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Cover illustration: The Tassie Portrait of James Hutton

EDITORIAL

ONE HUNDRED AND FIFTY NOT OUT

Avoiding the temptation to comment upon the folly of the protagonists in a declining coal industry we shall keep this editorial short. We shall record the pleasant events of the summer such as the Lord Provost's visit to the Festival Fringe Exhibition 'Geological Maps of the World', the Council's visit to see the 'hammer' on the Mound and another fine series of excursions, the highlights of which, we hear, were the joint venture with Glasgow to Burntisland and the week at Balmacara. We look forward with great interest to a new season of notable speakers, wide-ranging geology and friendly collaboration with sister organisations. We salute the Royal Scottish Geographical Society in its Centenary year, and wish our own Society many happy returns on the occasion of its 150th birthday.

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THE TASSIE PORTRAIT OF JAMES HUTTON

Jean Jones

Hutton's celebrated paper on the theory of the earth, in which he first made public his geological speculations, was delivered to the Royal Society of Edinburgh in the spring of 1785. The first part was read on March 7th, the second a month later. The approaching bicentenary prompted me to made a small study of the Tassie medallion (illustrated on the cover of this issue) since Hutton's admirers may buy modern casts of it from the Scottish National Portrait Gallery but little is generally known of the sculptor or the time and manner in which it was fashioned.

The medalion, dated 1792, is the last, the most formal, and perhaps the least approachable, of the surviving likenesses of Hutton. It is preceded by Raeburn's painting[1], and three playful etchings by Kay, executed in 1787[2]. Tassie, like Hutton, had come almost to the end of his career when he modelled it. He was born at Pollockshaws, near Glasgow, in 1735. As a young man he worked in Glasgow as a stonemason and also attended classes at the drawing academy established by the Foulis brothers. In 1763 he moved to Dublin to work for Dr. Quin, a physician who had been experimenting with coloured pastes which could be used to make reproductions of antique gems. Together the two men devised the familiar white vitreous paste which was to make Tassie famous, and, with the encouragement of his mentor, Tassie set up on his own in London in 1766. Soon his gems were in great demand and, subsequently, his medallions. Private citizens, politicians, scientists, and scholars all sat to him, including some of the most eminent men of the day. He died in London in 1799, his business being carried on by his son William.

The busts sculpted by Tassie for his medallions are usually about three inches high and he worked in red wax, using a few simple modelling tools. The wax, though soft enough to model, hardened to give a clear edge. A mould was then cast in plaster of Paris, which (since it did not need to be heated) left the wax unaffected. From this concave image Tassie cast a plaster cast in relief, subsequently using it to cast another concave image, this time in clear glass. The glass, unlike the friable plaster, was strong enough to give numbers of accurate casts of the final medallion in vitreous paste. At the end of the nineteenth century, the paste was analysed at the instigation of J.M. Gray, the first keeper of the Scottish National Portrait Gallery and Tassie's biographer. It was found to be basically a lead potash glass to which arsenic had been added to prevent the lead oxide from darkening.[3]

Only two of Tassie's original wax models have survived, the Hutton being one of them. It belongs to the Royal College of Physicians of Edinburgh and is inscribed "James Hutton MD 1792 Tassie F". It is mounted on a clear ground backed with green paper and is set in a black oval frame.

At the time the portrait was taken, Hutton was in his sixty-fifth year and had not long recovered from a serious illness which had beset him the previous summer. As the same illness was to recur in 1794, leaving him an invalid until his death in 1797, the medallion shows him almost at the end of his active days.

Like nearly all Tassie's subjects Hutton is shown in profile, and, in common with roughly half of them, he is looking to the right. Of those of his circle who sat to Tassie, Hutton was the last: the Smith portrait is dated 1787, Black 1788, and Robison, Ferguson and Robertson all 1791. In contrast to his friends, and also to most of his contemporaries, Hutton is shown in classical not eighteenth century, dress. No other scholar of the Scottish Enlightenment is portrayed in the antique manner except for Robert Adam, the high priest of neoclassicism, and the philosphers David Hume and Thomas Reid. [4] However, by the time of the portrait, Hutton had written not only on geology, but on physics, chemistry, meteorology and agriculture, and had probably drafted most of his three volume work on philosophy. He had come to believe that science, although a useful discipline in its own right, was ultimately only the hand maiden of philosophy; he likened scientific facts to the bricks and mortar of a building, and philosophy to the design which welded them into a coherent whole.[5] It was therefore perhaps as a philosopher (in the broad eighteenth century sense), rather than as a scientist or man of affairs, that he wished his image perpetuated. Certainly the classical mode of the portrait is unlikely to have been suggested by Tassie, for he was apparently unaware of Hutton's reputation, referring to him only as "an Edinburgh gentleman".[6]

Tassie was apparently well satisfied with the Hutton medallion for he chose it, with one other, from his considerable annual output to exhibit at the Royal Academy in the summer of 1792. Since Tassie never disclosed the identity of his sitters, the medallion appears in the Academy catalogue simply as "Portrait of a Gentleman".

The only known copy of the Hutton medallion is lodged in the Scottish National Portrait Gallery. We do not know how many casts Tassie made of it or, indeed, of most other medallions. The number of casts made probably varied according to the eminence of Tassie's subject, though it appears that some sitters chose to control the number of copies. The price of a cast on sale to the general public was usually between 10s 6d and 15s, depending on the size, the background, the degree of polish and the frame. Tassie wrote to his Glasgow agent: "I have taken the liberty of sending you two of Mr Smiths Portrait and one of Dr Blacks .... I have put them in frames. The pastes being rough grounded enables me to afford them for the same price as Lapideryed... I charge you for the large portraits 9/- each you dispose of them at 10/ 6".[7]

Unfortunately little can be said with certainty about the subsequent history of either the wax or the cast. Hutton died unmarried and intestate, and all his property passed to his sister, but there is no trace of either of the two medallions in her lengthy Trust Disposition of 1805 nor her will of the same date. In 1903 the wax appears in an inventory of the Royal College of Physicians of Edinburgh, but as the College has no record of its acquisition its history before that time is lost to us. The cast came to the National Portrait Gallery among the large collection of Tassie gems and medallions handed over by the National Gallery of Scotland in 1889. Since the bulk, or perhaps all, of the National Gallery collection had been bequeathed to the Board of Manufacturers in Edinburgh, who ran the Gallery, by William Tassie, it appears that the extant Hutton cast is the one which the artist had retained as a record in his studio. Presumably other casts were sent to Hutton, but what happened to them we shall probably never know.

Notes

1. In a private collection.
2. J. Kay, *A series of original portraits and charicature etchings* vol. i, pt. i, 55, 56; vol. i, pt. ii, p. 243 (Edinburgh, 1787).
3. J.M. Gray, *James and William Tassie*, (Edinburgh, 1894), p. 39.
4. Tassie made two medallions of both Hume and Adam. In each case the version in contemporary dress is by far the better known.
5. J. Hutton, *A Dissertation upon Heat, Light and Fire*, (Edinburgh, 1794), p. vi.
6. Tassie to Wilson, letter 56, 12th April 1792; Scottish National Portrait Gallery
7. Tassie to Wilson, letter 35, 19th Jan. 1789.

THREAT TO HOLY OF HOLIES

Reprinted by kind permission of the Editor, What's on Across Scotland *magazine (April 1984), this editorial will inform senior members of the Society of progress since the demolition of the Synod Hall.*

The citizens of Edinburgh were stunned by the news last month that talks had opened on the possible removal of one of the city's major international attractions. The moment the news leaked through the city's own national paper, the howls, of protest could be heard.

Edinburghers, a pretty reticent bunch at the best of times and not given to displaying their corporate emotions, are at this very moment, organising themselves into pressure groups to lobby against what they believe could become one of the greatest acts of civic vandalism since the destruction of Sodom and Gomorrha. The very core, the very substance of the City's heritage is at stake. Short of a cruise missile taking out the Castle, the damage that may be done to the city's reputation as a centre of tourism, and culture is beyond contemplation.

The announcement that caused the shock waves to reverberate around the city and had its citizens choking on their muesli was that a new theatre is to be launched in the city and in a superb example of "Coup de theatre" the authorities have chosen none other than "The Hole in the Ground" as the silo.

Years of planning, countless hours of designing by some of the country's most gifted architects, not to mention millions of pounds, have been spent on producing one of the greatest Holes in the world, rivalling the Great Hole at Kimberley in South Africa and even thought by some to be of more significance than the much vaunted Black Holes of inter stellar space. The Edinburgh Hole, known to millions under its quaint generic name, the "Opera House Site", is one of the greatest manifestations of man's ability to create nothing out of something, a singular achievement in such a small City.

Currently protected by specially designed wooden walls and surrounded on two sides by covered viewing platforms, the site has a mysterious quality not unlike the holy Kaaba in Mecca. Within the Hole the balance of nature is as delicate as the Namib desert, indeed as an area of unused natural and scientific significance it is to be included in the revised edition of David Attenborough's, "The Planet Earth".

It is this striking example of man and nature living in harmony that is now under threat and it must be saved for future generations. The cry must not be "Save the Whale", but "Save the Hole". It is part of Scotland's Heritage and a constant source of national inspiration. Our Hole is miles Better than anybody elses Hole, a better Hole by far.

PETROLEUM GEOLOGY OF THE SOUTHERN ARABIAN GULF AREA (WITH A PINCH OF ARABIAN SAND!)

Stephen F. Newton

This contribution is partially intended to complement that written on 'Hydrocarbon Exploration in the North Sea' by D. Hall in the Autumn 1982 issue of *The Edinburgh Geologist* (pages 9-15). The Arabian Gulf area serves to illustrate several features of hydrocarbon occurrence that are not often seen in the North Sea. Perhaps the major difference between the two areas is the extensive development of carbonate reservoir rocks in the Gulf.

In the following paragraphs I hope to outline the general structure and stratigraphy of the area and indicate source rocks, reservoirs, cap rocks and hydrocarbon traps before giving a little more detail on some of the established exploration targets. The examples given mainly apply to the State of Qatar, Dubai and Sharjah (United Arab Emirates) and the Sultanate of Oman; and this simply reflects the limitations of my experience in the area and not the occurrence of oil fields and exploration targets. Indeed, Saudi Arabia and Abu Dhabi are perhaps the most prolific producing nations in the southern Gulf area. Figure 1 shows some of the better known and larger fields.

The development of the petroleum resources of the area typically commenced in the more central and western areas (both on- and offshore) especially in Bahrain, Saudi, Qatar and Abu Dhabi. In general sequences were often thinner and reservoirs shallower. Recent exploration targets have frequently been in the more easterly onshore areas, for example, in Sharjah and Oman where the sequences are thicker and tend to complicated by thrusting.

Stratigraphy and Structure

The Arabian Gulf has long been part of a major sedimentary basin. Between the late Carboniferous and the Miocene the southern Gulf

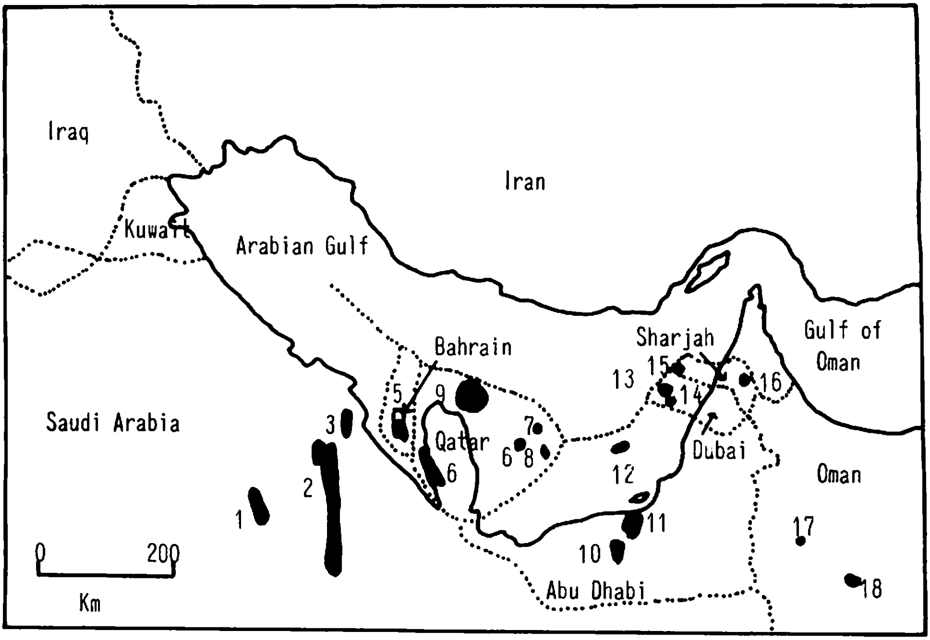


Figure 1. Map showing the distribution of some of the major oil fields in the Southern Arabian Gulf area.

Saudi Arabia:	1 = Khurais 2 = Ghawar 3 = Abqaiq	Abu Dhabi:	10 = Bu Hasa 11 = Bab 12 = Zakum
Bahrain:	4 = Awali	Dubai:	13 = Fateh 14 = Rashid
Qatar:	5 = Dukhan 6 = Idd el Shargi 7 = Maydan Mazam 8 = Bul Hanine 9 = Northwest Dome (gas)	Sharjah:	15 = Mubarrak 16 = Sajaa (gas/condensate)
		Oman:	17 = Shams (gas/condensate) 18 = Fahud

area was situated on a relatively stable shelf, bordered on the southwest by the Precambrian Arabian Shield and the open Tethys ocean to the northeast (Figure 2). Sedimentation was dominated by shallow-water carbonate environments though towards the west there was some clastic influx early in the period. Intra-shelf basins formed at times giving rise to greater thicknesses of clastic sediments.

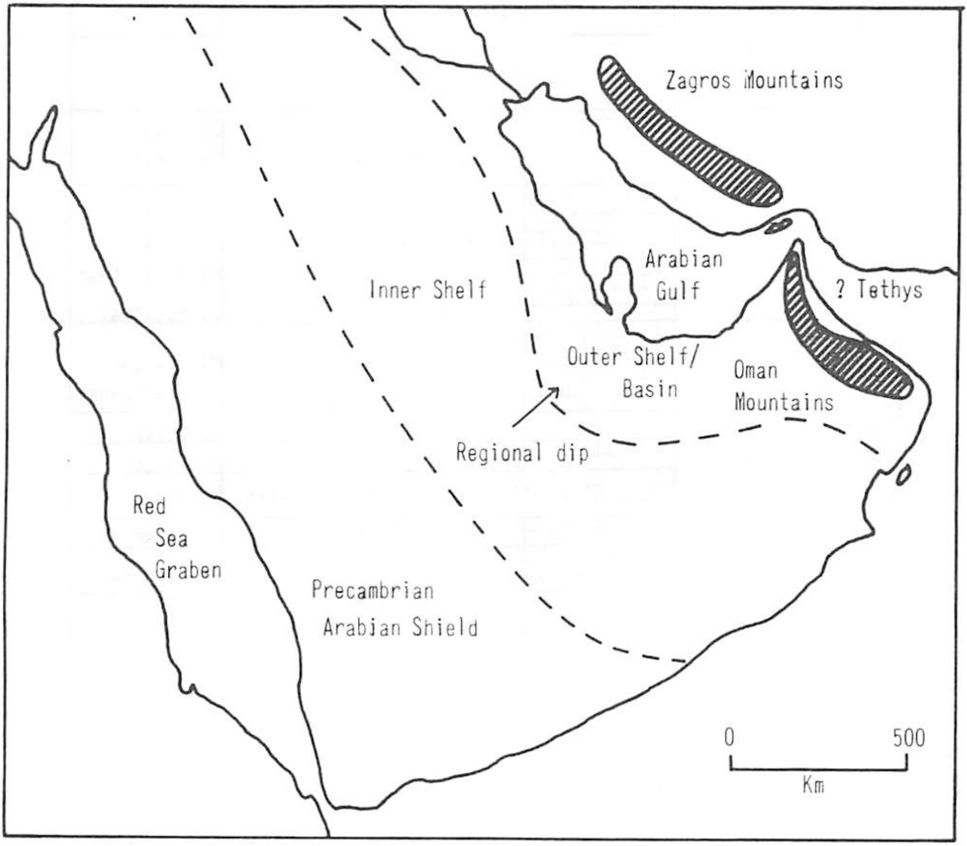
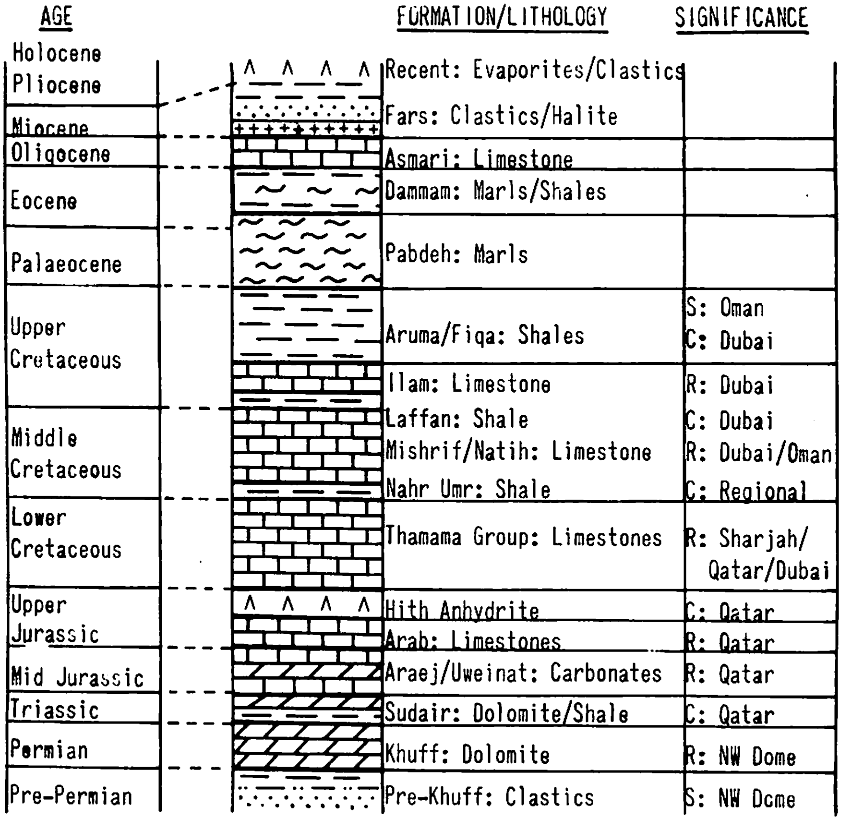


Figure 2. Generalised structural regions of Arabian Peninsula.

Figure 3 illustrates a very generalised stratigraphical column indicating which formations comprise source rocks, reservoirs and caps.



KEY: S = Source; R = Reservoir; C = Cap/Seal.

Figure 3. Generalised stratigraphy of southern Arabian Gulf.

Source Rocks: generally organic argillaceous sedimentary deposited in relatively 'starved' basins. Such horizons are not of exceptional thickness or richness and include the Khatiyah in Dubai and the Fiqa in Oman.

Reservoir Rocks: predominantly well-winnowed oolites although chalky limestones sometimes have suitable porosities. Perhaps the area is most well known for its unique development of the aberrant Rudistid Bivalve reef reservoirs. Limestone reservoirs are particularly prone to diagenetic processes and these may either increase or reduce porosity and permeability. In some areas porosity is also increased by fracturing that occurred during folding in the Zagros orogeny.

Cap Rocks: evaporites and shales are most common. Particularly good examples are the Hith Anhydrite and the Nahr Umr Shale. Neither are particularly thick, but they have a wide areal extent and they thus considerably restrict the upward movement of oil and gas. Thus hydrocarbon traps are not necessarily major structures.

Hydrocarbon Traps: traditionally traps are divided into anticlinal, fault-bounded and stratigraphical. Folding and faulting in the southern Gulf area has mainly been due to the uprise of Cambrian salt plugs (halokinesis) at the end of the Middle Cretaceous and in the late Miocene (either piercing the strata or forming relatively gentle folds) and during major mountain building (Zagros orogeny) in the Upper Cretaceous. This also continued in the Tertiary and included the thrusting of the Semail Ophiolite onto the shelf from the northeast and the subsequent growth of the Oman Mountains. However, the general regional alternation of limestones and argillaceous/evaporite facies indicates that stratigraphic traps can be important. Much of the current exploration effort is directed at locating these.

Exploration Targets: Stratigraphic Traps

1) A major regional target is the Lower Cretaceous Thamama Group Limestones. Excellent reservoirs are frequently found in the porous high-energy limestones (often oolitic) which alternate with lower energy, more 'dirty' carbonate mud facies as a result of minor local transgressions and regressions. Detailed sedimentological modelling, coupled with inter-well correlation allows the prediction of suitable prospects. Similar energy level variations in areas of shallow-water

carbonate deposition has produced similar prospects in the Upper Cretaceous Ilam Limestone.

2) During the Middle Cretaceous the progradation of the Rudistid (Mishrif) reefs over organic-rich shales (Khatiyah) at the intra-shelf basin margins provides a good example of suitable reservoir rocks directly overlying potential source rocks. The reef and fore-reef areas are typified by high energy levels and 'clean' bioclastic limestones, and the back-reef area by 'dirty' low-energy lagoonal limestones. Even within the latter facies porous patch-reefs developed producing yet another reservoir-cap combination (Figure 4).

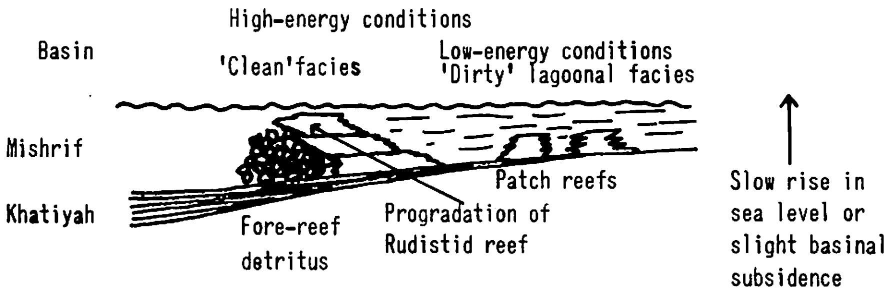


Figure 4. Middle Cretaceous reef development.

3) Uplift and erosion at the end of the Middle Cretaceous caused some faulting and the formation of structural 'highs' and 'lows'. This sometimes resulted in the re-working of Rudistid reefs on the 'highs' and their redeposition in the 'lows'. These detrital lenses provide an additional potential reservoir but their accurate location can be somewhat problematical.

In summary, the outstanding feature of the southern Gulf area is in the horizontal scale of the basin coupled with the uniformity and persistence of the major lithological units. The vertical dimensions of the basin are by no means extraordinary. Most folding is gentle and thus the effectiveness of cap rocks is not impaired by major fracturing.

Reservoirs are characterised by zones of good porosity and permeability in areally extensive limestones. Significant long-distance hydrocarbon migration is often feasible and even relatively poor traps/structures can hold major accumulations of oil and gas.

For anyone with an interest in geology visiting the Gulf area, there is not a lot on offer outside the realm of petroleum geology. Unfortunately, outcrop geology is often somewhat limited by the preponderance of aeolian desert sands, although quite a few areas do have some foraminiferal limestone outcrops containing huge Nummulites! However, even a short excursion into the desert can give opportunities to look at different dune formations and their migration; 'desert roses', silicified wood and dreikanters can be locally abundant and add to the interest. Perhaps the area is better known as being the 'type-locality' of sabkha formation. Thus some of the Gulf coastal flats with their recent evaporites and carbonates are well worth a visit and can give a valuable insight to this fascinating sedimentological process. The Semail Ophiolite is very well exposed in the mountainous parts of the Eastern U.A.E. States and Oman. Here the hard-rock geologist will find much of interest in the mantle sequence of layered cumulate rocks and the sub-ophiolitic metamorphics formed during obduction of the oceanic nappe into the Arabian continental margin. The mountain regions also reveal some other striking structural features. For example, the elongated 'whale-back' anticline of the Jebel Akhdar deserves to be in any textbook and can even be seen from a 'jumbo-jet' at 30,000 feet!

EDINBURGH GEOLOGICAL SOCIETY LONG EXCURSION TO BALMACARA – MAY 1984

Margaret M. Rusbridge

We left Edinburgh in bright sunshine, which gave way to showers as we travelled north-westwards. Our cottages for the week were situated on a grassy shelf just above the high-water mark. After the week's rations had been distributed we were able to venture out onto the patio to admire the views towards Glenelg, Sleat and the distant Cuillins, and to be greeted enthusiastically by the midges, who were already thriving after 6 weeks of warm, dry weather. Minor deficiencies in the kitchen equipment provided soon became apparent as the first meal was prepared – the occupants of one cottage, with the help of a large screwdriver found in a cupboard, had to remove the handles of a large saucepan to improvise for a roasting tin/casserole.

After everyone had settled in and partaken of the first gargantuan meal Dr. Frank May gave a stimulating introduction to the geology of the area. This was followed by what must have appeared to any still hungry midges waiting outside to be a micro version of the 'summer sales'. Sweat shirts, one of the items introduced to commemorate the Society's 150th anniversary, were produced, tried on and bought by many members of the party.

Sunday dawned dry and bright and it was decided to start the excursion by walking across the beach to the Balmacara Thrust, which brings Lewisian mylonite on to strongly deformed and inverted Torridonian sandstone of the Diabaig group. The buses were then taken to Loch Iain Oig and the party walked up the hill between the two lochans, looking at the spectacular dewatering and other sedimentary structures in the inverted Torridonian. After lunch in sunshine on the top of the hill the party dropped down to a roadside quarry to examine a small sill. The last locality of the day was to the escarpment of Carn a Bhealaich Mhoir, above Plockton. Here, increasingly deformed and mylonitised Torridonian was studied as we climbed up to the inverted Torridonian-Lewisian unconformity. The base (stratigraphically) of the Torridonian was marked by a strongly deformed conglomerate. Many of the party climbed to the top and were rewarded with excellent views along Lochs Carron and Kishorn. The accessibility of the locality is being made difficult by a Forestry Commission plantation.

In the evening the majority of the party went to examine a new road-cutting where actinolite crystals more than 20cms long could be seen. Some even remained after the party had left!

Monday morning was cloudy and the party headed for Skye and the Sleat Peninsula. The morning was spent looking at sedimentary structures in the undeformed Torridonian (Sleat Group) on the NE shore of Loch na Dal. A few members decided to forego lunch and continued along the section until they reached the Epidotic Grits. After lunch the party continued to Ord; en route a stop was made at Loch Meodal to locate the Moine Thrust. At Ord we first went to the south side of the bay where an inverted succession of Torridonian overlying Cambrian Quartzite could be seen. On the north side of the bay, below the thrust, 3 groups of the Durness Limestone, the Fucoid beds, Pipe Rock and basal quartzite were examined on the shore. Some of the limestone is pitted by bores, probably made by the bivalve *itiatella arctica*. Of great interest is the fact that the bores can be traced to about 3 metres above high water mark, suggesting they were formed when sea-level was higher than it is today.

Tuesday was cloudy and the party set out for Glen Shiel. The first stop was the road cutting near Kintail Lodge Hotel, where a search was made for molybdenite. The next locality was about 1 mile east of the site of the Battle of Glenshiel, where Dr. Doug Peacock demonstrated the Sgurr Beag Slide, which separates two major divisions of the Moine – the Morar to the west and the Glenfinnan to the east. Thin slivers of Lewisian have been caught up in the sliding and we spent some time looking at one such sliver in a stream section to the north of the road. Localised concentrations of garnet sand in the River Shiel also caused a certain amount of interest. We then moved another mile up the glen, and after lunch spent most of the afternoon looking at structures in the Moine to the south of the road. The degree of metamorphism is such that sedimentary structures are not preserved, but spectacular refolded folds were much in evidence, and the relationship of the cleavage to the different ages of folding was also studied. Towards the end of the afternoon the party moved further east to the northern shore of Loch Cluanie, where more exposures of the Moine were studied. Here the degree of metamorphism is such that sedimentary structures are preserved, and even refolded cross-bedding was relatively common, and much photographed.

This was also an eventful day for several members of the party. During the afternoon two of our number discovered that not all the bogs had dried up! One member, luckily finding solid ground beneath his feet after he had sunk to below knee level, could not extricate himself and needed the assistance of four other members of the party. An hour of so later, a small 'splinter group', trying to expend some excess energy (there were no 'hard' and 'sedate' subdivisions this year) walked a little way up the ridge and there discovered a packed rucksack, tent and sleeping bag in an extremely wet and muddy condition. Examination of the area only revealed the tattered remnants of a German book. It was obvious that they had been there for several months and the group decided to carry them down and inform the police. Further investigation at the cottages revealed the passport of a nineteen year old German boy, together with cash, travellers cheques and other documents. Telephone calls to the local police were not successful until the following morning, after which the local constable came to remove the items, promising to let us know the outcome. Speculations on how anybody could become separated from all their gear, including passport and money, was rife, but we were glad to hear that the items had been reported missing the previous summer, and that the owner was alive and well. We hope he will communicate with the finders and let them know the circumstances.

Wednesday dawned bright and sunny, and even the weather forecast was good! This was just what we had been awaiting for the visit to Applecross. After the 'interesting' drive up from Kishorn the party stopped at the viewpoint on the Bealach na Ba – to be asked by a passing American tourist where he was! The party walked slowly to the top of Meall Gorm (710m) looking at structures in the Foreland Torridonian en route, and also finding a lone Tertiary dyke. After lunch the party continued towards Applecross where two stream sections in the Trias and fossiliferous Broadford beds (Jurassic) were to be studied. The temptations of tea, ice creams or a swim were so overwhelming that some members of the party foresook the second section and headed directly for the village. The local store did a roaring trade and stayed open for an extra half hour.

A small get together was held in the evening to celebrate in retrospect the 80th birthday of Alex Mackie (actually in February 1984). An iced birthday cake was produced, complete with candles – not eighty but two, an '8' and '0', which incidentally were purchased in the Applecross store! Alex expressed his thanks and commented that he was glad we had got the date right at last as an 80th birthday card had been sent to him last year! Before Alex's party several members had been very industrious gathering driftwood on the beach, and the pyromaniacal tendencies of some members were in evidence; only one match was used as had been promised! After the party everyone was invited to partake of incinerated sausages and coffee by the bonfire. The festivities led to one or two members being confused about whether the patio doors were open or closed, with consequent side effects (not too serious, thank goodness).

As Thursday didn't look, or sound, very promising weatherwise, an attempted climb of the Five Sisters was cancelled and the entire party went to Skye again. The first short (!) stop was at Tarskavaig, and luckily we all carried our lunch with us. The party looked at the numerous dykes cutting the Torridonian of the Kishorn Nappe. After lunch a small group departed to look at a remnant of ancient woodland at Dalavil – it was rumoured they couldn't face the ride back to the main road! The rest of the party continued along the beach for a short distance, and spent some time looking at a large multiple dyke with gabbro xenoliths and the Tarskavaig Thrust plane, which brings Moine rocks over the Torridonian.

There was just time to get to Aird of Sleat to see one of the few exposures of the Moine Thrust, where sheared Lewisian is thrust over Moine rocks of the Tarskavaig Nappe at Port a'chuil. More members of "arsonists anonymous" were busy on the beach again that night.

Friday – the last day in the field and it didn't look very promising. The party split into three – one group, not to be deterred by the weather, did part of the South Cluanie ridge, another went to the Falls of Glomach, and a third (reputed to be the 'sedate' party) tackled the geology and very steep grassy slopes above Carr Brae to the east of Loch Duich. This was easily the most energetic day of the week. The weather produced the first rain of the week – a few very short rain showers which were reported to be of snow by the climbers. Geologically, the purpose of the day was to study the Eastern Lewisian of the Glenelg inlier, and the unconformity between the Moine and the Lewisian. The Eastern Lewisian includes a variety of rock types, including metasediments such as marbles with large diopside nodules and eulysite (an iron rich rock containing hedenbergite and grunerite), large concentrations of magnetite which caused a complete reversal of the compass, and metamorphosed basic rocks – eclogites showing retrogression to amphibolites, as well as hornblende biotite gneiss, garnet biotite gneiss and quartzo-feldspathic gneiss. The party looked at the great variety of rocks and variations within them. The Moine and hornblendic gneisses of the Lewisian weather in very characteristic fashion so that the unconformity which the party followed for about 1km was easy to pick out, although it was not so easy to believe that you were right as it seemed impossible that an unconformity could become so contorted.

The excursion finished with the usual gathering: this year we were the guests of Fred Brownlee and his family, who reside in Dornie. The festivities included the presentation of the 'Strontian Hammer' – this year to David McAdam for suggesting that a "two Friday week" should be introduced so that the energetic could participate in all the geology as well as climbing nearby hills!

STRANGE EARTH No. 1

Bill Baird

Glacier surges, also known as exceptional or catastrophic advances, galloping glaciers, or pulsatory glaciers, have been observed in many parts of the world. Although hundreds of glaciers are known to surge, and several have been studied at the height of their activity by glaciologists, there is still insufficient data available to allow a precise definition or description of glacial surges. Most descriptions of surging glaciers mention or imply a sudden advance which does not seem to be related to a variation in climate or any other obvious causes.

The Black Rapids glacier in central Alaska ran amuck in the autumn of 1936 and gained the attention of the World's press. The 12.5 mile long valley glacier had been retreating slowly for many years prior to 1936 and its terminus was a few miles from the Rapids Roadhouse on the Richardson Highway. Then in November it began to surge and by December its 300 foot high mile wide front could be seen from the roadhouse. Within two months the glacier was threatening not only the roadhouse but the Richardson Highway itself. The *New York Times* ran a headline saying "Black Rapids Glacier sets a speed record" in a front page story of 23rd February 1937. By March 7th 1937 the tremendous surge of the Black Rapids Glacier, four miles in three months, had brought the ice to within a mile and a half of the roadhouse and the highway. Then the glacier simply ground to a halt and began slowly to retreat once again, leaving scientists at a loss to explain the forces which had set it in motion.

General comment on surging glaciers is available in *Glacier, 1982* by Ronald H. Bailey. This is one of the Time-Life series of books under a general heading *Planet Earth*. More detailed information can be gained from the *Canadian Journal of Earth Sciences,* Vol. 6, 1969, Pt. 2, Surging Glacier Conference Issue, pp. i-iii & 807-1009.

RECENT VOLCANIC AND HYDROTHERMAL ACTIVITY AROUND ROTORUA, NORTH ISLAND, NEW ZEALAND

Angela E. Anderson
British Geological Survey

Regional setting

A zone of Quaternary volcanism extends through North Island, New Zealand for about 160 miles in a northeasterly direction, from Mt. Ruapehu in the south to White Island in the Bay of Plenty. It continues out to sea for another 600 miles along the Kermadec ridge to Raoul Island, forming an island arc. Present day volcanic and hydrothermal activity in New Zealand is mainly confined to this zone. Over the central part of the landward portion, the zone reaches a maximum of 25 miles in width but tapers southwards to less than 10 miles. (Figure 1) This part of the zone is known as the Taupo Volcanic zone and takes the form of a linear depression controlled by northeast trending faults, bounded to the east and west by Mesozoic basement rock and extensive ignimbrite plateaux. Within the zone are a number of major rhyolitic centres e.g. Rotorua caldera. Andesitic volcanism is concentrated at the ends of the zone i.e. White Island and the Tongariro group. To the east ranges composed of Mesozoic greywacke and argillite are separated from the ignimbrite plateau by a series of steep, west facing fault scarps. It has been estimated that nearly 4000 cu. metres of mainly rhyolite with lesser amounts of andesite and basalt have been erupted from vents within the zone since the Pliocene. The volcanically derived material fills the linear trough to a depth of over 12,000 ft. (Figure 2)

Numerous hot springs are associated with the rhyolite and andesite centres in the Taupo Volcanic zone. The hydrothermal activity is of economic importance both as a major tourist attraction and as a source of geothermal energy. The main areas of hydrothermal activity in the form of hot springs, geysers, steaming ground and fumaroles are around Rotorua and Wairakei. At the latter, geothermal steam is used to generate electricity and a 150 MW station supplies up to 20% of the

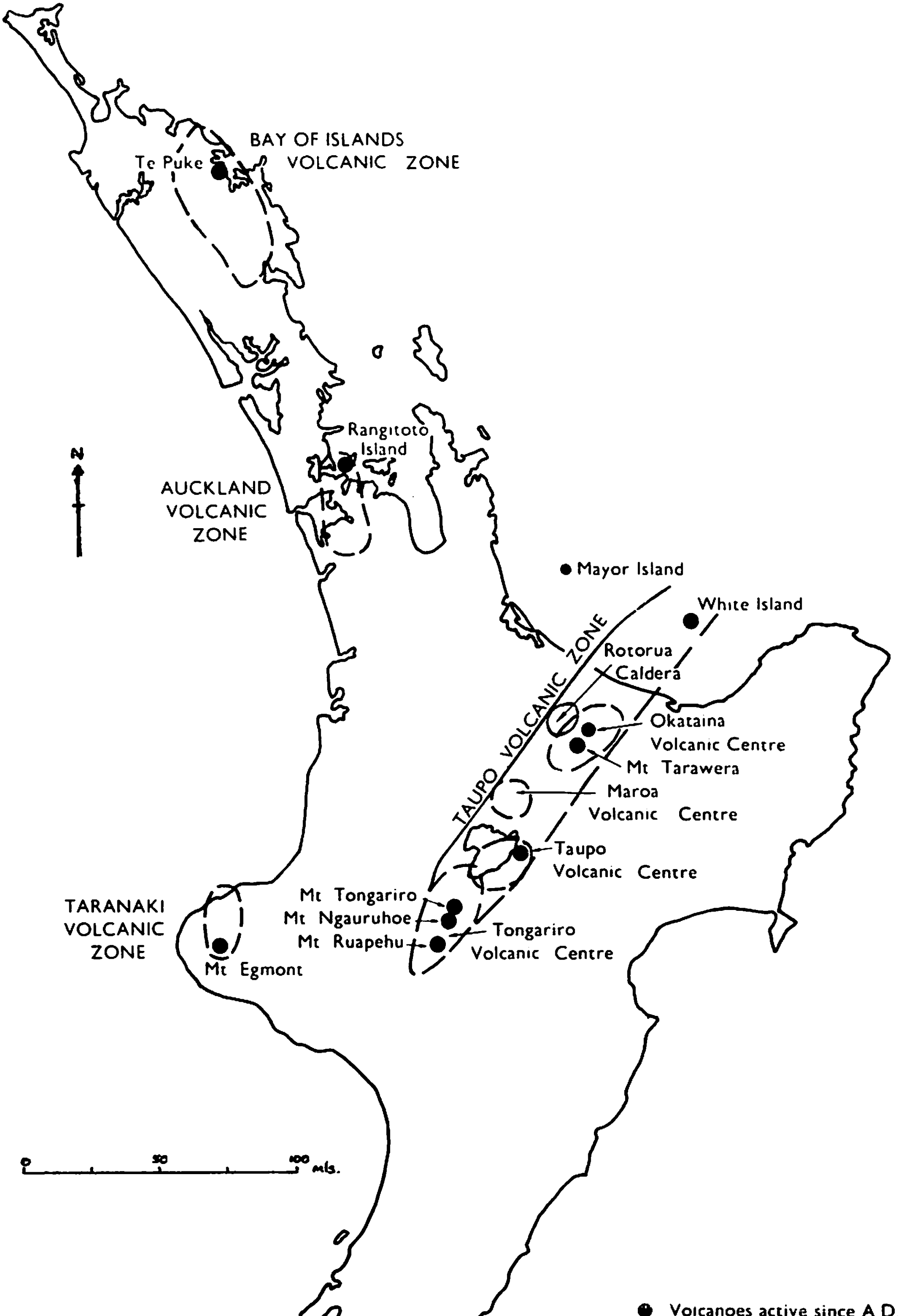
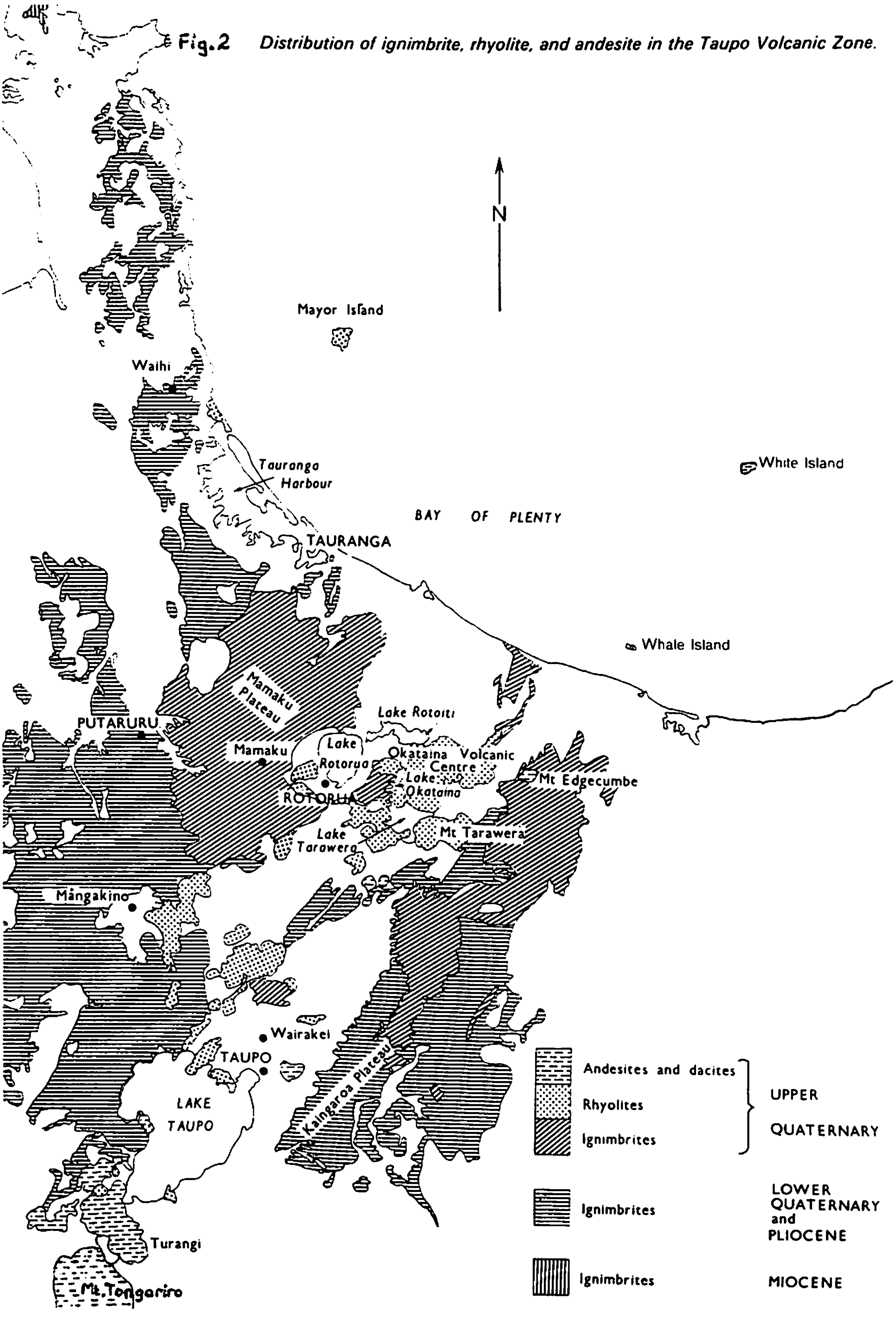


Fig. 1

Upper Quaternary volcanic zones in the North Island of New Zealand.

Fig. 2 *Distribution of ignimbrite, rhyolite, and andesite in the Taupo Volcanic Zone.*



power requirements of North Island. Many homes in the Rotorua area are heated by natural hot water and/or steam.

The chemistry of the waters can be divided into two broad groups: a) near neutral with sodium and potassium chlorides as major constituents and b) acid with sulphates dominant. Deep drilling indicates that both types of water are derived from near neutral chloride water at depth, and, on isotopic evidence, the bulk of the water is thought to be meteoric in origin. In addition to sodium and potassium chlorides, the waters contain appreciable amounts of silica and boron and small amounts of lithium, rubidium, caesium, calcium, magnesium, arsenic, antimony, fluorine, bromine, iodine and sulphate. Ignimbrites, rhyolites and volcanic sediments are hydrothermally altered with the introduction of silica and potassium in the form of potash feldspar. Pyrite, sphalerite and galena are also deposited in fissures in some areas and siliceous sinter may contain localised concentrations of gold, silver, arsenic, antimony, mercury and thallium.

Rotorua (Figure 3)

The Rotorua caldera in its present form dates back only 140,000 yrs BP., to the major ignimbrite eruptions forming the Mamaku plateau. A large volume of rhyolitic magma rose under Rotorua to form a shallow chamber or reservoir. Initially eruptions were small producing steep-sided domes and pumice beds. The size of the eruptions increased as more gas escaped from the magma and culminated in large scale explosive eruptions which poured 200 cu. km. of ash and pumice into the atmosphere and discharged large volumes of lava and ignimbrite which flowed outwards in a large fan burying the pre-existing topography and forming the gently sloping plateaux to the north and west of Rotorua.

Withdrawal of these large volumes of material from the magma chamber weakened the roof, and its collapse along arcuate fissures, shortly after the main eruptions, produced a 15km wide depression similar in size, but deeper than the modern Rotorua caldera. (Figure 4)

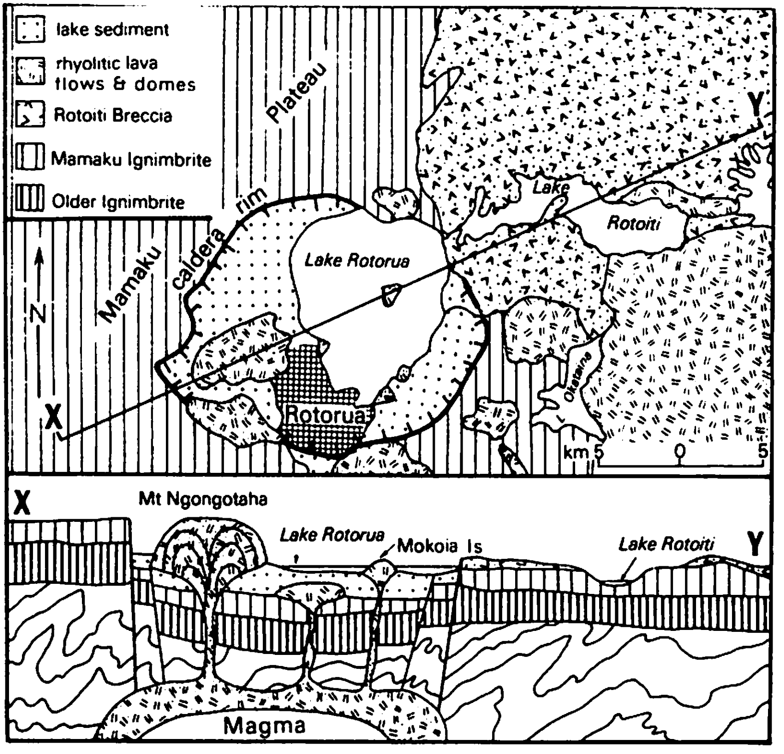


Fig. 3. Map showing geology of Rotorua Basin or Caldera and a simplified cross-section along XY. Hatched heavy line is caldera rim.

Mamaku Ignimbrite is the welded ignimbrite which was erupted immediately prior to caldera collapse and Rotoiti Breccia is the unwelded ignimbrite erupted from Okataina Caldera 42 000 years ago, the youngest large ignimbrite in the district.

Eruptions continued in the caldera and extrusion of gas-poor lavas produced several small domes. Ash and pumice from the more explosive eruptions alternated with lake sediments in the now water filled caldera and by 20,000 yrs BP activity within the caldera seems to have died down, as most of the ash from that date appears to come from the neighbouring volcanoes of Tarawero and Haroharo. (Table 1) A lake formed in the Rotorua basin almost immediately after the formation of the caldera. Its modern outlet is to the northeast through the Ohau channel to Lake Rotoiti and thence to the Kaituna river but evidence suggests that this outlet was, in the past, dammed by ashfall

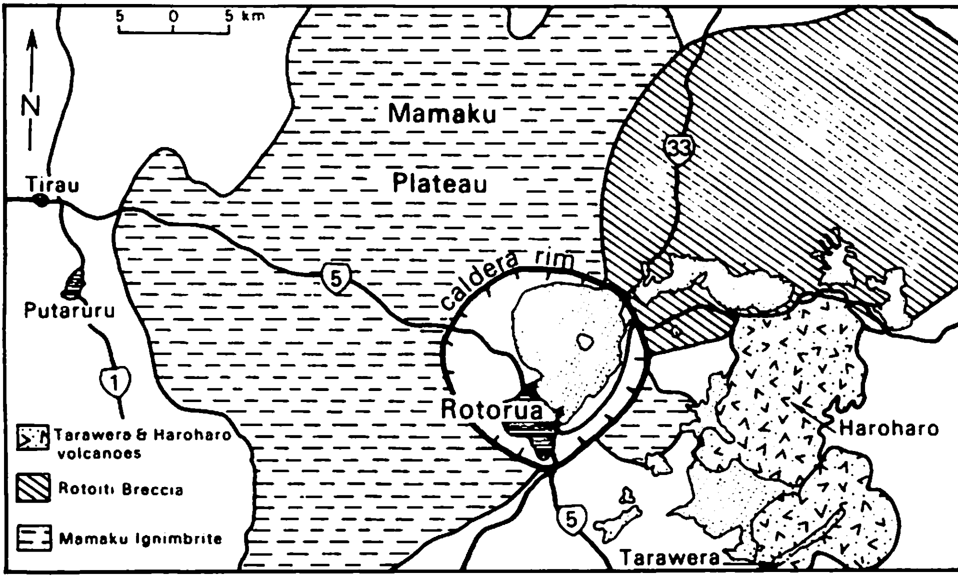


Fig. 4. Distribution of Mamaku Ignimbrite. This deposit forms a gigantic fan over at least 400 square kilometres centred on Rotorua Caldera. Its eruption is thought to have immediately preceded caldera collapse. To the east Mamaku Ignimbrite is buried under the younger Rotoiti Breccia ignimbrite erupted from Okataina Volcanic Centre. to the east

and breccia from the eruptions at Okataina to the east. The dam was not breached until 20,000 yrs BP when the water level fell steadily till around 17,000 yrs BP., standing then below its present level. Partial damming by ash has produced smaller fluctuations in the level since, and present-day changes are still caused by variations in rainfall and siltation rates in the Ohua channel. (Figure 5)

Hydrothermal activity occurs in several areas inside the Rotorua caldera, some of these within the city itself: e.g. Ohinemutu/Kuirau/ Government Gardens area at the north end and Whakarewarewa to the south. Figure 6 shows the extent of the Rotorua field. The shallow rocks are largely interbedded lake sediments and volcanic ash. Some of these rocks are nonporous and act as a barrier to the upward escape of hot water. Underlying the sediments is a rhyolite whose upper portion is

Table 1. History of Rotorua District.

Time — Years ago	*Rotorua Caldera*	*Okataina Caldera*
98		1886 Tarawera eruption
700–900		Kaharoa Ash, Tarawera
		Rotokawau Ash, Haroharo
5 000		Whakatane Ash, Haroharo
7 000	Lake level 13 m above present	Mamaku Ash, Haroharo
9 000	Lake level drops to equal present	Rotoma Ash, Haroharo
11 000		Waiohau Ash, Tarawera
13 000		Rotorua Lapilli
15 000		Rerewhakaaitu Ash, Tarawera
19 000		Okareka Ash, Tarawera
22 000	Lake level drops rapidly	Te Rere Ash, Haroharo
26 000		Mangaone Subgroup
36 000		Mangaone Subgroup
42 000	Rise of lake level Mt Ngongotaha extruded Caldera Collapse	Rotoiti Breccia
140 000	Mamaku Ignimbrite	
140 000		Younger Kaingaroa Ignimbrite
155 000		Older Kaingaroa Ignimbrite
260 000		Matahina Ignimbrite

sufficiently fractured to allow the free flow of water. A large body of superheated steam rises rapidly towards the surface under Whakarewarewa, up faultlines associated with the southern rim of the caldera. The temperature of the water at depth may be as much as 230°C. Under Whakarewarewa the water is still sufficiently hot to exist as a mixture of water and steam and approximately one third of it is discharged as hot springs and geysers. The remainder is diverted northwards and flows towards Lake Rotorua as a tongue of hot water trapped within the lower sediments and the rhyolite aquifer. This water is prevented from reaching the surface by impermeable beds above, but if these beds are penetrated by a well, water is discharged at the surface under its own pressure. Additional hot water rises along a fault at Ohinemutu to mingle with the outflow tongue. Drilling has proved that the main body of hot water extends under much of the inner city, and

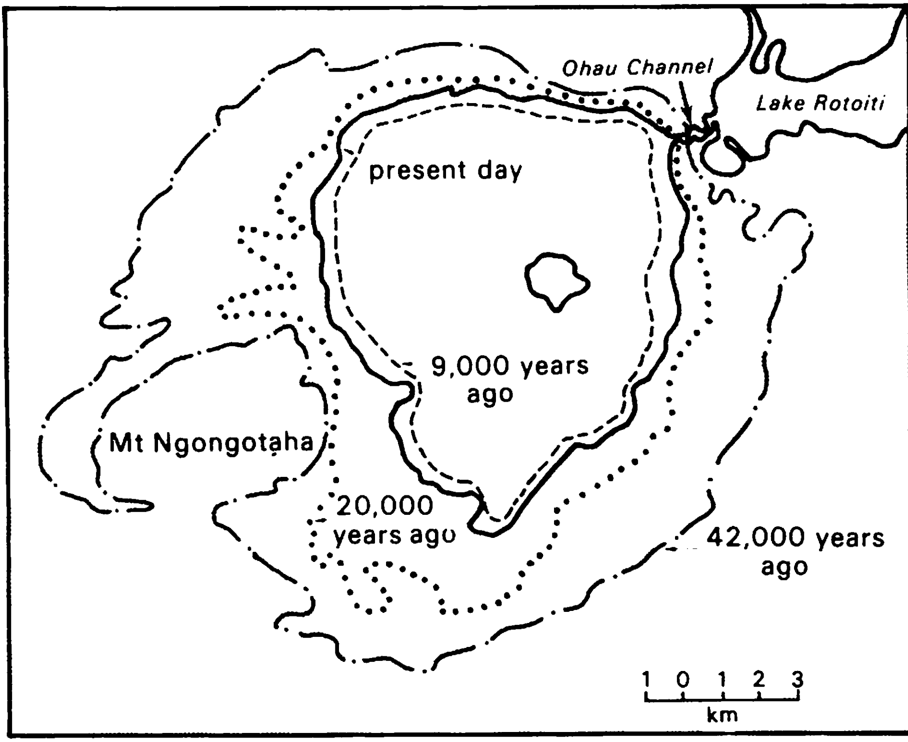


Fig. 5 Ancient shorelines of Lake Rotorua. From work of Kennedy, Pullar and Pain.

over 550 wells produce hot water to heat houses and commercial properties. Due to the corrosive nature of the sulphurous waters, they cannot be circulated directly through domestic plumbing systems. Instead, a heat exchanger system is used. In recent years concern about the depletion of the hydrothermal system from over-extraction has led to the use of thermostats and valves on many extraction pipes but there is still much concern about the rate at which the water table is dropping, thereby causing cessation of the more visual aspects of hydrothermal activity in the tourist park at Whakarewarewa. It is possible that many of the extraction pipes will have to be shut down until the balance is restored.

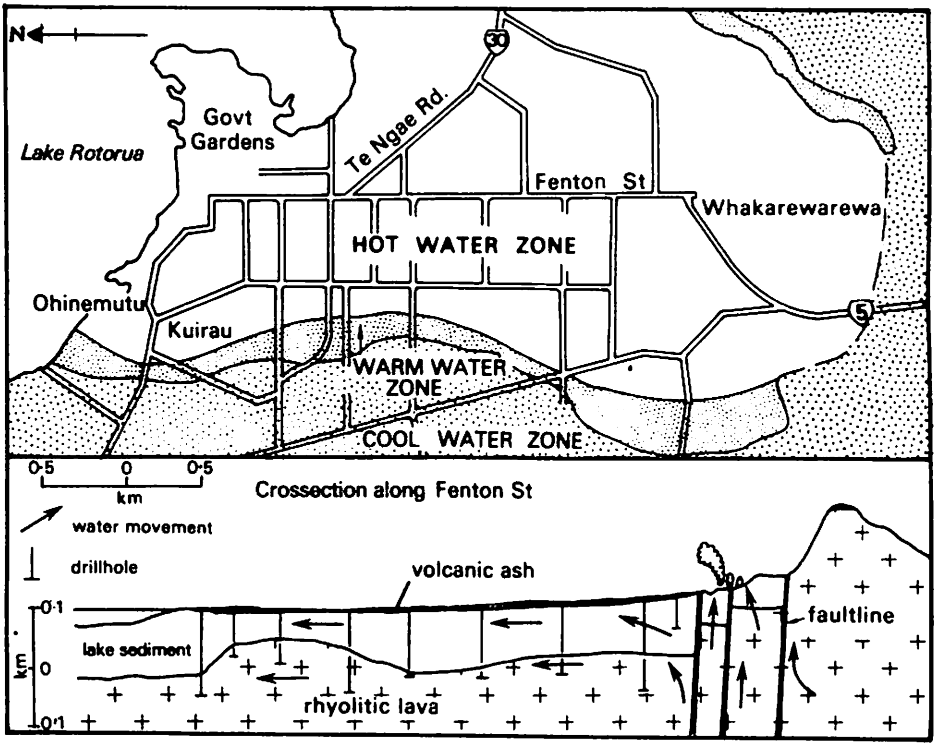


Fig. 6 Map showing distribution of hot and warm (fine stipple) water beneath Rotorua and geological and hydrological cross-sections along Fenton Street.

References

HOUGHTON, B.F. 1982 "Geyserland: A guide to the volcanoes and geothermal areas of Rotorua". *Geological Society of New Zealand Guidebook No. 4.*

SUGGATE, R.P.; STEVENS, G.R.; TE PUNGA, M.T. (Eds.) 1978. *"The geology of New Zealand"* 2 vols New Zealand Geological Survey.

The Society's Library

For a trial period of a session, the chief librarian of Edinburgh University has agreed to Council's request that the Society's library housed in the Grant Institute be open for an hour (i.e. 6.30 to 7.30 p.m.) before each meeting. This will enable Fellows to borrow books or consult the journals. In order to make the scheme more attractive, Council has agreed to the purchase of £200 worth of books with the possibility of further purchases on an annual basis should the venture prove to be popular. The first selection has already been made and these, along with a most generous donation of books from Scottish Academic Press, should be on the library shelves in time for the first opening on 24th October. These books will be held with the general book collection and in order to help members to find them, it is hoped to produce a list with their catalogue numbers. As new books are added, supplementary lists will be prepared from time to time and it is hoped also to be able to display new acquisitions after meetings.

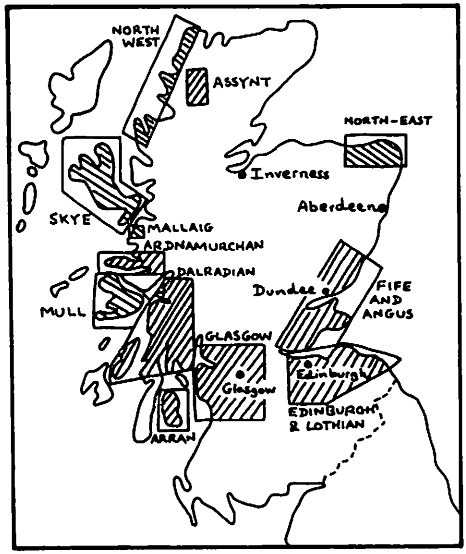
It is perhaps worth outlining the rights of Fellows with respect to the University libraries. When the Society's collections were handed over on permanent loan, it was agreed that Fellows should have the same rights as the University Staff. This means that all the libraries may be used including the main library in George Square. Before each library will allow borrowing, registration is necessary which, in the case of Fellows, requires proof of membership. A note to this effect may be obtained from the Membership Secretary or myself and this will be provided to anyone on request. It will not be needed however for the geology library as the librarian will be provided with an up to date list of members.

The Society's books (all clearly marked on the bookplates) may be borrowed for the whole period between meetings. Other books may also be borrowed but these could be requested to be returned before the next meeting. Thus before taking out University books, Fellows should keep this in mind and be aware of the normal opening hours namely 9 a.m. – 5 p.m. Monday – Friday. Journals are only available for overnight borrowing. I am therefore offering to provide a xeroxing service to help offset the difficulties caused by these restrictions. In following University policy I will be able to copy limited amounts from books and journals provided members sign a short declaration and pay for the copying before the work is carried out.

Council very much hopes that increase use of the library will be made as a result of the new opening hours and that the scheme will be seen by the University to be successful. It is hoped that members will feel free to send in suggestions for further purchases and that occasionally gifts or books, maps or journals will be presented to the Society by individuals.

W.B. Heptonstall
Librarian.

GEOLOGICAL EXCURSION GUIDES



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Dalradian Guide	£4.00	Murchison House, Edinburgh EH9 3LA
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Glasgow Guide	£2.50	c/o Geology Department
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North-east Scotland (No 31)	60p	Piccadilly
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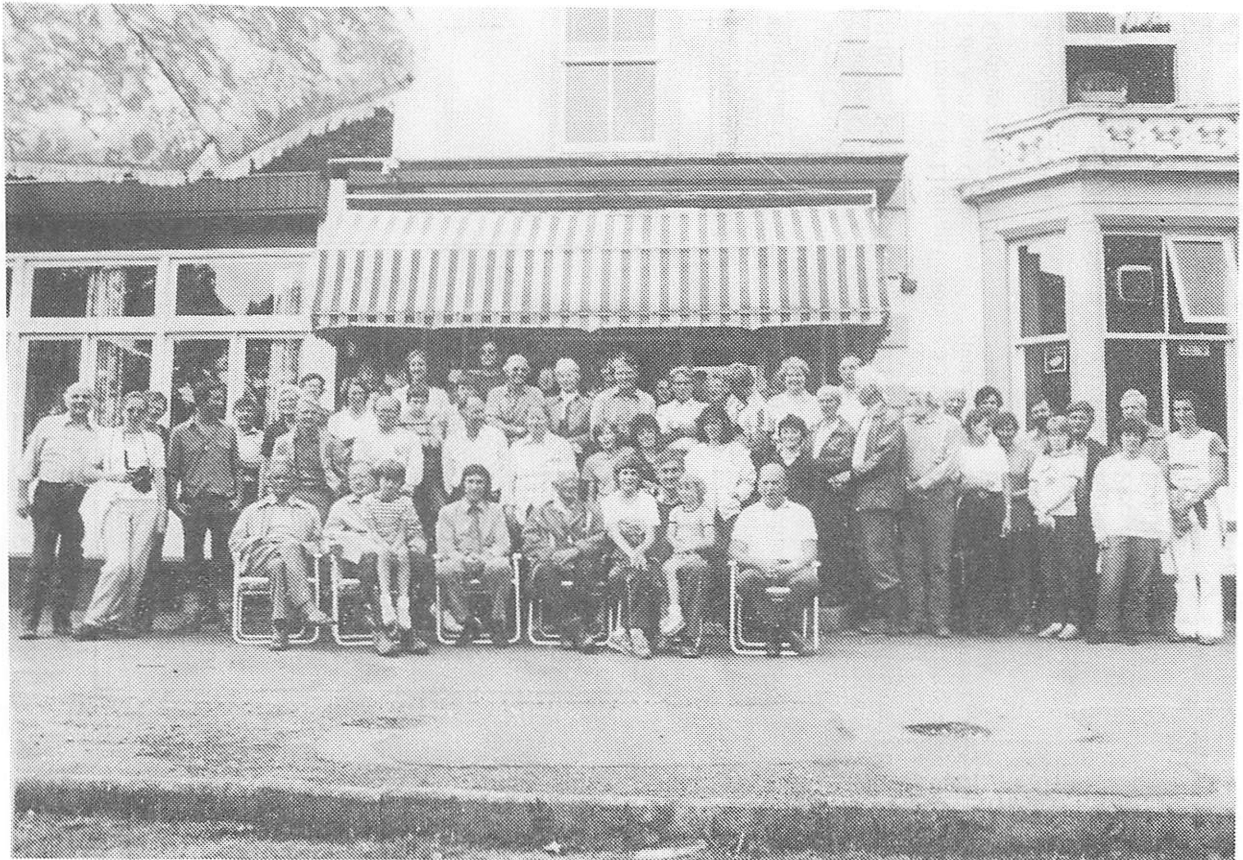
Mallaig (No 35)	60p	

All guides (except Geology of Scotland) can be obtained through the Edinburgh Geological Society. Postage is extra. Members receive discount on most guides.



Participants on the joint Edinburgh-Glasgow field excursion to Burntisland and Aberdour on June 16th 1984.
Photograph by Tim Anderson

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CONTENTS

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