillings a week more, so he and his friend persuaded the clerk to show them their indentures and while his friend held down the clerk, Robert set fire to them. This was an offence they could probably have been imprisoned for, so when about two months later, his new foreman in Glasgow told him that "a lame man with a tall hat and a policeman" were waiting to see him, Robert, knowing it was Blackwood, dropped over the wall and fled.

Figure 1 Robert Dunlop (left); with his grandson, Robert; son, Walter; and father, Walter. Taken about 1890.

In the space of a week or two he was settling down to work at "The Standard" foundry, newly started up by Adamson in Airdrie. Two years later, on 1 March 1870 he married Ann Hunter. They had five sons and two daughters, and were together for 38 years. He described her as his "helpmate", and although not of a "scientific turn of mind" she "sympathised" with every hobby he took up.

The small collection he had made while living with his parents near Kilmarnock was lost, but once settled in Airdrie he started his collection in earnest. He also became a keen photographer, but came up against problems that could only be solved with a knowledge of chemistry, so he started going to chemistry evening classes at Gartsherrie Science School in Coatbridge. After his first year he passed his exam with flying colours, winning the Queens Prize for Scotland. He went on to be a demonstrator at the school and achieved a first class pass at the advanced stage. Then he taught classes of 40-60 students for 10 years; three times the pass rate was 100%.

His tenacity and hard work were rewarded when in 1882, word of his expertise as an analyst reached Mr Jeffrey, a partner of Wm Black and Sons, who arranged his employment at the Stanrigg Oil Works.

A year later he joined the Geological Society of Glasgow. It seems he had waited until he was a recognised scientist, as he had been collecting fossils for 14 years, seven of those in the company of James Thomson for whom he had been photographing coral sections. He was by now a keen photographer and collector for leisure and interest. He would report anything of interest to the societies in central Scotland, believing that it was his duty to have it put on record. He seldom expressed personal feelings in his unfinished autobiography, but his attitude to science may be gleaned from the following lines:

"... with the true Scientific Man
every new born fact in nature
by his love and care through time
becomes useful to humanity"

At Stanrigg Oil Works he was initially employed to conduct experiments on a process for extracting tar and sulphate of ammonia from coal dross. After doing some reading he had an idea, and persuaded the partners to alter the existing works and run a full scale experiment in order to extract benzol – a newly found constituent of coal gas which was fetching a good price. Good yields of benzol, and many other valuable products, such as toluol, solvent naphtha, sulphate of ammonia, carbolic acid, etc were retrieved by this method, and the partners were so pleased that they permanently adopted Robert's new idea and twice expanded the works according to his specifications.

The Scottish oil-shale industry was facing fierce competition from newly discovered oil wells in America, so he was constantly improving the design of the plant to make it ever more efficient. He became manager of the works in 1884.

Figure 2 **Robert Dunlop (seated left) with his daughter Elizabeth and wife Ann; his sons David and Walter (right); Walter's wife Janet with their children Robert, Agnes and Annie (on her mother's lap). Taken about 1899.**

Figure 3 Robert Dunlop's son Walter with his wife Janet and children Annie (left), Robert and Agnes. Taken about 1903.

An English company put up a plant at Shettleston to extract benzol, but was unsuccessful. On his own initiative Robert negotiated a good price to buy the disused plant, and became a partner when the resulting Shettleston Oil and Chemical Co Ltd was formed in December 1890. The number of oil companies in Scotland was dwindling, and most of them were making losses in real terms, yet the revitalised works at Shettleston lasted right through until 1958.

During these years with William Black & Sons, he searched avidly for fossils and discovered several species new to science. The one he was certainly most proud of was *Eoscorpius dunlopi* (Wright), a scorpion he found while searching through shales of the Upper Coal Measures, near Airdrie. He recognised it as darkness fell at 9 o'clock and with horror saw the wind move some loosened fragments, so he quickly protected it with his handkerchief and wrapped it in paper. The untrimmed block was so weighty that it was two in the morning when he arrived home with it. He also collected insects and birds, so the Airdrie people must have often seen him on the moors with a butterfly net and jam jar, or a shotgun, in the fashion of the day. He was undoubtedly a well known member of the local community as he was the first President of the Clydesdale Photographic Society (which is extant), a founder member of the Clydesdale Naturalists Society, and he became the honorary curator of the Airdrie Museum in 1894 where "his special knowledge and enthusiasm made the Museum popular and educative from the beginning".

He remained with Black & Sons until 1899 when on 9 February, he sailed away to New Zealand. While setting up a new oil-shale plant in Orepuki, on behalf of the Pumpherston Oil Co he came across many unusual problems. For example the proposed site was riddled with ruts and gullies made by miners in pursuit of gold. Some of the trenches were 20-30 feet deep, and even when filled in did not provide sufficiently firm foundations. Robert had to arrange for the works to be built on solid ground which could only be found here and there.

By 1903 he was back in central Scotland again, exhibiting the interesting specimens he had found, and lecturing about that exotic far-away land, with numerous lantern slides, to the enthralled audiences of many societies.

His wife Ann died suddenly on 13 February 1908 and he was alone again for the first time since his brief spell in Glasgow.

Three years later he married a widowed cousin, Annabella Reid, and it was possibly the squeezing of the contents of two houses into one that made him start looking for a safe place for his collection, which by then was vast. He offered it all to the Dick Institute in Kilmarnock. It was his home-town, and they potentially had the space, as the fire of 1909 had destroyed the fine collections of Thomson and Hunter-Selkirk, two of his closest friends. He asked £300 for it, I think as proof of its value to them. The Public Library committee had several lively discussions deciding whether to buy it or not.

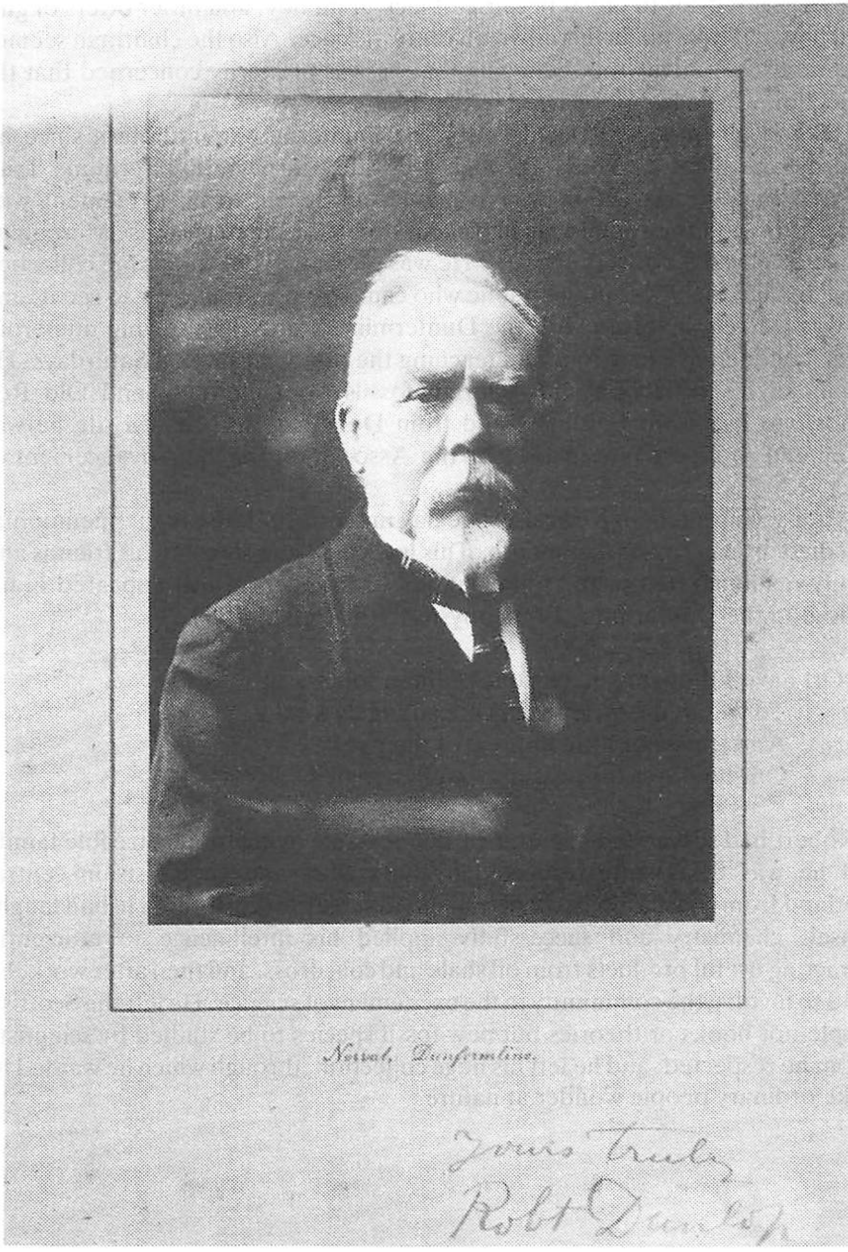

Figure 4 Robert Dunlop. Taken about 1920.

They did not offer to buy it because of lack of money, and other offers of gifts which would take up an unknown quantity of space. Also the chairman seemed to doubt his motives, not believing that he was primarily concerned that the collection was to be appreciated.

He had given several lectures for the Dunfermline Naturalists since his return from New Zealand. Through them the Carnegie Dunfermline Trust learned that the collection was available, and came to an agreement with Robert. In 1911 they employed him as curator of Pittencrieff House Museum to which he gave his collection gratis. He was pleased to talk about the collection to interested members of the public who came from near and far to see it, and he was actively involved with the Dunfermline Naturalists, giving numerous talks, conducting excursions and teaching the junior section on Saturdays. He expanded his collection with Silurian fossils from Gotland, and Old Red Sandstone fish from Caithness and from Dura Den in Fife – a site he was appointed to investigate in 1912 by the Association for the Advancement of Science.

After giving a talk in Kirkcaldy one day in April 1921 he caught pneumonia, and died on the 21st of that month. This loss came as a shock to his friends and family, as illustrated in the following lines of a poem which appeared in his honour in the Dunfermline Press, mysteriously signed "T.D.":

"Oft have I thought – here's one of those folk
To whom the tyrant years are strangely kind,
And leave but little impress of their yoke
On shoulders for resistance well designed..."

Robert had succeeded in earning a comfortable living for his sizeable family and he was deservedly respected by naturalists and geologists in central Scotland from coast to coast, in his pursuit to satisfy his curiosity. He had taught himself chemistry and successfully applied his intelligence to efficiently extracting useful products from oil shale and coal dross, and then after work, he liked to involve the community in the excitement of science. He left the Scottish people not books or theories but new fossil species to be studied by scientists whom he respected; and he left his huge collection, through which he wanted to make ordinary people wonder at nature.

THE USE OF RADIONUCLIDES IN CHEMICAL OCEANOGRAPHY

Graham B Shimmield
Grant Institute of Geology, University of Edinburgh

Introduction

Recent studies have emphasised the importance of several radionuclides, particularly certain members of the three natural radioactive decay series (Figure 1), in evaluating adsorption processes on particle surfaces (chemical "scavenging") and hence, controls on ocean chemistry. Evidence indicates that horizontal mixing by ocean currents coupled with intense particle scavenging common at ocean margins causes a net flux of reactive metals such as thorium (Th) protactinium (Pa) and lead (Pb) towards the ocean margins. The causes of such scavenging are still not well understood, but probably result from a combination of four main factors that almost certainly vary in their relative importance both spatially and temporally: (1) high flux of particles falling to the ocean floor, (2) increased fallout of biological remains, (3) manganese (Mn) and iron (Fe) reduction/oxidation (redox) recycling, and (4) resuspension effects by bottom currents and biological organisms.

To date there have been very few published data on the fractionation of Th and Pa at oceanic boundaries. A detailed study of such fractionation, from an area where complementary data on the four factors listed above has been collected, would yield valuable insights into the degree of inhomogeneity in ocean chemistry and the role of high particle flux and redox processes at ocean margins. In addition, depth profiles of radionuclide activity enable sediment accumulation rates, the degree of bioturbation, and/or the effects of diagenesis (i.e. chemical reactions within the sediment) on actinide metals to be assessed, all of which are very important in the interpretation of sediment geochemical profiles. This article reviews some of the advances made in marine radiochemistry over the last five years, and outlines the proposed research in this field that will be undertaken at the Grant Institute over the next three years.

Element	U-238 Series							Th-232 Series					U-235 Series				
Neptunium																	
Uranium	U-238 4.47×10^9 yrs		U-234 2.48×10^5 yrs										U-235 7.04×10^8 yrs				
Protactinium		Pa-234 1.18 min												Pa-231 3.25×10^4 yrs			
Thorium	Th-234 24.1 days		Th-230 7.52×10^4 yrs					Th-232 1.40×10^{10} yrs		Th-228 1.91 yrs			Th-231 25.5 hrs		Th-227 18.7 days		
Actinium									Ac-228 6.13 hrs					Ac-227 21.8 yrs			
Radium			Ra-226 1.62×10^3 yrs					Ra-228 5.75 yrs		Ra-224 3.66 days					Ra-223 11.4 days		
Francium																	
Radon			Rn-222 3.82 days							Rn-220 55.6 sec					Rn-219 3.96 sec		
Astatine																	
Polonium			Po-218 3.05 min		Po-214 1.64×10^{-4} sec		Po-210 138 days			Po-216 0.15 sec	64 %	Po-212 3.0×10^{-7} sec			Po-215 1.78×10^{-3} sec		
Bismuth				Bi-214 19.7 min		Bi-210 5.01 days					Bi-212 60.6 min					Bi-211 2.15 min	
Lead			Pb-214 26.8 min		Pb-210 22.3 yrs		Pb-206 stable lead (isotope)			Pb-212 10.6 hrs	36%	Pb-208 stable lead (isotope)			Pb-211 36.1 min		Pb-207 stable lead (isotope)
Thallium											Tl-208 3.05 min					Tl-207 4.77 min	

Figure 1 Radioactive decay series.

Marine Geochemistry of U, Th and Pa

Both ^{230}Th and ^{231}Pa (half-life $t_{1/2}$ 75,200 and 32,000 years respectively) are naturally occurring daughter radionuclides of the cosmogenic uranium series, produced during stepwise decay to the stable isotopes of lead (Figure 1). Many other daughters are also produced, each having a different half-life and distinct chemical properties. The fathers of ^{230}Th and ^{231}Pa are the primordial isotopes of uranium, ^{238}U and ^{235}U. These occur in a constant ratio of 137.88/1 and may be released to the geochemical cycle via weathering. On entering an oxidising aqueous system, such as the ocean, uranium tends to form a stable uranyl carbonate complex $[UO_2(CO_3)_3{}^{4-}]$ which is generally chemically stable in sea water; but it is decaying all the time by alpha particle emission, and its isotopes ^{234}U and ^{235}U and ^{235}U produce ^{230}Th and ^{231}Pa (via ^{231}Th). Both nuclides are strongly attracted by particle surfaces, particularly oxides of Mn and Fe. Th and Pa have similar chemical natures with Th reflecting Group IV-B (of the Periodic table of elements) behaviour similar to zirconium (Zr) and hafnium (Hf) and Pa to Group V-B elements similar to niobium (Nb) and tantalum (Ta). As a result of their different chemical behaviour we have the ability to investigate rates of oceanic processes by measuring the concentration of radionuclides within the sediment and water column. Within oceanic waters depletions of daughter radionuclides, relative to their parents, exist for the ^{234}Th/^{238}U, ^{230}Th/^{234}U, ^{210}Pb/^{226}Ra and ^{210}Po/^{210}Pb daughter/parent pairs. The depletions would not be present if the daughter radionuclides were not continually removed by scavenging. We can estimate the rate of such removal (R_d) from a parcel of water by invoking the relationship:

$$R_d = d_d\,(A_p - A_d)$$

which simply states that the removal rate is proportional to the difference in chemical activity between the parent (A_p) and daughter (A_d) nuclides corrected for the decay of the daughter (d_d) within that parcel of water. Hence, at a first approximation it would seem that the concentration of Th and Pa nuclides is controlled by particle adsorption and that the flux of particles within the water column influences the residence time of the nuclides (about 20-40 years for ^{230}Th and about 50-130 years for ^{231}Pa in the open ocean).

In spite of their short residence times ^{230}Th and ^{231}Pa appear to be fractionated (i.e. one preferentially removed relative to the other) on incorporation into the seafloor deposits. Theoretically, they should be produced in an activity ratio of 10.8/1; a ratio fixed by their half-lives and the isotopic composition of U in seawater. However, Anderson and others (1983) have shown that particles in the open ocean preferentially scavenge ^{230}Th relative to ^{231}Pa leading to the high activity ratios commonly observed in open ocean deep-sea sediments. In contrast manganese nodules, metalliferous

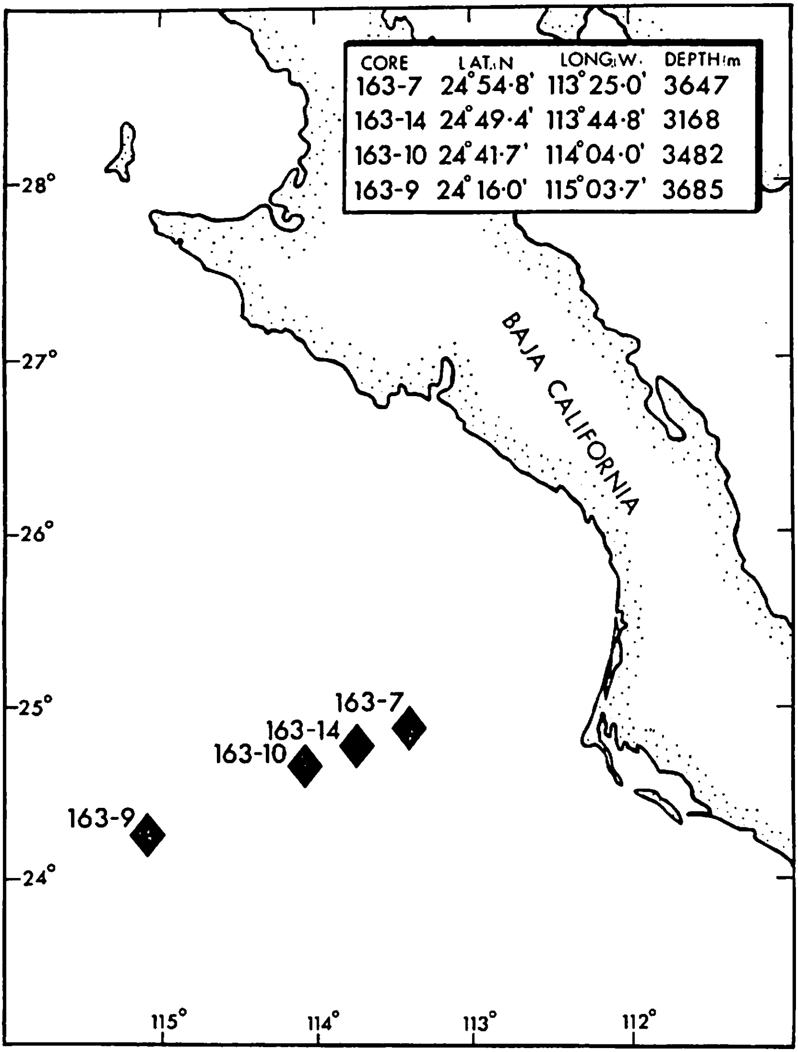

Figure 2 Marginal transect off Baja California.

sediments, siliceous oozes, and recently, particulate material from ocean margins have much lower ratios suggesting a preferential sink for ^{231}Pa in these deposits. Thus oceanic gradients exist in the concentration of ^{230}Th and ^{231}Pa with ratios <10.8 commonly occurring where production is greater than predicted from the concentration of parent ^{234}U and ^{235}U in the overlying water column. Particulate data suggests that Pa is redistributed more readily than Th. The mechanism by which these two isotopes become fractionated is unknown but must be due to their removal from seawater and behaviour towards particulate material.

A recent study (Shimmield and others 1986) from a marginal transect off Baja California, Mexico (Figure 2) produced results (Figure 3) that confirm that high fluxes of ^{230}Th and ^{231}Pa occur exceeding the theoretical water column supply by up to about 4× for ^{230}Th and 6.2× for ^{231}Pa. This enhanced flux increases towards the coast indicating that the level of scavenging is possibly related to the overall flux of particles to the seafloor. At all stations the ratio of measured to predicted flux of ^{231}Pa exceeds that for ^{230}Th suggesting that the type of carrier particles are very different to the open ocean. Although the cores taken off Baja California penetrated pre-Holocene glacial sediment, they were not long enough to establish reliable initial activity ratios in order to ascertain if glacial/interglacial sedimentary espisodes influence the scavenging of these two nuclides. Similarly, a deep biomixed layer, together with the short core length, precluded accurate determination of the sediment inventory of ^{230}Th and ^{231}Pa. Although tentative results indicate that the present flux of nuclides exceeds the water column supply, there is an overall deficiency in total nuclide activity within the sediment which may suggest that resuspension and translocation of the actinides has occurred in the past. This work represents the first detailed investigation from the sediment record for U, Th and Pa across an ocean margin and highlights the importance of a multi-faceted approach in evaluating the possible removal processes operating on these elements.

Scientific methodology and future research

The Grant Institute now has a dedicated laboratory for the alpha-particle spectroscopic analysis of actinide elements. This lab has been set up by Dr Graham Shimmield through NERC grants and support from Edinburgh University under the "New Blood" scheme. Technical assistance is provided by Frances Lindsay whose responsibility it is to perform the chemical procedures outlined below and maintain the day-to-day running of the lab.

Briefly, the technique involves taking about a gram of dried sediment which has been subsampled from box and piston cores. Following the addition of ^{228}Th, ^{232}U and ^{233}Pa spikes and total sediment digestion, the samples are subjected to ion-exchange chromatography to separate the U, Th and Pa fractions. U and Th extracts are then electroplated onto stainless steel planchettes; Pa by solvent extraction and evaporation onto silver planchettes. ^{232}U, ^{234}U, ^{238}U, ^{228}Th, ^{230}Th, ^{232}Th and ^{231}Pa are determined by standard alpha-spectroscopy equipment (Si-surface barrier detectors, pre-and main-amplifiers, multiplexer routers and an 8000 channel multi-channel analyser which is based around an IPC PC-XT microcomputer). ^{233}Pa, added as a yield tracer, is measured by beta-counting its photoelectric peak at the Scottish Universities Research Reactor Centre at East Kilbride, whose advice and encouragement has helped get this project off the ground.

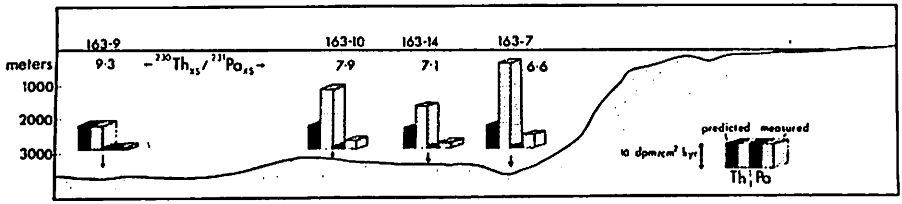

Figure 3 Th and Pa fluxes off Baja California.

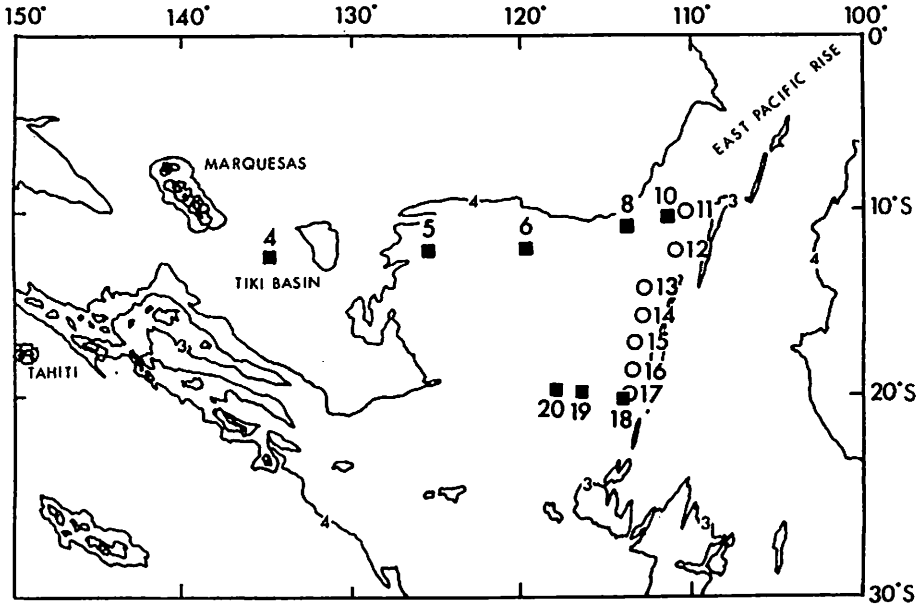

Figure 4 Sample sites in the south equatorial Pacific.

The Indian Ocean

The sediments of the continental shelf, slope and rise off Oman in the NW Indian Ocean have been little studied, despite the fact that this is a major area of upwelling and displays a well-developed midwater oxygen minimum between 150 and 1200m water depth. The most recent report on the area was compiled by a French organic geochemistry expedition in 1978. Although the sediments were characterised for bacterial populations and organic constituents, very little study was made of inorganic diagenesis or the composition and magnitude of the particle flux to the sediments. In addition ^{210}Pb data of Spencer and others (1981) for the North Arabian Sea, Persian Gulf region, suggests that a strong sink for ^{210}Pb occurs on the upper slope and shelf indicating that boundary scavenging processes are important in this area. Therefore, although this region has been comparatively under-studied, comparison with other upwelling regimes would suggest that a high biogenic particulate flux (augumented by detrital aluminosilicates from the arid hinterland of the Oman), organic-rich sediments and enhanced diagenetic reactions are likely to occur. From a radiochemical viewpoint this type of environment will provide a unique opportunity to address some of the major questions concerning the processes influencing Th and Pa distribution in oceanic sediments.

The opportunity to study the area is now available as I am being supported by NERC as a member of the scientific party on Leg 16-17 of the RRS *Charles Darwin* in October, 1986 (P.S., Dr N. B. Price, Edinburgh). During this leg a series of stations along transects (probably 3) normal to the margin will be occupied and sediment, pore water, particulate matter and seawater samples collected. This multidisciplinary approach will be effected by brining together scientists from throughout the oceanographic community in Britain and abroad. From this wide range of expertise concentrating on this one area of the ocean it is hoped that a coherent and detailed picture of the oceanographic controls operating off the Oman shelf will be built up.

This large database of information makes possible an extremely useful study of U-series disequilibrium at an ocean margin. From bulk sediment and particulate matter analyses, it should be possible to define biogenic and aluminosilicate inputs, together with the patterns of remobilisation of redox-sensitive elements such as Mn and Fe. Measurement of other shorter –lived man-made isotopes ($^{239,240}Pu$, ^{137}Cs) will define patterns of bioturbation and excess nuclide accumulation, whilst comparison of actinide behaviour with the rare earths may be drawn. It will be possible to examine the role of biogenic, aluminosilicate and/or oxyhydroxide substrates on Th and Pa removal by analysing box-cores from a well characterised transect from shallow water depths, through the oxygen minimum, down to abyssal pelagic conditions outside the influence of biogenic productivity. In order to examine the historical variations in Th/Pa fractionation two long piston cores will be examined. Consequently, initial activity ratios for ^{230}Th and ^{231}Pa may be calculated through the Holocene and into the Pleistocene thereby evaluating the role of glacial/interglacial cycles on particle flux and radionuclide scavenging.

The South Equatorial Pacific

As a secondary, but no less important, adjunct a study of core material from the south equatorial Pacific collected during cruise 154 (Figure 4) of the RV *Thomas G. Thompson* made in 1980 will be made. This fully oceanic transect from Tahiti to the East Pacific Rise (EPR) has three characteristics with which to compare and contrast the area of study in the Indian Ocean: (1) the overall particulate flux to the seafloor will be much lower, (2) the cores traverse the lysocline enabling the influence of biogenic particles on Th/Pa fractionation to be examined, (3) the effect of hydrothermal emanations from EPR on the actinides may be investigated. To date, a full geochemical analysis (XRF) of 27 elements from bulk sediment samples has been completed. Examination of the radionuclides in these cores will not only enable metal accumulation rates for a mid-ocean ridge system to be evaluated, but will also point to factors influencing the marginal versus open ocean fractionation of Th and Pa. Such factors are critical to evaluate in order to construct an oceanwide mass balance for U, Th and Pa.

Summary

Together, radionuclide data from these two oceanic settings will significantly augment our knowledge of the following processes: (1) the influence of detrital versus biogenic particles in open ocean and ocean margin settings on Th/Pa removal, (2) the efficiency of Mn cycling during diagenesis and hydrothermal emanations at scavenging Th and Pa from the water column, (3) what fractionation of Th and Pa, if any, occurs during this process, (4) how the distribution of U, Th and Pa is related to geochemical, mineralogical and geotechnical properties of the host sediment, (5) whether diagenesis of organic-rich sediments influences the distribution of U, Th and Pa in the sediment column, and finally, (6) can we identify some or all of these processes in the sediment record to elucidate varations in decay-corrected Th/Pa ratios.

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ROGART RAMBLE

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Another year had passed so quickly and it was time once again for the Long Excursion, the eleventh, which was to be based near Rogart, Sutherland, a few miles to the south east of Lairg. After the previous year's expedition to Dalavich, when rain and low temperatures had been the norm, we all hoped for better weather, but the forecast was not too hopeful. The party, this year restricted to 30 because of the accommodation available, converged on unsuspecting Rogart in the late afternoon of Saturday 16 May. As usual, the first hour after arrival was spent in distributing the mountains of food to the correct chalets, which were situated at Inchcape, high on the hillside with superb views along Strath Fleet: Rogart itself was not in sight! After dinner the party gathered together in one chalet so that Wally Mykura could let us all know what was in store for us over the next few days.

Sunday dawned rather dismally. The main interest of the day was to be the Rogart Complex, which consists of a granodiorite body surrounded by a zone of contact migmatites; the country rock is in the Moine Series. The granodiorite body is composed of an outer tonalite, a middle coarse-grained granodiorite and an inner biotite granite. The first locality of the day, and the wettest of the week, was a section on the River Brora at Braegrudie, where a gorge cuts through the narrowest part of the migmatite zone; unfortunately accessible exposures were sparse. The second stop was to make a traverse over Creag a' Bhata, just north of Rogart Station, in part of the inner migmatite zone. It was hoped that a contact between the outer foliated tonalite and migmatite would be found to the north of Rovie Lodge, but it proved to be rather elusive; the search was not helped by the fact that the geological map had few topographical features marked. This paucity together with the lack of exposures in traversing from the Moine rocks to the tonalite, via the migmatite zone, certainly illustrated the difficulties in mapping this type of transition as well as in interpreting the maps of others. The next locality was a traverse to Loch Muidhe, across granodiorite and adamellite to see rafts of an earlier intrusion of appinite that had been contaminated by the granodiorite to form hybrid rocks similar to those of Achuaine – the pronounciation of which was avoided by the majority of the party! The final locality of the day was the Grudie Burn to the south west of Lairg, where indications of lead, copper and fluorine mineralisation were sought and a few commando-type exercises practised.

The first locality on Monday was a spectacular section of Lower Old Red Sandstone breccio-conglomerate near Loch Fleet; the party then headed northwards for Golspie and the environs of Dunrobin Castle. Some walked along the shore section below the castle, studying the Trias, consisting of calcareous sandstones overlain by red and green marls with bands of cherty limestone, and the Lower Lias, a sequence including a soft white sandstone with plant remains and micaceous marine shales rich in ammonites and brachiopods. The remainder of the party visited the castle, the interior of which was even colder than the exterior. Examination of the castle walls revealed some excellent plant fossils; other specimens, geological and otherwise, including samples of oil from the local oil-shales, were examined where they were being prepared prior to being exhibited in the Castle Museum. Trophies of past Dukes of Sutherland, not only the ubiquitous stag's heads but also those of giraffe and stuffed crocodiles rampant, were also on show, not in their normal presentation looking down from on high, but all looking balefully up from the floor. Lunch was taken at the broch east of Dunrobin, and was made memorable by a demonstration of 'One Man and His Dog' – it did not look quite so easy with a large flock of sheep, scattered over half a mile of grass and gorse. The dog did quite well, dropping a few points on the outrun. The afternoon was spent near Brora, on the shore looking at the Brora Argillaceous and Brora Coal Formations, and along the Brora river to see the site of the Old Brora Coal Mine. Capaldi's Ice Cream Parlour was visited by the majority of the party before the scenic route via Loch Brora to Rogart was taken. In the evening the eleventh long excursion was celebrated in traditional style, complete with cake and candles, and also a celebratory beverage.

On Tuesday we headed northwards, following Thursday's itinerary! The rendezvous point was near the Castle of Old Wick, where the Lybster Beds (Middle Old Red Sandstone) were studied – an introduction to syneresis cracks for many. We continued northwards to Duncansby Head, where we were blown along the path to view the famous sea stacks, partaking of lunch on the way – a welcome respite from the wind. After lunch the party divided, some to continue along the north shore towards John o'Groats to see the volcanic neck at Ness of Duncansby; others travelled to John o'Groats – a lonely tourist spot only famous because it is situated a long way from Lands End. Both parties visited the megalithic chambered cairns at Camster on the way back. The advance party also made a stop to the north of Helmsdale to collect uranium-bearing minerals.

On Wednesday morning the tide was right, it not the wind, for a visit to the famous 'Fallen Stack' at Portgower – an Old Red Sandstone 'boulder' measuring approximately 34m × 27m × 9m, in boulder beds of Kimmeridgian age. Thence to Lothbeg Point; before lunch we looked at the shore section to the north of the point, which was composed of more of the Kimmeridgian Boulder Beds, and in the afternoon the sandstones and interbedded marine shales were studied and abundant ammonites and plant fossils found. Sheltered from the wind and with the sun out it felt almost tropical! The party walked along the shore to the mouth of the Loth Burn and there divided – some to return to the vans while others continued southwards to see the Allt na Cuile Sandstone. Some interesting accounts were given by a few members, who had gone the wrong way, of the ascent to the road! After the party had been reunited we descended, by invitation, on the premises of the Orcadian Stone Company at Golspie, run by Don Shelley and his family, where we looked at the workshops, excellent dispays and specimens, and very tempting showrooms.

Thursday was another day for the north. The party regrouped at Dunnet Bay Campsite, and were greatly relieved that there was an almost completed Natural History Display room there with picture windows, so that the geology could be pointed out while warm and sheltered from the gale force northerly wind. The first stop was on the shore near West Dunnet, where a section of Dunnet Head Sandstone could be seen, luckily sheltered from the wind. A dyke was also sought, and after recognising the baked sandstone margins, found after a bit of burrowing. After lunch we headed for Clardon Head where excellent three dimensional suncracks, as well as more syneresis cracks, were displayed in the Mey Beds of the Caithness Flags. At this point the party split – two thirds going to Achanarras Quarry (with the permission of the NCC) and Spittal Quarry to search for fossil fish – some excellent specimens were found, more by luck than judgement (?). The other third headed westwards to visit the diorite quarry to the west of Reay, where the banded Reay Diorite could be seen, and also, with a bit of searching, its junction with migmatised Moine rocks. A short stop was made at Portskerra, to look at the unconformity between Old Red Sandstone and underlying Moine rocks before heading south down Strath Halladale; a few short stops to look at the migmatised Moine rocks, the granite and scyelite – the Caithness equivalent of the Achuaine hybrids – being made on the way.

Friday was the last day in the field, and the plan of campaign was first to visit Kintradwell to see the lowest Kimmeridgian Boulder Beds and then Navidale to see the Helmsdale Boulder Beds, again Kimmeridgian, where particular points of interest were the large blocks of reef coral, small fragments of jet and pebbles of fossil wood. By this time the sun had come out and the wind had dropped significantly, so that at last it felt very warm. A short stop was made at Helmsdale, where a bat was observed flying around in the sunshine, before heading up the Strath of Kildonan to Baile an Or. Hunger overcame gold fever and lunch was taken before the prospecting started in earnest. A small party took one van up to the Suisgill Burn and walked up the burn looking at the geology. On the way back an 'expert' demonstrated the technique of gold-panning and let some of the group have a go. Specks of gold were seen even in this short time. This group then returned to the Kildonan Burn to study the many 'panning' techniques employed by members of the Society – these ranged from the very energetic swirling of unsieved sand and gravel to sitting in the middle of the stream and hoping that flakes of gold might adhere to woollen socks. The return journey was made via Glen Loth, where one stop was made at a viewpoint overlooking the Strath of Kildonan to Morven, the highest point in the area, and the Scaraben ridge, and a second stop to look for the junction between the Helmsdale granite and Old Red Sandstone – this proved to be rather elusive and was found by only one member of the party, some distance from where it was expected! A final stop was made in Brora to say farewell to Capaldi's – it was rumoured that one van had managed to stop there every day – before heading back to Rogart.

The excursion ended in traditional style on the Friday night with a get together so that all could reminisce about the week; the sad moments – Dundee United losing two finals, and the happy – gold panning and Capaldi's. The Strontian Hammer* was awarded this year to John Laxton in recognition of "services to Wards for driving to distraction with due care and speed at all times and for preserving half an exhaust pipe..........." The only other mention this year was to Ian Hogarth for "services to Mr Capaldi and maintaining the economy of Brora"; no certificate could be given out as the usual supplier had not materialised this year.

The vans only had to make it back to Edinburgh – this was not quite such a certainty as one would imagine, as the problems we had incurred with them included a brake light on a new van with a part actually missing, an exhaust pipe on a nearly new van supported with barbed wire that finally broke, a door that fell off and chipped windscreens. The participants fared better this year compared to last, although they were expected to be up and out by 9.00 a.m. on the Saturday morning, (bad news, especially for those who had watched Scotland's first match in the Rugby World Cup on TV during the night), but we didn't have to do any cleaning this year (good news). Thus the long excursion had ended; geologically it had, on some days, suffered from some rather elusive contacts, and meteorologically, although very windy and cold it was at least mostly dry. Now we have only another fifty-one weeks (much less by the time you read this) to go before the twelfth excursion to Shetland.

* The Strontian Hammer was found on a beach during the Long Excursion to Strontian in 1983, and has since been awarded to one member of each excursion for services rendered, or other misdeeds.

EDINBURGH UNIVERSITY ION MICROPROBE FACILITY

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A Cameca 4F ion microprobe, funded by NERC, is being installed in the Grant Institute of Geology and will operate as a national facility for the earth sciences. The 4F ion microprobe was delivered on September 23rd 1987 and then underwent installation tests. On commissioning, access to the ion microprobe for long-term projects will be through a scientific steering committee.

The ion microprobe is a very versatile instrument which permits analysis not only of a mineral's major and trace element chemistry but also its isotopic composition. Samples are prepared as polished one inch round thin or thick sections. As its name suggests, the 4F ion microprobe is a microbeam instrument, and is capable of imaging the distribution of nearly all elements from hydrogen to uranium. The analysed area can be up to $250 \times 10^{-6}m^2$ and features of less than a micron ($10^{-6}m$) can be observed. After commissioning, the basic instrument will be improved by the addition of a new digital imaging system. This system will reduce the concentrations required for imaging from the percent to the part per million level for many elements. If the analysed area can be relatively large ($>10 \times 10^{-6}m^2$) some elements e.g. the rare earth elements, can be determined to the part per billion level.

Unlike the electron microprobe, the ion microprobe is a destructive technique since the ion beam slowly sputters away the surface during analysis. This can, however, be used to advantage. Laboratory simulation to determine the mobility of elements during igneous or metamorphic processes are often limited by the relatively short time period over which experiments can be run. The movement of elements over short distances can, however, be determined by slowly stripping away the outer layers of mineral grains with the ion beam. Similar "in depth profiles" are used extensively by the semi-conductor industry.

The isotopic analysis of geologically important cations, e.g. strontium and lead, in thin section has been possible for a number of years. The 'in situ' analysis of anions, especially oxygen and sulphur, has proved very difficult. Recent improvements in technology which are incorporated on the Cameca 4F, should permit the isotopic analysis of these elements in standard thin section.

The combination of the ion microprobe and the electron microprobe facilities should make Edinburgh an important centre for microanalytical techniques.

The facility will be run by Richard W Hinton who did his Ph.D on the application of the ion microprobe to the study of lead isotopes in minerals at the University of Cambridge. For the last four-and-a-half years he has run the ion microprobe laboratory at the University of Chicago.

BOOK REVIEW: *"Lothian Geology: an excursion guide"*

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Lothian Geology: an excursion guide gives detailed itineraries, with maps, of 32 geological excursions within Lothian Region. Each can be accomplished within a day from Edinburgh. The book also includes an introduction to general geology and to the geology of the region. It is the third edition of the guide first published in 1960 and it follows very closely the pattern of its predecessors, though the geographical coverage has been restricted to the Lothian Region and 'social geology' is catered for with two new excursions, to the Paraffin Young Heritage Trail and to study the building stones of Edinburgh. Excursions to Lower Palaeozoic rocks at Peebles, Lamancha, and the Moffat area are to be included in a new 'Borders Geology'. However, Professor Craig has been allowed to take a small step into the Borders Region in the wake of James Hutton. After all, a threestar locality like Siccar Point '*vaut le voyage*', as the Guide Michelin might say.

Like its predecessors, the guide is concerned almost equally with both igneous and sedimentary rocks and also directs the reader to many of the conspicuous relics of glacial activity. Palaeontology is an important topic of several excursions. In general no feature of geological interest is overlooked, however marginal to the main objective. Only a few of the itineraries are restricted to either volcanic or sedimentary terrains, so that most excursions have something of interest for even the most specialised geologist. Important recent research is recognised, for example the arthropods and fish of Granton and Wardie and the metamorphic clasts in North Berwick vents.

The introduction is a very useful and comprehensive chapter and the criticisms which follow reflect the difficulty facing the authors in drafting, within a few pages, an outline of the broad and ramifying science of geology at a level of explanation appropriate to the unknown reader, whose existing 'database' may be extensive or very limited. In this connection the absence of a glossary is a significant change from the past. Within the chapter the level of explanation is rather variable. Thus an understanding of chemical symbols is assumed in the description of the minerals of sedimentary rocks, but the minerals of igneous rocks are named without any explanation. On the other hand a full explanation of 'fossils' is given. The fossil illustrations are good, but for the beginner it might have been an improvement had the examples been related to the major groups described in the text. An example of a graptolite might have been included, to give the beginner some idea of what he might find in parts of the North Esk Inlier. Illustrations of tectonic structures inspires the thought that figures of sedimentary structures would be helpful.

The geological history of the region is well set out, conveying a clear picture of the succession of events and environments from the Lower Palaeozoic onwards. The animism of the authors finds expression in ...'land and sea fought a constant battle for supremacy'... over the Carboniferous coastal plains. But we get the idea.

In such a publication, it is most appropriate that the Geological Code of Conduct should be included, but it seems to the writer that in drawing attention to it the authors identify a dilemma facing the publishers of such guides, particularly in relation to the collecting of specimens. The Code requires individuals to 'avoid removing fossils, minerals or rock specimens from *in situ* outcrops unless they are to be used for serious study' but many of the itineraries inevitably give details of, for example, richly fossiliferous strata, and it is unlikely that the temptation to collect merely to satisfy aesthetic or acquisitive enthusiasm will always be overcome. It is to the credit of the authors that attention is drawn in no uncertain terms to the 'no hammers' rule at several sensitive exposures.

The excursion itineraries are clearly and consistently presented, with useful information on maps and logistics, and explicitly detailed maps, easily followed and related to the text. Sub-headings for each locality permit a quick appraisal of each itinerary, and the main objectives of each excursion are set out early in the chapter.

Despite the useful Introduction, unexplained technical terms crop up in places, for example, 'conchostracans' (p.77), 'Brigantian' (p.133), and 'bioherm' (p.211), presumably quite familiar to any who need to know, but perhaps to the uninitiated reinforcing the idea that geology is a secretive cult.

The paper back edition is suitable for the pocket, and the cover has an excellent colour photograph of Arthur's Seat; but the monochrome plates inside have a rather ghostly, low- contrast appearance, which does not, however, detract from the illustration of the geology. References to literature are listed together at the end of the book.

To this reviewer, the essentials of a good geological excursion guide are implicit in these four words. The geology must be 'good', i.e. rich in features of interest easily seen and understood, and preferably in some variety. The excursions must be 'good', in being of convenient length, in areas which are readily accessible and agreeable to visit. The guide must be 'good', showing clearly the location of the excursion, the route to be followed and the ways in which the localities can be recognised on the ground. This guide comes close to achieving these ideals, limited only by the range of geology and topography of the area. The text is lucidly presented by professional geologists with an intimate knowledge and understanding of the areas and phenomena described, while the general introduction to relevant aspects of geology is an additional bonus, and the informed enthusiast is further guided to more specialised publications.

Lothian Geology is an essential addition to the bookshelves of locally based geologists, and is highly recommended to all who are interested in the geology of the area, be they visitors in their field-boots, students in their libraries, or veterans nodding in their armchairs and dreaming of the *Bothriolepis* that got away.

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Contents

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