BIOGRAPHICAL MEMOIRS

Sir Frederick Henry Stewart. 16 January 1916 –– 9 December 2001: Elected FRS 1964

M.J. O'Hara

Biogr. Mems Fell. R. Soc. 2006 **52**, 331-348, published 1 December 2006

SIR FREDERICK HENRY STEWART

16 January 1916 — 9 December 2001

Biogr. Mems Fell. R. Soc. **52**, 331–348 (2006)

SIR FREDERICK HENRY STEWART

16 January 1916 — 9 December 2001

Elected FRS 1964

BY M. J. O'HARA FRSE FRS

Golwg-y-Mor, Talybont, Ceredigion SY24 5EQ, UK

INTRODUCTION

'Fred Stewart was charming, canny, perceptive, patient, incisive, highly intelligent, ever so stubborn and completely laid-back', was the opening assessment of Gordon Craig, his friend and close associate for several decades, in his obituary for *The Scotsman* on 14 December 2001. All that and a keen sense of humour came into play on an occasion during a game of chess on the London–Edinburgh express when for once I had the upper hand and launched a sacrificial attack. 'I can take that rook', said Fred, engrossed over the board. 'Are you *sure* that you can afford to lose it?' After a few more rounds of this, Fred gave in, looked up with a mischievous grin and was duly checkmated—but his philosophy was that there was no point in giving in until you are quite certain that your opponent knows that he has won and, moreover, is absolutely sure that he has won. I was a junior lecturer at the time, but learning fast. Fred was Regius Professor of Geology but maintained an informal relationship with staff that was unfamiliar but very welcome after my previous institution.

BACKGROUND AND EDUCATION, 1916–41

Frederick Henry Stewart was born on 16 January 1916 in Aberdeen, the only son of Frederick Robert Stewart of Cathcart, Glasgow, who was a lecturer in civil engineering at Aberdeen University and at Robert Gordon's Technical College, and of Hester Josephine Alexander of Aberdeen. He had an elder and a younger sister.

Fred's line of the Stewarts can be traced back to John Stewart, who arrived at Nether Downham in Glenlivet, Banffshire, in 1636. His descendants were farmers, landowners and

doi:10.1098/rsbm.2006.0023

army officers, then more recently lawyers and stockbrokers. His cousin, James Stewart, is better known as the film star Stewart Granger—who could swash a buckle with the best!

Fred's maternal grandfather was owner of the *Aberdeen Free Press* before its amalgamation with the *Journal*. One of his sons, Fred's uncle William Alexander, was responsible for developing his interest in geology but was himself noted for his work on Scottish place names. The other, Sir Henry Alexander, became Lord Provost of Aberdeen and was a member of the Scottish Mountaineering Club (Vice-president 1931–33, editor of *Cairngorms District Guide* 1928 and 1938). Both uncles were keen mountaineers and took him for long walks in the Cairngorms and other mountains.

His maternal grandmother was descended from John McCombie Mor of Glen Isla (1604–74), whose descendants included the original breeder of Aberdeen Angus cattle and the author of the Scottish classic *Johnny Gibb of Gushetneuk*.

Fred was introduced to geology in his early youth by his uncle, William, collecting minerals and fossils and observing natural processes at work. He displayed a keen interest in this and in natural history generally because of his father's interest in the photography of birds and their nests. He was given a collection of crystals by Professor W. T. Gordon, one of his father's friends, and taken at about the age of eight years to search for scarce fossil fish at Stonehaven—which he found very exciting and fired a lifelong interest. Fred was often to be found in his Edinburgh laboratory at the end of the day, spending an hour relaxing and working on his fossil or mineral collections.

He attended Angusfield House Preparatory School, Aberdeen, between 1924 and 1929, and remembered with gratitude Miss Mackintosh, who fostered those interests in natural history; he then moved on to Fettes College, Edinburgh, from 1929 to 1932. Fred regarded the teaching of science there as being poor in those days, although a Mr Macdonald encouraged his geological interest. Taking firm control of his destiny, he left Fettes to learn enough physics, chemistry and mathematics to enable him to pass the University Preliminary examination at Robert Gordon's Technical College, Aberdeen, where he studied from 1932 to 1933.

He entered Aberdeen University in 1933 intending to take an honours degree in either geology or zoology, taking three years of both subjects and one year each of physics and chemistry and deciding on his final year in geology. He recalled Professor Ritchie as a good teacher in zoology and Professor A. W. Gibb as an exceptionally gifted lecturer although out of date with current developments in the subject. Gibb died just before Fred's final year, to be replaced by Professor T. C. Phemister, who, although in Fred's opinion a bad lecturer, brought him up to date in mineralogy and petrology. His final-year project was on the Belhelvie Gabbro Complex in Aberdeenshire.

He gained a first-class honours degree and won the Hugh Mitchell Prize in 1937; he was also awarded the Kilgour Scholarship for postgraduate work, continuing his work on the Belhelvie gabbros in Aberdeen. This was followed by a Carnegie Scholarship to Cambridge in 1940.

Fred was a rugby enthusiast, later attending many international matches at Murrayfield with small groups of his staff. He had a build and acquisitive–combative nature that brought comparisons with noteworthy scrum-halves to mind—but in real life he played wing three-quarter for Aberdeen University.

From Aberdeen he went on to study at Emmanuel College, Cambridge, from 1939 to 1941 for his doctorate in the Department of Mineralogy and Petrology under the supervision of Professor C. E. Tilley FRS, but while there he was also greatly influenced by Dr S. R. Nockolds (FRS 1959).

Imperial Chemical Industries, 1941–43

His doctorate studies completed, from 1941 to 1943 he worked as a mineralogist in the Research Department of Imperial Chemical Industries at Billingham, encountering a set of geological problems very different from those of the crystallization of molten rock deep underground. The origin and location of potassium-rich evaporites had become an issue; they were economically and strategically important to the war effort while the German Stassfurt deposits were inaccessible. Here he was unravelling the partial crystallization of salts from warm brines in desert lagoons and lakes 250 million years ago, yielding textures and mineral assemblages described by a colleague as fiendishly complex. However, many of the principles of behaviour that govern the slow crystallization of large bodies of molten silicate deep underground in the Belhelvie and Skye gabbros were readily extended to the evaporite situation by Fred's subtle mind.

He demonstrated the extensive metasomatism (baffle-speak for one mineral that has already been deposited becoming redissolved and replaced by a different, in this case potassium-rich, crystal species) that has affected evaporites containing potassium salts.

Subsequently Fred toured a number of American institutions in 1952 in the course of a lecture tour organized ahead of an award presentation by the Mineralogical Society of America, to be followed by a visit to the evaporite deposits of New Mexico.

Durham University, 1943–56

As the end of the war in Europe approached, he was appointed to a lectureship in geology in the Durham Colleges in Durham University in 1943, later being promoted to Senior Lecturer—a post that he held until 1956.

While in Durham Fred returned to research on gabbros in northeast Scotland and Skye in collaboration with Professor Lawrence R. Wager FRS (Professor of Geology at Oxford, who had with Percy Wyn Harris and Sir Jack Longland established Camp VI on the 1933 Everest expedition; then, climbing with the former, had found what may have been Irvine's ice axe at 28 100 feet on the North Face). Wager was a member of the Alpine Club and a world authority on slowly cooled gabbro masses, thanks to his exploration and description of the extreme chemical differentiation within the Skaergaard intrusion of East Greenland. Fred, in his own notes, described him as a wonderful man and I suspect that Mary Stewart modelled one of the characters in *Wildfire at Midnight* on someone not too dissimilar. Also part of that collaboration was Professor J. E. Richey FRS, renowned if not revered for his descriptions of the dissected bowels of the safely extinct Ardnamurchan and Mull volcanoes.

Fred's students at Durham included one, later Sir Malcolm Brown FRS, who went on to work with Wager at Oxford, take the chair in Geology at Durham and follow Kingsley (later Sir Kingsley) Dunham FRS from that post to be Director of the Geological Survey.

Marriage

Fred met Mary, a staff colleague in the English Department at Durham, at a VE (Victory in Europe) dance on 9 May 1945. Mary Florence Elinor Rainbow was the daughter of the Rev. F. A. Rainbow, vicar of Kelloe, and Mary (*née* Matthews) of Kaitaia, New Zealand. These Matthewses were among the earliest British settlers in New Zealand, and her cousin, Professor

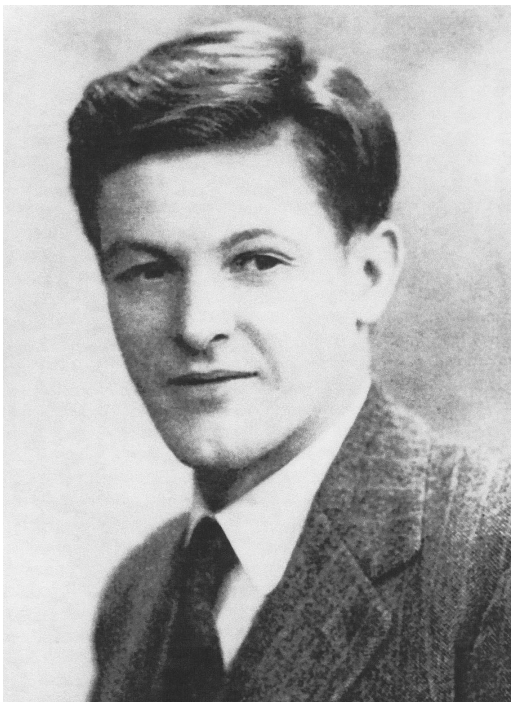

Figure 1. Fred Stewart at the Mineralogical Society of America Ball in 1952.
(Picture from *Am. Mineral.* **38**, 297–300 (1953).)

R. E. F. Matthews of Auckland, was a Fellow of the Royal Society—there was indeed talent on all sides.

They were married barely four months later (Fred was never one to waste time when the issue was clear) in Kelloe Church, by her father. Mary published the first of a series of adventure novels with both modern and Arthurian settings in 1954, and also children's fantasy novels, making for herself a highly successful and financially rewarding career and giving Fred a Jaguar Mark 2 one birthday, to the envy and admiration of the entire University of Edinburgh. Mary survived Fred, but there were no children of the marriage.

Awards and distinctions at Durham

For his work on the evaporite deposits of Yorkshire he was awarded the Lyell Fund by the Geological Society of London in 1951, and the J. B. Tyrell Fund by the same society in 1952. The prestigious Mineralogical Society of America Award, made to a scientist for research published before they are 35 years old, was made in 1952—only the second time it had been awarded, with his predecessor being O. F. Tuttle. Fred (figure 1) was followed in 1954 by Hatten S. Yoder Jr. Distinguished company indeed!

Edinburgh University, 1956–82

Regius Chair

Following in the steps of his predecessor at Durham, Professor Arthur Holmes FRS, he was invited to apply for, and was appointed to, the Regius Chair of Geology by Sir Edward Appleton FRS, Vice Chancellor of Edinburgh University. This post he held from 1956 until his retirement to emeritus status in 1982, despite many tempting offers of even more prestigious chairs elsewhere and a vice-chancellorship or two.

Fred soon set about building Earth Sciences at Edinburgh up into one of the major departments in Britain, rapidly tripling its size, increasing sophisticated equipment, and the technical staff to support it, and attracting a lively young staff, two of whom were later elected to the Fellowship of the Royal Society. In the 1960s and 1970s particularly, the department seemed vibrant with enthusiasm and full of overseas visitors. The department expanded and was strengthened, in part by opportunistic recruitment, in structural geology (Mike Johnson), igneous petrology (Keith Cox (FRS 1988), Brian Upton, John Wadsworth), metamorphic petrology (Ben Harte), palaeontology and sedimentology (Ewan Clarkson, Tony Hallam, Terry Scoffin), and igneous and sedimentary geochemistry (Ted Mercy, Brian Price). All did not go smoothly—when did it ever? Attempts were made to secure a top-rank British experimental petrologist, who unfortunately made his career in the USA. Several attempts were made to develop isotope geochemistry and to locate the Scottish Universities Reactor Centre on campus. I was recruited in 1958 as a field petrologist with an interest in high-temperature, high-pressure rocks.

In 1960 at the Copenhagen International Geological Congress, Fred just happened to fall into conversation with Hatten S. Yoder Jr, of the Geophysical Laboratory, Carnegie Institution of Washington. Hat, an outstanding experimental petrologist at the pre-eminent centre for such work, offered a year's Fellowship with himself and Frank Schairer (another name to conjure with) if Fred could find someone suitab—'Oh, yes *please*', I said before Fred could finish telling me about it, and I was reborn as an igneous petrologist.

He manoeuvred successfully for enough resource to construct a new building that could safely house and service vacuum and atmospheric-pressure furnaces and high-pressure vessels that would enable experimentation under conditions equivalent to those at the surface of the Moon and Earth, down to 100–150 km depth in the Earth, or close to the central pressures in the Moon. Additional staff were recruited (Gordon Biggar, Cliff Ford, Stephen Richardson). Fred had not overlooked the need for good logistical support and had expanded the secretarial and technical staff. The department had one of the best-equipped workshops in the universities by the mid-1960s. Edinburgh by then had the best experimental facilities outside the Carnegie Institution, Washington, and barely seven years after the birth of the idea in Fred's mind, the laboratory was selected by NASA in 1967 to perform studies on the first lunar samples expected to be recovered by the Apollo programme in 1969.

When the Moon samples arrived in September 1969 they were displayed in the Royal Scottish Museum for three days and several thousand people queued to see them—poor turnout for a football match, excellent for a university event.

Dean of Science Faculty

Fred served as Dean of the Faculty of Science from 1966 to 1968, and on the University Court from 1969 to 1970. Fred's casually dressed appearance and friendly unassuming manner

concealed the incisive mind at work. I recall his advice that you should never lose your temper in debate—but that it could sometimes be effective to *appear* to be about to do so. While Dean he oversaw the introduction of geophysics, microbiology and science studies, and the development of integrated courses in biology and engineering science. He also negotiated the location of Murchison House, a new building for the Institute of Geological Sciences, on campus at King's Buildings, in spite of strong pressure from the Civil Service to have it located well outside Edinburgh.

He also campaigned successfully for a fairer distribution of cash resources between the faculties—which, to no one's surprise, resulted in an increase in funds for the sciences.

Teaching

Inevitably his mushrooming involvement in university and national science administration meant that his contact with students became restricted, but Fred particularly recalled one student from his earliest years in Edinburgh, now Professor Ian W. D. Dalziel FRSE, of the University of Texas, Austin. In 1958 Ian, like me, was an assistant lecturer, both new boys on the staff at Edinburgh. We were engaged on an Easter field trip to Skye in 1959 for first-year students, led by Fred and supported by five additional staff. Three events are engraved on my memory: Ian returning ashen-faced with a last round of drinks from the bar on Saturday night, a bar dimly seen through frosted glass but full of gesturing figures, to announce that there were 'drunks clambering over other drunks for more drinks in there'; the staff walking six abreast along the shore, soaked to the skin by persistent rain, leading a straggling and somewhat dispirited gaggle of students, when we came to the outflow of a small river—'Straight through', murmured Fred and without a break in step or conversation we waded knee-deep through the water and continued—leaving an astonished group of milling students assimilating an important lesson about field geology; then Fred's urbanity when dealing with a hotel owner, nearly hysterical about the student-shaped hole that had appeared between two bedrooms (disagreement over a game of poker).

National science administration

Fred was a Fellow of the Geological Society of London and served as Vice President from 1965 to 1966. He also served a short term on the Council of the Royal Society from 1969 to 1970.

He was appointed chairman of the Natural Environment Research Council in 1971, when his knowledge of natural history and especially ornithology as well as his expertise in mineralogy and igneous petrology was perhaps surprising to some with whom he came into contact. He was deeply involved in the politics associated with the separation of the Nature Conservancy from NERC, and the reorganization of Marine Science in the UK. He also became deeply engaged in the aftermath of the Rothschild report on the framework of government research and development. With little time to practise, he also surprised his Edinburgh colleagues when he twice won the staff club billiards championship for the Lady Appleton Cup during this period.

He moved on to membership of the Advisory Board for the Research Councils in 1973, and I was with him in the Old College in 1974, shortly after news of his appointment as Chairman had broken. Congratulated by a passing colleague, Fred commented that it was a foothold in the corridors of power. 'No, Fred—in the *pastures* of power', came the reply. In his role as Chairman, which he held until 1979, he was responsible for advising the Secretary

of State in the Department of Education and Science on science policy, including the funding of a range of bodies whose annual budget then approached £500 million (more than £3 billion today).

In six years in office he worked with four Secretaries of State, namely Fred Mulley, Reg Prentice, Margaret Thatcher (FRS 1983) and Shirley Williams, which further developed his skills in the Byzantine intricacies of government science.

I recall, and Tam Dalyell records, that Fred was much impressed with Margaret Thatcher as an astute and effective Secretary of State. Less impressed by her handling of British industry, Dalyell reports that Fred was 'incandescent with anger' at the gratuitous insult inflicted by Oxford University on Margaret Thatcher as Prime Minister—which some see as a self-indulgence that did little to ameliorate the coming storm, which probably set back Fred's efforts and whose consequences weighed heaviest on those who had had no say in the matter. Fred also had a high regard for Shirley Williams in the same role, a respect that was fully reciprocated.

As part of that job he also chaired subcommittees on the important topics of postgraduate support, on the dual support system and on energy research.

He served on the Council for Scientific Policy from 1969 to 1971 and as an Assessor from 1971 to 1973. He also served on the Advisory Council for Applied Research and Development from 1976 to 1979.

Awards and distinctions at Edinburgh

Birth, education and research qualified him and he secured his election to Fellowship of the Royal Society of Edinburgh in 1961, joining some very distinguished names in the history and development of Earth science.

Proposed by nine of the most influential UK Earth scientists of the time, he was elected to the Fellowship of the Royal Society in 1964, for his work on the layered igneous rocks of northeast Scotland, the metamorphic rocks of Kilchrist in Skye and above all for his studies on the petrogenesis of evaporites.

In 1970 he was awarded the Lyell Medal of the Geological Society of London, a medal that is awarded to outstanding Earth scientists who show a breadth of knowledge and achievements over more than a narrow field and usually for work on the 'soft' rock side.

The Clough Medal of the Edinburgh Geological Society is 'awarded annually to a geologist whose original work has materially increased the knowledge of the geology of Scotland and/or the north of England, or who is Scottish by birth or by adoption and residence and has significantly advanced the knowledge of any aspect of geology'. Fred was outstandingly qualified and received the medal in 1971.

He received a hard-earned and well-deserved knighthood in 1974. At that time Fred, Gordon Craig and I frequently went down for lunch at the University Staff Club in Chambers Street (observed understandingly by other staff who referred to us as 'The Three Bears'), where the downstairs sandwich bar was a favourite watering hole. Fred, who was a trifle portly at the time, was very well known (as 'Sunshine') to the bar staff. That day it was 'Sir Sunshine', but as we stood in the queue teasing Fred about what grandiose title he should take, a gem came from behind the bar. 'What about Circumference!' Fred loved it—a Very Important Person who was devoid of self-importance.

Fred was awarded the Sorby Medal of the Yorkshire Geological Society in 1975, again a very appropriate choice because it honours 'distinguished contributions to geological knowledge of Yorkshire and the north of England'.

Figure 2. Fred and Mary Stewart at honorary degree ceremony, Aberdeen University, in 1975. (Photograph courtesy of the Press and Journal.)

There were honorary degrees also from Aberdeen in 1975 (figure 2), Leicester in 1977, Heriot-Watt in 1978 and, after his retirement, from Durham in 1983 and Glasgow in 1988.

Consultancies

He maintained his industrial contacts in connection with evaporites, acting as consultant especially on potash deposits for Fisons Ltd between 1949 and 1955, and again between 1962 and 1968; for the British Petroleum and Gas Council (1955–57); and for Imperial Chemical Industries and the Cleveland Potash Company between 1968 and 1971.

Travel

A lot of travel went with the jobs that he undertook. His own notes indicated succinctly that he had travelled in the USA and Canada to visit evaporite deposits; to New Zealand and Hawaii to visit volcanoes; to Peru on holiday; and to Romania and other countries in Europe, to Canada and the USA—all in connection with his role in formulating science policy.

Active retirement

On Fred's retirement in 1982, he and Mary went to live in the village of Lochawe, Argyll, where he was able to pursue his interests in fishing for both live and fossil prey, extending his love of the lochs of Caithness and Harris to the River Orchy.

Activities

Even in retirement Fred kept his hand in and his wits stimulated by service as a Trustee of the British Museum Natural History from 1983 to 1987 and on the Council of the Scottish Marine Biological Association from 1983 to 1989.

Sapphire hunting

In retirement Fred resumed an active interest in mineral collecting. He formed the Mull Expeditionary Sapphire Society (MESS) and found the largest sapphire ever found in Scotland. Nearly three inches long, it was later put on display in the National Museum of Scotland.

Fishing

Fred's interest in the collection of 350-million-year-old fossil fish from the Old Red Sandstone resulted in a very substantial and extremely valuable collection of these scarce early vertebrates. This collection and his mineral collection, described variously as 'fantastic', 'major' and 'exquisitely curated', were donated to the Royal Scottish Museum after his death, where it is hoped that they will soon be displayed.

Helicopter mountaineering

Always fond of the hills, Fred and Mary were on occasion to be encountered walking the tops of the nearby mountains of western Scotland, appropriately elevated by helicopter.

Scientific contributions

At election to the Fellowship of the Royal Society, Fred had just 15 publications, only 4 of which would be described as substantial in today's assessment-oriented environment. But Fred rarely spoke unless he had something significant to say, and those less substantial publications include his acceptance of a prestigious American award that has been won by UK citizens on only about six occasions in the 53 years of its existence.

Science resource and research environment

His most important contribution to science in the round was the very important role he played in creating a congenial, intellectually stimulating environment and bringing home the resources that enabled and encouraged others to get on with the job.

He created this important magic first at the level of his department, guiding and encouraging a tripling in size, and at least as great an increase in stature. He took a relatively small department, whose survival might have been in question, and turned it into one of European and international stature.

He repeated the exercise as Dean of the Faculty of Science, extended his influence as chairman of the Natural Environment Research Council (NERC) and was able to influence events nationally as chairman of the Advisory Board to the Research Councils (ABRC). There may be much about the state of science in 2006 that is less than satisfactory, but consider: it could have been much worse.

Tam Dalyell, with a politician's eye and from the standpoint of a consumer of scientific advice, assessed Fred to have been one of the half dozen most influential scientists in Britain between the mid-1960s until the early 1980s (Obituaries, *The Independent Monday Review*,

17 December 2001, p. 6). He recalls Fred as his wonderfully considerate and charming mentor on the All-Party Parliamentary Scientific Committee.

Tam Dalyell's obituary contains several statements from Fred's colleagues that paint the picture of a calm, friendly and effective negotiator who won the day without leaving a battlefield littered with the aggrieved.

Dalyell observed that 'eminent scientists do not always turn out to be successful administrators and statesmen of science', thus displaying that chacteristically British capacity for understatement. Personally, I found that administration, teaching and research each called on the same pool of adrenalin, concentration and commitment. Each demanded total immersion at the time if the job was to be done to my satisfaction. The same may have been true of Fred, but I suspect that he really enjoyed pitting his wits against those of other shrewd operators at the highest level—a mere Vice Chancellorship would have frustrated him and been a waste of his talent.

His first and only individual publication on science policy appeared in 1971 (20)*, but a further 13 statements appeared (23–35), mostly in official reports, between 1972 and 1979. I remember sitting with Fred in the staff club in the mid-1960s together with several other young staff. The financial taps had just been turned on (perhaps the reader is old enough to remember the 'white heat of technology') and we were all arguing that it was poisoned money. Fred just muttered that everyone else was taking it and we were going to get our share. Appropriately, perhaps, that first 1971 contribution was an address to the Geological Society of London that opened with two relevant quotations from the previous century, oozed pragmatism and realism, summarized the financial situation, pointed out that the bonanza could not continue, and in general conveyed the message 'The party is over!'. Fred was stressing that the community needed the right organization to manage change. That may still be true today. A phrase from the context of the Earth Science Review 15 years later is equally relevant to the response in 1971—'a flock of sheep debating the best recipe for mint sauce'.

Mineral 'finds', gabbros, granites and metamorphic rocks

Fred published 12 papers on British igneous rocks and their associated metamorphic products, between 1941 and 1970. Some of these were individual efforts; others were co-authored variously with W. Q. Kennedy FRS, J. E. Richey, L. R. Wager or members of staff in his new department.

His first publication of all was a concise, careful, meticulously documented description and chemical analysis of a new 'find' of a rare mineral in northwest Scotland (1) and its comparison with the few similar discoveries worldwide. His second was an equally careful description of a silica-poor hornfels produced by thermal metamorphism of muddy sediment adjacent to the gabbros of northeast Scotland (2) with analyses of bulk rock and the constituent cordierite, garnet, biotite and spinel. These data found quite wide application in later discussions about the stability of iron-rich cordierites, magnesium-rich garnets and the use of the assemblage as a geothermometer and geobarometer, as well as debate whether such silica-poor hornfels were generated by partial melting and extraction of a silica-rich melt from more normal muddy source rocks. What one needs to keep in mind is that this was 'traditional' mineralogy and petrology—hours of labour crushing the rock and separating the constituent minerals in sufficient quantity for chemical analysis, then days of work per analysis to carry

* Numbers in this form refer to the bibliography at the end of the text.

out the tedious procedures of gravimetric silicate analysis (which were still in use at the start of the Apollo programme in 1970).

Some of these early papers were no more than brief letters (3, 17, 19) or short clear summaries (19), but two major papers (3, 18) dealt with the mapping and description of rhythmic and cryptic layering, and the first identification in Britain of gravity stratification in the Belhelvie basic igneous complex. A third major contribution was his 49-page chapter (17) reviewing the Scottish Tertiary Igneous Province in *The Geology of Scotland*, which put to the test his ability to select, simplify and synthesize complex information. The chapter closes with a short lucid summary of the place of these rocks in the global debate about the origin of the major types of basalt. That debate was concentrating on how a magma might evolve from tholeiitic basalt to the volumetrically less prominent alkali basalt—a time when mid-ocean-ridge basalt was barely known, komatiite completely unknown and the existence of picritic magmas an article of faith to another Scot, Harald Drever at St Andrews.

Marine evaporites

Twenty-two publications relating to his work on evaporite deposits appeared between 1949 and 1972. Among these there are six major papers, totalling about 250 published pages, that alone contain enough material to constitute a respectable scientific career.

Scientific method—the ideal approach of observing, recording, then reasoning and so reducing the number of viable alternative hypotheses—is the essential foundation of good geology, but geologists also require fertile imaginations (controlling the latter is an important and all-too-often neglected part of the trick). A geologist rarely has much control over the variables affecting the experiment whose products he is examining, and I see similarities with forensic science. What was the mad scientist trying to do—and why—just before the explosion that killed the staff, destroyed the notebooks and scattered the debris to the four winds? There may be inadequate resources to collect *all* the evidence; data collection is therefore often hypothesis-led, a process that has obvious built-in perils.

Imagine, then, a 25-year-young Fred Stewart in 1941, presented with a load of samples derived from unknown depths from a drill hole 1500 metres deep—samples full of water-soluble minerals, samples that had been left lying exposed on the ground for three years, plus a collection of well chips collected every 5–10 feet but likewise devoid of their original water-soluble components, and a handful of nicely preserved, properly located but irregularly spaced core samples; but no field outcrop to provide control. Add in the thoughts that he was dealing with the products of dehydration of seawater, which may vary with the water temperature—that is, the season—and with the extent and frequency of recharge with ‘fresh’ seawater, that the process produces late-stage dense brines that can soak into and alter the deposited crystals, that the deposits produced are extremely vulnerable to subsequent alteration by groundwater, and that the minerals formed are easily deformed and recrystallized by earth movements. He was faced with rocks the like of which he had never met before, containing more than a dozen mineral species of which he had little experience. Plenty of room for multiple working hypotheses here. ‘Ee, what’s tha complainin’ about, lad? Get on wi’ t’job!’

Fred got down to it and did a superb job of piecing together the evidence and justifying his decisions where he was sure, laying out the alternatives where he was not. The results were published in three parts (4, 6, 7) totalling 102 pages, in *Mineralogical Magazine*, a journal in which the average length of article was less than 10 pages!

The basics of sedimentology are simple. Sediments, including evaporites, are being

deposited today across much of the Earth's surface. What is being deposited at any given place varies according to latitude, local geography, climate, and so on, in ways that reflect local conditions—and can later be used to identify those conditions from a rock sample. What is being deposited at any one place also varies in the short term because of storm, tide and seasonal effects. These differing environments grade into one another laterally, creating a patchwork quilt of sedimentary facies spread across the Earth's surface. On the longer time scale there are global changes in climate, sea level and the distribution of land masses that have changed the position of that quilt on the globe—and the relative sizes of the patches. An outcrop or a borehole presents a tape recording of which part of the quilt lay over that particular part of the crust at successive times. Almost there now! Remembering that each tape recorder is itself moving around over the surface of the globe (continental drift), all that the geologist has to do is to listen to as many tape recorders as are available and deduce the positions and movements of the quilt. Oh, yes—and why it moved? You should, perhaps, know that Fred was also very good at first-off-the-board chess and five-second-a-move chess.

What makes the study of evaporites so challenging is that the products are water-soluble (by definition), readily replaced one by another, and prone to flow quite readily under moderate stress. The salts being deposited and the consequent evolution of the brine composition depend on, among other factors, the concentration of the brines, the water temperature and the rate of evaporation relative to the rate of supply of new seawater. The balance between evaporation, salt deposition and seawater recharge can set up quasi-steady states of the chemical systems. These wobbly states might vary laterally on a scale of tens of metres in the evaporite-forming environment.

In late 1953, after a visit to the USA, Fred presented to the Yorkshire Geological Society a major paper reviewing and comparing what was known about the Permian evaporites of Europe and the central and southern USA (9). Where the earlier papers had revealed his grasp of complexity and clarity of exposition at the scale of individual specimens, this latest work demonstrated his ability to absorb information from a plethora of sources, to see the controlling processes and patterns, and to present these clearly and concisely to a reader.

He clearly appreciated the complex simplicity of the global picture. I was struggling with a mundane approach to sedimentology in my second year at university at that time—I wish Fred had been teaching me. Only 37 years old, he was already grasping concepts that the rest of the community would take another decade to assimilate, and was displaying the skills that he transferred later to science administration with such success.

Fifteen years after meeting the Eskdale No. 2 drill hole, Fred had the opportunity to describe and interpret the Forden No. 1 hole, which was drilled in 1956 and was thoroughly sampled throughout the evaporite section. His study extended for seven years, overlapping the great increase in his knowledge of this rock type that is distilled into the major 1953 review just mentioned and the very different review in his other major evaporite paper of 1963 (see below).

His description and interpretation of the Forden deposit was published in *Proceedings of the Yorkshire Geological Society* (15) in 1963. The record here was complete enough to permit the consideration of cyclical effects in deposition and to attempt to relate the observed products to the physical chemistry of the brine systems. He transported from igneous petrology the familiar distinction between fractional and equilibrium crystallization in closed bodies of fluid and clearly envisaged that open-system behaviour might be different—an important concept not pursued in igneous petrogenesis for a further 15 years. It is probable

that his idea of developing a large experimental petrology facility at Edinburgh was born in those first few years in the Regius Chair as he appreciated the importance of an understanding of the phase equilibria in understanding the message written in the rocks.

Also published in 1963, although completed five years earlier, was his review and summary of available geochemical data for evaporites (14). This appeared as a United States Geological Survey *Data of Geochemistry* series professional paper, to complement the 1953 review by concentrating on the chemical data and phase equilibria relevant to evaporites. The abstract of this paper is a lucid summary of the field and makes a good starting point for anyone wishing to enter the field even today. Its Table 2 lists the chemical formulae of about 80 crystalline phases encountered in marine evaporites and illustrates the complexity of the field. There is an invaluable summary of the experimental data, and the bibliography includes about 350 sources.

This was a major contribution—citation data are difficult to interpret but the paper was clearly very influential, as were the three early papers on the Eskdale borehole. The two papers in *Proceedings of the Yorkshire Geological Society* were either too inaccessible or left little more to be said—but what I consider the best piece of science I ever put my name to had achieved only two citations after 20 years and has acquired not many more since.

Big pictures are built up from small, precise brushstrokes. An unidentified accessory mineral was mentioned in the description of the Eskdale borehole. Fred pursued it by laborious mineral separation and hand picking, eventually obtaining a fraction of a gram of the pure mineral for chemical analysis. It was identified in 1954 as a strontium borate, veatchite, new to Britain (8). The matter was not forgotten, however, and when new information appeared, Fred backtracked to demonstrate in 1960 that the mineral was in fact the variety with a primitive lattice, *p*-veatchite (11). This capacity to attend to loose ends while also having a grasp of the broader picture is a recurrent theme in his work.

The year 1965 saw Fred's last major contribution to matters concerned with evaporites (16), an admirably concise and clear summary of the complex mineralogy of the British Permian Evaporites that appeared very appropriately in the Tilley volume of *Mineralogical Magazine*—Fred had been Tilley's student at Cambridge, and Tilley had made one of the earliest identifications of potassium-bearing minerals in Britain.

Regional geology, overviews and minutiae

Preceding his overview of the Tertiary igneous rocks of Scotland (17), Fred had collaborated with M. R. W. Johnson to look at the structural evidence relating to the Older and Younger Igneous rocks of northeast Scotland, leading to two brief papers in *Transactions of the Edinburgh Geological Society* (12, 13). In these they determined that there was no structural impediment to these two rock suites' being different manifestations of the same event. The matter has wider importance because these events involved intrusions of very large volumes of basic magma into a compressional environment—whereas most such events are associated with tensional environments and often incipient continental rifting. It takes breadth of mind to contemplate this bigger picture while encouraging a sedentary cow to move off the only good outcrop for several miles!

The first of several overview papers concerned with broader aspects of Earth science was published (10) in 1958—his inaugural lecture in Edinburgh at the age of 42 years. Reviewing with simplicity and clarity the development of geology as a discipline and the major role of Edinburgh and Scottish geologists in that progress, Fred simultaneously illustrated how much

damage had been done by a charismatic presenter of hypotheses that, although compatible with existing beliefs, were incompatible with observations and, to be frank, common sense. Through disciples that damage had been propagated for decades through the nineteenth century after the issue should have been decided. Adherence to familiar dogma obstructed impartial testing of hypotheses. What a good thing that the scientific method precludes such wasteful mistakes today! Irony aside, Fred was clearly aware of the lessons still to be learnt from history.

In that lecture he also indicated his intention to take Edinburgh down the road of a large expansion in equipment, and of the experts to use it, across the whole spectrum of activities in the Earth sciences—the specification for an international Earth science department that Fred drew up in 1957 would do very nicely today with the addition of provision for the extraterrestrial opportunities that have opened up since he wrote.

A little gem in *Mineralogical Magazine* has been saved for last (5). Under the unassuming title of 'Note on garnet crystals from Cairnie, Aberdeenshire', a two-page note describes and characterizes the largest (5 cm) garnets reported up to 1950 from the whole of Scotland. The mineral collection that Fred accumulated was comprehensive, and excellently catalogued and curated. Together with his outstanding collection of Old Red Sandstone fossil fish, it was donated to the Royal Scottish Museum after his death.

Finally

Fred considered himself to have been extremely lucky in having a varied career, developing an interest at an early age and being able to pursue it. He had experience of four good universities and of industry, and of involvement in policy and the 'political intricacies' of government science. He felt that he had been lucky also in having worked with such distinguished and stimulating men as Dunham, Tilley and Wager. But to a large extent he made his own congenial colleagues.

Fred died in Oban hospital on 9 December 2001. The headline to his obituary in *The Scotsman* read 'geologist, former Dean of Science Faculty at University of Edinburgh', suggesting that the spirit of 'Aberdeen man drowns' is alive and thriving. The *Guardian* came closer with 'Master geologist steering science for academic and practical ends'. 'Death of Superman' sums it up nicely for me.

A memorial service was held in the Canongate Kirk, Edinburgh, on 8 March 2002. I was unable to attend, but Mary wrote to me afterwards, 'It was a most beautiful day. (So was the funeral: I think he's already at the top of the Council table up there!).' I would expect no less of this warm and wonderful man.

Acknowledgements

My thanks to Lady Mary Stewart, Professor Gordon Y. Craig FRSE, Tam Dalyell MA DSc, Professor Ian W. D. Dalziel FRSE, Dr Michael R. W. Johnson FRSE, and the library staff of Edinburgh University, the Geological Society of London and the Royal Society, whose help in the compilation of this memoir was essential.

BIBLIOGRAPHY

The following publications are those referred to directly in the text. A full bibliography is available as electronic supplementary material at http://dx.doi.org/10.1098/rsbm.2006.0023 or via http://www.journals.royalsoc.ac.uk.

(1) 1941 On sulphatic cancrinite and analcime (eudnophite) from Loch Borolan, Assynt. *Miner. Mag*. **26**, 1–8.

(2) 1942 Chemical data on a silica-poor argillaceous hornfels and its constituent minerals. *Miner. Mag*. **26**, 260–266.

(3) 1947 The gabbroic complex of Belhelvie in Aberdeenshire. *Q. J. Geol. Soc. Lond.* **102**, 465–498.

(4) 1949 The petrology of the evaporites of the Eskdale no.2 boring in east Yorkshire. Part I. The lower evaporite bed. *Miner. Mag.* **28**, 621–675.

(5) 1950 Note on garnet crystals from Cairnie, Aberdeenshire. *Miner. Mag.* **29**, 252–253.

(6) 1951 The petrology of the evaporites of the Eskdale no.2 boring, east Yorkshire. Part II. The middle evaporite bed. *Miner. Mag.* **29**, 445–475.

(7) The petrology of the evaporites of the Eskdale no.2 boring, east Yorkshire. Part III. The upper evaporite bed. *Miner. Mag.* **29**, 557–572.

(8) 1954 (With R. A. Chalmers & R. Phillips) Veatchite from the Permian evaporites of Yorkshire. *Miner. Mag.* **30**, 389–392.

(9) Permian evaporites and associated rocks in Texas and New Mexico compared with those of northern England. *Proc. Yorks. Geol. Soc.* **29**, 185–235.

(10) 1958 The Development and Progress of Geology: Inaugural Lecture. *Univ. Edinb. J.*, Spring, 22–31.

(11) 1960 (With C. A. Beevers) *p*-Veatchite from Yorkshire. *Miner. Mag.* **32**, 500–501.

(12) (With M. R. W. Johnson). On Dalradian structures in north-east Scotland. *Trans. Edinb. Geol. Soc.* **18**, 94–103.

(13) (With M. R. W. Johnson). The structural problem of the Younger Gabbros of north-east Scotland. *Trans. Edinb. Geol. Soc.* **18**, 104–112.

(14) 1963 *Data of Geochemistry, 6th edit. Marine Evaporites.* US Geol. Surv. Prof. Paper no. 440-Y.

(15) The Permian Lower Evaporites of Fordon in Yorkshire. *Proc. Yorks. Geol. Soc.* **34**, 1–44.

(16) 1965 The mineralogy of the British Permian evaporites. *Miner. Mag.* **34**, 1965, 460–470. [Tilley Volume.]

(17) Tertiary igneous activity. In *The geology of Scotland* (ed. G. Y. Craig), pp. 417–465. Edinburgh: Oliver & Boyd.

(18) 1966 (With W. J. Wadsworth & A. T. V. Rothstein) Cryptic layering in the Belhelvie intrusion, Aberdeenshire. *Scott. J. Geol.* **2**, 54–66.

(19) 1970 The ‘younger’ basic igneous complexes of north-east Scotland, and their metamorphic envelope. Introduction. *Scott. J. Geol.* **6**, 3–6.

(20) 1971 The place of geology in government scientific research. *J. Geol. Soc*. **127**, 437–446.

(21) Review of ‘Salt Deposits, their Origin and Composition’ by O. Braitsch in *Minerals, Rocks and Inorganic Materials*, 4, Springer-Verlag. *J. Geol.* and *Geol. Mag*.

(22) The Hathern Anhydrite Series, Lower Carboniferous, Leicestershire, England. *Inst. Mining Metall. Trans.* **80**, 47–48.

(23) 1972 Framework for Government Research and Development. *NERC News J.* **5**, 2–3; (6), 2.

(24) *Natural Environment Research Council Report of Council for the year 1 April 1971 – 31 March 1972.* London: HMSO.

(25) *Minutes of Evidence on a framework for Government research and development*, pp. 170–218. Select Committee on Science and Technology. London: HMSO.

(26) Report of the working group on scientific priorities. In *Third Report of Council for Scientific Policy* (Cmnd. 5117), pp. 18–26. London: HMSO.

(27) 1973 (With R. J. H. Beverton) *Natural Environment Research Council Report of Council for the year 1 April 1972 – 31 March 1973.* London: HMSO.

(28) Problems of the Environment. *Int. J. Environ. Stud.* **4**, 306–308.

(29) *Minutes of Evidence on postgraduate education.* Expenditure Committee (Education and Arts Sub-Committee). London: HMSO.

(30) 1974 *First Report of the Advisory Board for the Research Councils* (Cmnd. 5633). London: HMSO.
(31) *The Organisation and Funding of State Sponsored Research in the United Kingdom. Fourth Anglo/Romanian Colloquium*.
(32) 1975 *Minutes of Evidence on the financing of scientific research in British universities*, pp. 343–353. Select Committee on Science and Technology (Science Sub-Committee). London: HMSO.
(33) 1976 *Second Report of the Advisory Board for the Research Councils* (Cmnd. 6430), p. 33. London: HMSO.
(34) 1977 *Minutes of Evidence on research and development in the EEC*, pp. 71–86. Select Committee on the European Communities (Sub-Committee F). London: HMSO.
(35) 1979 *Third Report of the Advisory Board for the Research Councils (1976–78)* (Cmnd. 6430), p. 27. London: HMSO.