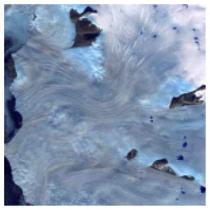
Geochemical News #131 - April 2007


Glacier flow to the western c...

In This Issue

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From the GS President (#131)

Prof. Susan L. Brantley

Last summer, approximately 1250 participants attended the Melbourne Goldschmidt conference. As of May 1, the organizers of the Cologne Goldschmidt conference have received approximately 2400 abstracts! In general, the Goldschmidt conferences in Europe are larger than the conferences held in North America, but these meetings have been growing on both sides of the Atlantic.

The conferences are organized by the Geochemical Society when they are in North America and by the European Association of Geochemistry when they are in Europe. The two societies have occasionally decided to run meetings outside of the North America-Europe rotation (e.g. Japan and Australia), but we have no current plans to do this in the foreseeable future.

Currently, we are seeking draft proposals to host the 2010 and 2012 conferences in North America. If you have ever run a large meeting, you know that reserving conference and hotel facilities well in advance in North America is a requirement. I am writing this letter to encourage geochemists to consider hosting a conference. We have one absolutely excellent proposal for 2010 but for backup purposes we would love to have at least one more. A group that proposes for 2010 but does not host the meeting in 2010 might become the winner to host the 2012 conference.

Of course, our meetings have become very large and this represents a significant responsibility and privilege for organizers. Seth Davis, our business manager for the GS, is now in charge of helping to coordinate with the conference organizers. We also have accumulated significant experience in terms of running these meetings. For example, most recently, Scott Wood (Univ of Idaho) and Mike Hochella (Virginia Tech) ran meetings and can be emailed for advice. Information about running Goldschmidt meetings is contained in the Goldschmidt Organizer's Handbook. The GS has also discussed and will continue discussing whether it is a good idea to retain a professional conference organizer to facilitate these meetings.

The EAG is discussing whether the Goldschmidt in Europe should always return to Davos Switzerland (the proposed site for 2009). Obviously, returning to a site every year would make organizational tasks easier. The GS will also be discussing such a possibility as well, and I solicit GS member opinions on this idea. Would you like to see the Goldschmidt meeting held in the same place every other year in North America? If so, where would you like it to be held?

On other topics, I would like to mention that we have changed our procedure for choosing the Vice President and other officers of the society. We are currently seeking nominations for these positions and you should have received an email requesting your participation in our new procedure. We hope this will open up the society to new participants and new voices.

On a personal note, I would also like to express my personal condolences and support to my geochemical and geological colleagues at Virginia Tech after the horrifying events this past month. I am sure that the entire membership of the GS have been thinking of our colleagues as they heal from the trauma inflicted upon their campus.

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The Life and Times of Lawrence Wager

Lawrence Wager - "Bill" to his friends - was by any measure one of the most important geologists of his time. His discovery and studies of the Skaergaard Intrusion of East Greenland were a landmark contribution to igneous petrology, and his work, together with that of his students and colleagues contributed to some of the most basic concepts of magmatic differentiation.
- Alexander R. McBirney, University of Oregon

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Introduction

Panorama of the east side of Kangerdlugssuaq

In May 1965, I decided to do my Part II thesis in chemistry at Oxford in the Geology Department. My tutor (L.E. Sutton) arranged for me to meet Malcolm Brown to discuss my thesis topic. When we had finished, he took me to see the professor to confirm the arrangements. I was introduced to a short man (5 ft 4 1/2 ins) with receding white hair who looked older than his 61 years (at least by today's standards) but with a very erect posture and an athletic frame. When we shook hands, he squeezed my hand in a powerful grip. I knew immediately that I had met Somebody. As we left, I asked Malcolm Brown whom that was. 'That was Professor Wager. He was highest up Everest before the war.'

Lawrence Rickard Wager was born in Batley in West Yorkshire in 1904 and his younger brother, Hal, in Hebden Bridge in 1906 (Hargreaves 1991). In 1905, his father became headmaster of Hebden Bridge Secondary School where he stayed until 1926. From the early days, his parents rented a cottage at Arncliffe in Littondale in the Yorkshire Dales and the two boys lived for the 14 weeks of holiday each year at Arncliffe. There, they were free to wander as they pleased and made most of this freedom. From an early age, Lawrence searched out fossils and minerals from the local lead mines and later became interested in the Carboniferous Limestone of Littondale. Hal, on the other hand, was more interested in plants and algae. There is no doubt that this freedom to roam in some of the most beautiful scenery in Britain had a profound influence on the boys.

Lawrence attended his father's school from 1914 until 1919. However, in 1916 his mother died of pernicious anaemia, casting a dark shadow over family life. His father became run down by the war and his wife's death and, in 1919, was granted leave of absence for one year to take the boys to Trinidad. The highlight of the year was a two-day expedition to Tucutche, the highest mountain in Trinidad (3,012 ft), to collect rare ferns for Kew.

On their return, Lawrence went into the sixth form at Leeds Grammar School from 1920 to 1922. During this time, he stayed with his uncle, Harold Wager, who was a chief inspector of schools, a botanist and a Fellow of the Royal Society (Seward 1930). Harold Wager had a great love of nature and it is hardly surprising that he had a great impact on a maturing schoolboy with a scientific bent (Deer 1967).

In 1922, Lawrence obtained his Higher School Certificate in Applied Mathematics, Physics and Chemistry with distinctions in Applied Mathematics and Chemistry and was awarded an Exhibition in Science by Pembroke College, Cambridge (Hargreaves 1991). He went up to Cambridge to read geology at a time when geology at Cambridge was very strong. J.E. Marr was Woodwardian Professor, Alfred Harker Reader in Petrology and Gertrude Ellis and C.E. Tilley members of the teaching staff (Deer 1968). Wager always felt it was Harker to whom he owed his real awakening to the science of petrology (Anon 1965).

In 1926, Wager obtained a First in Geology in Part II of the Natural Science Tripos. As an undergraduate, Wager joined many societies and rowed for his college 4th eight in the Lent term of 1924. However, his main interest at Cambridge was always the Cambridge University Mountaineering Club (CUMC) of which he became Treasurer in 1924-25 and President in 1925-26. The meets in the vacations became an integral part of his life (Hargreaves 1991). Wager's brother Hal followed him up to Cambridge and subsequently obtained his Ph.D. in botany there.

Following his success in Finals, Wager was awarded a Goldsmiths' Company Research Studentship which he used to work on metasomatism in the Whin Sill and on the joint pattern tectonics of the Great Scar Limestone of the Craven highlands of West Yorkshire. This work is described in some detail by Deer (1967). During this time, he took up Morris Dancing and became a member of the Cambridge Morris Men in 1928. It was here that he acquired the name Bill by which he became known by his close friends and colleagues for the rest of his life. In 1929, Wager was appointed to a lectureship in Mineralogy and Petrology at Reading University under Professor H.L. Hawkins who did much to further his career (Vincent 1994). Wager took up his position in Reading in October of that year.

By the time he left Cambridge in 1929, Wager was already beginning to establish his credentials as a field geologist and had acquired a reputation as being one of the best and safest climbers in Britain.

Lawrence Wager had the rare distinction of making his mark (at the highest levels) in three separate fields, as an explorer,

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mountaineer and geologist, as I will now attempt to show.

Next: Explorer

Explorer


Fig.1 Wager's Expeditions i...


Fig.2 Map showing Kangerd...

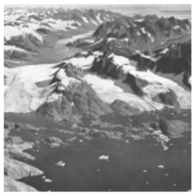
Fig.3 Southern part of the ...

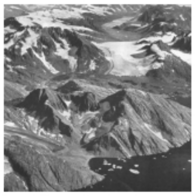
Fig.4 Northern part of the ...

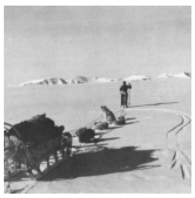
Fig.5 Sledging on the middl...


Fig.6 Rhythmic layering in ...

In January 1930, Wager was invited by Gino Watkins to join the 1930-1 BAARE (British Arctic Air Route Expedition) Expedition to Greenland. This was the first of four expeditions to East Greenland and one to Everest in which Wager was involved in the 1930s whilst at Reading. It was very generous and far-sighted of Professor Hawkins to support Wager's applications for long periods of leave of absence (without pay) from the university to participate in these expeditions, which were to form the basis for Wager's research at Reading (Hargreaves 1991, P. 27). In all, Wager was absent for about five of the ten years he was at Reading!

Wager's involvement in the BAARE Expedition has been described by Watkins (1932), Deer (1967) and Hargreaves (1991). During the northward voyage of the Quest along the east coast of Greenland in August 1931, at the beginning of the expedition, Wager identified a number of Tertiary igneous intrusive centres stretching from Kap Gustav Holm at 66°N to Kangerdlugssuaq (meaning large fjord in the eskimo language) at 69°N (Hargreaves 1991). He also identified and named the Skaergaard Intrusion after the peninsula at the mouth of the Kangerdlugssuaq Fjord (Figs. 1 and 2). The exposure of the rock was excellent and its layering could be easily seen. Wager made this discovery from the deck of the ship because they were unable to go ashore then. At this time, the entire coast of the Kangerdlugssuaq Fjord was photographed from the air (D'Aeth 1932). Many high quality aerial photographs were taken, a few of which showed the Skaergaard Intrusion (Figs 3 and 4). However, these photographs could only be properly interpreted geologically in the light of field evidence. Wager subsequently prepared geological maps of the areas from Angmagsalik to Kangerdlugssuaq and from Kangerdlugssuaq to Kap Dalton (Wager 1934, Plates 11 and 12).

In his obituary of Wager, Deer (1967) wrote that 'Other geologists would have recognized the presence of the plutonic centres in the area, some would have realized their unique interest but it is doubtful if any other British geologist of the period would have had the necessary toughness, persistence and scientific insight to exploit the discovery to the extent that Wager did'. Brooks (1985) considered that the recognition the importance of the Skaergaard Intrusion at that stage was 'a stroke of genius.'

In an earlier letter to his father dated August 8 (Hargreaves 1991), Wager had written that this area on the East Coast of Greenland (see Deer 1967) 'forms an absolute continuation with the work I am doing in Ireland. One could almost believe Wegener and accept his idea that this had recently shifted from Ireland!' Wager (1932) subsequently concluded that the igneous rocks of this region were closely comparable to the Tertiary igneous rocks of the Hebrides, Arran and Antrim but he found new features not yet seen in any of the Tertiary rocks.

Wager was fortunate in 1931 because the ice conditions were favourable and the 65 mile long Kangerdlugssuaq Fjord could be approached by the Quest and the ship's boats (Deer 1967). However, this area is normally treacherous because of the great masses of polar pack ice constantly drifting southwards from the Arctic Ocean (Brooks 1985).

At the end of October, Wager participated in the second relief of the Ice Cap Station, which was located at the highest point on the Ice Cap. This involved a 250-mile return sledge journey (Watkins 1932, Hargreaves 1991). The weather conditions were extremely bad for most of the journey and it took 39 days to reach the station. Because of the shortage of rations, August Courtauld volunteered to remain alone at the station to make the

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remain alone at the station to make the necessary meteorological observations. However, he could not be relieved until the following May! On the way back, Wager and his colleagues encountered terrific blizzards and returned to base on December 19 with practically no provisions left.

Wager also took part in an attempt to climb Mount Forel, the highest known peak in the Arctic at that time (11,500 feet). This involved a 360 mile return journey to get there. However, the party turned back about 700 ft below the summit because of the very steep slope at the top and it would probably have taken two days to cut the ice steps up it. Instead, they opted to spend the time surveying the surrounding country (Brown 1968). Nonetheless, this was still the highest climb in the Arctic to that date (Watkins 1932). They returned to base on June 10, 1931.

In the summer of 1932, Wager returned to East Greenland as part of the Danish Expedition organized by the Scoresby Sound Committee and led by Captain E. Mikkelsen (Deer 1967, Brooks 1985; Hargreaves 1991). During this expedition, he spent about a month working in the Kangerdlugssuaq area in almost continuous good weather extending his investigations northwards to Kap Dalton. For safety reasons, he invited his brother Hal to participate in ths expedition as his geological field assistant, to help carry his rocks and to accompany him in wild places.

In the summer of 1934, Wager was invited by the French explorer, Dr. Jean-Baptiste Charcot, to participate in a cruise of the Pourquoi Pas to the Watkins Mountains and attempt to climb them. Charcot is best known for his 1903-05 expedition to the west coast of Graham Land on the Antarctic Peninsula aboard the Français. However, in 1934, the Pourquoi Pas could only limp to Iceland and was forced to turn back before reaching Greenland (Deer 1967, Hargreaves 1991). Wager subsequently described Dr. Charcot as one of the kindest and most charming men it had been his fortune to meet.

In 1935, Wager organized and led the British East Greenland Expedition (BEGE) 1935-1936 which lasted from July 1935 to September 1936. Wager was personally responsible for organizing the financing and logistics of the expedition. Finance for expeditions in the 1930s was, of course, very difficult to obtain (Deer 1967). Wager was helped in this matter by August Courtauld who had the idea of hiring the Quest himself and joining in with a summer expedition to climb the highest mountain in the Arctic. Courtauld was the elder son of Samuel Courtauld who was chairman of Courtaulds from 1921 to 1947 and was therefore in a position to make this very generous offer. As a result, Wager was obliged to go up to Cuillins in Skye in January, 1935, to give Courtauld and Ebbe Munck some concentrated lessons in climbing with rope and ice axe (Hargreaves 1991).

The party Wager chose for the expedition consisted of Lawrence Wager, Hal Wager, Dr. E.C. Fountaine, W.A. (Alex) Deer, Philip Chambers and the two Wager wives, Phyl and Kit, for the entire expedition plus August Courtauld and Jack Longland, their wives Mollie and Peg, and Ebbe Munck for the summer. Phyl and Kit were the first two British women ever to winter over in Greenland. This expedition is described in considerable detail by Wager (1937), Deer (1967), Brooks (1985) and Hargreaves (1991).

Wager chose Deer for the expedition on the recommendation of James Wordie, Deer's tutor at St. John's College, Cambridge, who had been the geologist on Shackleton's Transantarctic Expedition of 1914-1917 and who had participated in a number of expeditions to the Arctic since the war (Deer 1974). At that time, Deer held the degrees of B.Sc. (1932) and M.Sc. (1933) in Geology from The Victoria University of Manchester and was a 25 year old Ph.D. student working under C.E. Tilley on the Glen Tilt complex of Perthshire at Cambridge. On being asked to go on the expedition by Wager, Deer readily accepted the opportunity to work with so dynamic a personality as Wager but had no idea of the petrological eldorado awaiting him there. Deer was subsequently awarded the degree of Ph.D. by Cambridge University in 1937 based of his thesis entitled '1. The dioritesand associated rocks of the Glen Tilt complex, Perthshire. 2. The petrology ofthe Skaergaard Halvoen gabbro complex, Kangerdlugsuak, east Greenland.'

The Quest sailed from Aberdeen on July 5, 1935. They had a very rough trip to Iceland and were very seasick (Hargreaves 1991). Wager was a notoriously bad sailor (Brooks 1985). When they reached Greenland on July 15, the Quest was jammed in by huge icebergs but they gradually managed to manoevre through them but not before the captain had announced that, if they touched a berg with the swell prevailing, the ship would be lost (Courtauld 1936). They later discovered that four Norwegian sealing ships had sunk that night just south of Angmagsalik but that the fifth ship managed to pick up 130 survivors from the ice. The team finally arrived safely at Angmagsalik on July 17.

The first task in Angmagsalik was to select the eskimos who would go to Kangerdlugssuaq with them. They eventually chose two families plus a strong and willing girl known as 'the horse' making 14 in all. The Wagers wanted contact and friendship with eskimo families who knew about living conditions and travelling in Greenland. The eskimos wanted access to polar bear skins, narwhal tusks and seal skins. This was a symbiotic relationship that appears to have been very successful and together they made a friendly little community. In practice, the eskimo formed an essential part of the expedition. In all, the eskimoes killed 410 seals, 28 bears and 40 narwwahls during their year away (Wager 1937). On the other side, an influenza epidemic at Angmagsalik killed 70 out of the total population of 800 there during their absence (Wager 1937). On this expedition, Wager would have been in the position to follow the example of Gino Watkins of living hard and following eskimo customs in dress and hunting (Hargreaves 1991, Brown 1992).

The Quest arrived at Kangerdlugssuaq on August 4 and Wager had time to choose the site for his prefabricated winter home in Home Bay at the northern end of the Skaergaard Peninsula. They also had at their disposal two wooden houses put up in 1932 during Mikkelsen's expedition (Wager 1937). On August 7, the climbing party consisting of Wager, August Courtauld, Jack Longland, Hal Wager, Fountaine and Ebbe Muncke plus a supporting party of Alex Deer, Chambers and a member of the ship's crew set off to the north in the Quest. They were obliged to start from I.C. Jacobsen's Fjord 90 miles to the southwest of where they had intended because of the heavy pack ice (Deer 1967). Jack Longland, a fellow climber on the Everest Expedition, considered that Wager did a magnificent job of reorganizing the route to what was then considered to be the highest peak in the Arctic. By a very careful study of the aerial photographs and maps he concluded the best chance of getting to the mountain was by sledging (with dogs) from where they were stuck (Hargreaves 1991). The party reached the east side of Christian IV Glacier in eight days and two days later had climbed the 12,200 ft mountain, which was subsequently named Gunnbjorns Fjaeld by the Danish authorities. They started the final assault on the summit at 4:20 AM in order to get better ice conditions, reached the summit at 5 PM and got back to their camp at about 9 PM (Courtauld 1936). Wager's inspired choice of route and tactics over the most uncomfortable terrain brought success against all expectations. The party returned to Irminger Fjord and got back half an hour before the Quest arrived to pick them up and take them to Kangerdlugssuaq. In their absence, Deer and Chalmers had almost completed the winter house (Courtauld 1936). On August 29, they saw the Quest off as it sailed back to England, their last contact with the outside world for a year.

Following the departure of the Quest, the geological programme began in earnest. This has been described in some detail by Wager (1937), Deer (1967), Brooks (1985) and Hargreaves (1991). There were two principal objectives, the main one being the detailed mapping of the Skaergaard Intrusion and the second one the mapping of as much of the area to the east of Kangerdlugssuaq as could be reasonably reached by short journeys. The field programme was extremely demanding and has been described in detail by Wager (1937).

Before the field programme could be undertaken, routes to the inland areas, where the glaciers provide the thoroughfares for travel by dog sledge, had to be reconnoitred and food dumps to support the geological field parties had to be laid down. These were logistical requirements of some magnitude, which took up a considerable amount of expedition time.

The weather was more problematic (Wager 1937). Temperatures ranged from a maximum of about 50°F in July to about -20°F in February. The sun remained below the horizon for about five weeks from the beginning of December but geological samples could still be collected during the four hours of twighlight around noon. Violent föhn winds periodically poured down from the Ice Cap into the huge Kangerdlugssuaq Fjord, leading to sudden increases in air temperature and rapid melting of the snow. In winter the föhn winds could occur at weekly intervals, causing snow and poor visibility (Wager 1937).

The geological field programme was undertaken principally by Wager, Deer, Dr. E.C. Fountaine and Hal Wager working in two two-man teams. Dr. Fountaine was the expedition's doctor, a mountaineer and responsible for any survey work that might be required. Wager kept up the pressure on geological fieldwork throughout the autumn and mapping was continued even in December during short spells when the weather permitted (Deer 1967). However, scientific work was also undertaken at base in winter during periods of bad weather. This included thin sectioning, microscope work, mineral separation and collating the results of field work. Rock sections were also used to direct future fieldwork. In addition, Fountaine began to make the large-scale map that was later used as the base for the detailed geological survey. From December 16-24, Wager and Deer were in Miki Fjord, Irminger Fjord and the mountains to the north and Fountaine and Chambers were out making measurements of the rate of glacier movement at the Friederiksborg Glacier. They arrived back at base on Christmas Eve to celebrate Christmas with the eskimos (Wager 1937). On New Year's Eve, Wager proposed the toast 'To Greenland, may it never be exploited.' (Hargreaves 1991).

On March 5, 1936, Wager and Fountaine set out to map the nunataks fringing the Ice Cap in the region of the Seward Plateau and the Prince of Wales Mountains (Fig. 5). The journey took 5 weeks. On June 1, Deer and Fountaine started on the second long sledge journey following the same route to Seward Plateau and on to Ice Cap and around the head of Kangerdlugssuaq to the Triangular nunataks and Hutchinson plateau before continuing through the mountain region west of the fjord (Fig. 6). This journey was completed sometime after July 11 but both Deer and Fountaine continued geological work with other parties nearer to base. During the course of these two journeys, reconnaissance mapping of about 10,000 square km was completed (Deer 1967).

In all, 35,000 square km of difficult country was mapped geologically during this expedition with some small areas mapped in detail (Deer 1967, Hargreaves 1991). This was a remarkable achievement accomplished almost entirely by two sledging parties, each of two men. It is clear that Wager was a bit of a slave driver (Deer 1967, Brooks 1985) but he was able to achieve these results through his own drive and enthusiasm, which he passed on to others.

On July 29, 1936, the expedition members were returning to base when they saw the S.S. Saelis in the bay, which they promptly charted to take them home. The Saelis returned on 20 August and they sailed from Kangerdlugssuaq on that day. On the way back, they encountered a tremendous storm on September 16 after calling in at Iceland. During this storm, the Pourquoi Pas ran aground just south of Reykjavik. All hands, including Dr. Charcot, were lost except for one sailor who survived (W.E.G. 1936).

Previous: Introduction | Next: Returns to Greenland

Returns to Greenland


Fig 7: Members of the British Eas...


Fig 8: cairn with plaque bearing t...


Fig 9: Members of the 1933 Moun...


Fig 10: Jack Longland pole-jumpi...

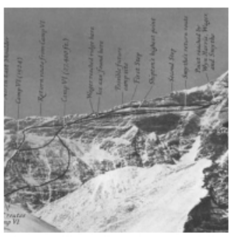
Fig 11: North Face of Everest fro...


Fig 12: Wyn Harris and Wager lea...

In 1953, Wager returned to Kangerdlugssuaq for a summer expedition with a combined Oxford and Manchester Universities party under the joint leadership of L.R. Wager and W.A. Deer. The expedition lasted from July 13 until early October. Wager spent most of his time carrying out a very detailed examination of some of the critical areas of the Skaergaard Intrusion and then later, when the ice conditions in the fjord improved, crossed to the South Syenite Glacier to continue work on the Kangerdlugssuaq alkaline complex (Deer 1967, Brooks 1985, Hargreaves 1991; Fig. 7). Not surprisingly, Wager returned to Oxford with a further extensive collection of samples which enabled E.R. Vincent and G.M. Brown to begin a second phase of investigations into the Skaergaard complex (Vincent 1994).

Based on material collected during this expedition, Wager et al. (1957) were able to formulate the concept of sulfide immiscibility in the Skaergaard Intrusion (Brooks 1992). Once again, Malcolm Brown stresses Wager's ability to assess difficult conditions, in this case crossing the ice-packed Kangerdlugssuaq Fjord in August. For days before, Wager had 'communicated with the weather.' The party could only cross the fjord in their small boats in a direct five-hour run and the weather rarely abated for that long. Eventually, Wager decided it was safe and they crossed with sledges and other loads rolling in the swell between towering icebergs. There was no doubt in the minds of the more junior members of the party that Wager's remarkable powers of leadership included an instinctive ability to assess such vital things as weather conditions, food requirements, ice and climbing conditions and, above all, the capabilities and limits of each member of the party. During this expedition they were stretched to their limits but never went dangerously beyond them (Hargreaves 1991).

In 1965, Wager and Deer obtained full financial support from the National Environmental Research Council (NERC) for a major expedition to East Greenland in 1966. This would have involved a programme to drill a deep borehole into the hidden part of the Skaergaard Intrusion and several minor holes in order to study processes of sedimentation in the layered series of the intrusion amongst other things (Deer 1967, Brooks 1985). This project was suggested to Wager by Alexander McBirney whom he met at the IUGG conference at Berkeley, California, in 1963 (Brooks 1985, Hargreaves 1991). Wager died before the expedition began but the expedition took place as planned under the leadership of W.A. Deer and a plaque was erected on the highest point of Skaergaardshalvö to commemorate a geologist and explorer of unique achievement (Deer 1967) (Fig 8). However, without Wager's drive and enthusiasm, the drill cores were never fully examined (Brooks 1985).

The geological results of Wager's four expeditions to East Greenland in the

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1930s were published in four volumes of Meddelelser om Grønland (Wager 1934, 1935, 1947; Wager and Deer 1939). According to Wager's obituary in The Times, the account of the Skaergaard Intrusion by Wager and Deer in 1939 was judged by many to be the most significant single contribution yet made to to the science of petrology (Anon 1965).

In The Times obituary, it states that those who were his companions on these expeditions all remember his remarkable powers of leadership in the field under trying conditions. He had the gift shared by certain rare leaders, of inspiring a kind of blind faith in his ability due to his deep understanding of the factors controlling the spirit and stamina of his party, to the cautious commonsense which governed all his decisions, and to his insistence upon the detailed organization of any venture in which he was concerned (Anon 1965). Vincent (1968) considered Wager to be one of the toughest, most single-minded explorers that Britain has produced for a very long time.

Wager the Mountaineer

In his obituary of Wager in the Alpine Journal, Jack Longland mentioned how much Wager had learned as a boy, walking and scrambling over the Craven hills of Yorkshire to which he kept on returning to the end of his life (Longland 1966).

Wager must therefore have already been quite an experienced climber when he joined the Cambridge University Mountaineering Club (CUMC) immediately on going up to Cambridge in 1922. He became Treasurer of CUMC in 1924-25 and President in 1925-26 (Hargreaves 1991). Being a member involved frequent lectures by notables such as Geoffrey Winthrop Young who had made many new and difficult ascentsand meets in the vacations. These meets were quite serious affairs and not for the faint hearted. By autumn 1924, Wager had already participated in meets in Wales, the Lake District and Switzerland. In one trip to the Lake District in March 1925, he cycled there and back from Arncliffe (about 11 hours each way) with a week's climbing in between. The weather was wintry with snow and hail for much of the week! In June 1925, he spent several days in North Wales climbing in preparation for a month in the Swiss Alps where they climbed many of the main peaks. Percy Wyn Harris and Jack Longland, his future companions on the 1933 Everest expedition, were in the party.

Wager described his philosophy of guideless climbing in the Cambridge Mountaineering Journal of 1925-26. Those with a little more experience in the Alps form a party with one or two less experienced climbers and attempt easy climbs. As a result, the leader has the responsibilites of leadership at an early stage and the others share something of the responsibility and learn something about route finding. Such a party will work better as a unit than one consisting of a guide, a porter and two beginners. This approach tends to lead to a better and safer attitude to mountaineering than more difficult expeditions led by a guide whose rapid and accurate judgement of conditions prevents the beginner from realizing the dangers of climbing and whose skill masks the difficulties of technique.

Wager went to the Alps for about a month every year between 1924 and 1928 usually from about mid-July to mid-August. In 1928, he was in the remoter Dauphiné Alps with Jack Longland and others (Longland 1966, Hargreaves 1991). It was on remote peaks such as the Aiguilles D'Arves that they found themselves entirely on their own and often would not see another climber in days. It was on these neglected mountains that they could explore new routes. One new traverse that year was the Pic Gaspard to the Pave where Wager's eye for a line brought them safely down the steep and muddled west Face of the Pic Gaspard where they had spent the previous afternoon reconnoitring the route up the other side of the mountain. By this time, Wager had achieved a reputation as one of the best and safest young rock-climbers in Britain (Dunham 1966, Deer 1967). He had completed his apprenticeship and was ready for Everest!

On December 19, 1932, Wager was invited to join the 1933 Mount Everest Expedition as a last-minute replacement for N. Odell (Ruttledge 1934a,b, Deer 1967, Hargreaves 1991, Venables 2003). The expedition arrived in Bombay on 10 February, 1933, and four of them, Wager, Hugh Ruttledge, the expedition leader, Jack Longland and Percy Wyn Harris, took the train to Agra to see the Taj Mahal. They arrived at Darjeeling on February 17 and began the long trek towards Tibet through lush vegetation, then climbing up to 14,900 ft at the Tibet boundary. Everybody was affected by headaches at this altitude. Between March 11 and 15, Eric Shipton, Longland, Wyn Harris and Wager climbed Chumunko at 17,500 ft to acclimatize. Wager was in the second party that covered 350 miles from the Tibet boundary to Base Camp between March 20 and April 17. He arrived at Base Camp with the 'hill trots' from which it took him a week to recover. However, by April 30, he was able to scramble up to 20,000 ft. Fig. 9 shows the members of the expedition.

At Tengke Dzong, half way between Darjeeling and Everest, the combined first and second parties improvized a sports day, which attracted every Tibetan man, woman and child from miles around (Ruttledge 1934). It began with rudimentary football involving a seething mass of Tibetans. Hugh Boustead who had won many Service boxing championships and captained the British Pentathlon team at the Olympic Games in 1920 then gave lessons in boxing and finally Jack Longland gave an exhibition of pole-jumping (Fig. 10). Of course, Tibetans are never passive spectators and Longland's exhibition was followed by some spectacular jumping and falling by them.

Following their arrival at Base Camp at 16,800 ft, it took Wager, Wyn Harris, Longland and Birnie until May 28 to reach Camp V at 25,700 ft because of bad weather and the steepness of the new route up to the North Col. On May 29, Wager, Wyn Harris and Longland managed to get up to Camp VI with eight porters.

On May 30, Wager and Wyn Harris made the first assault on the summit. They set off at 5:30 AM following a very cold night and got up to the second step but found it impossible to climb (Fig. 11). They then traversed across the north face 200 to 300 ft below the crest, crossed the great snow couloir and reached approximately the same point as Norton and Summerville in 1924 at about 28,100 ft. This was to remain the record for highest on Everest without oxygen until Reinhold Messner and Peter Habeler climbed Everest in 1978. Wager and Wyn Harris then wisely decided to return to Camp VI. It was already 12:30 PM and it would have required at least four hours to reach the summit. On the way back, they attempted to tackle the second step once more but were too exhausted once more but were too exhausted for further climbing. On the way down, they reached Camp VI twelve hours after setting out to find the second assault party consisting of F.S. Smythe and Eric Shipton already there (Deer 1967).

After an hour's rest, they descended the north ridge to Camp V where they stayed the night (Fig. 12). The following morning, they continued down the North Col to Camp IV. Going down the snow band, they glissaded on their bottoms because it was far too strenuous to stand up (Hargeaves 1991). However, Wager, despite his extreme exhaustion, forced himself up to the NE shoulder of the mountain and became the only climber to have looked down on the SE face of Everest until Hillary and Tenzing were able to do so twenty years later (Deer 1967). The last drag into camp was just about all they were capable of achieving. When Dr. McLean, the expedition Medical Officer, examined Wager and Wyn Harris, he found both were temporarily suffering from dilated hearts resulting from their experiences at high altitude without oxygen. On June 1, they were still very exhausted but descended to Camp III. They reached Base Camp on June 5 after a most tiring walk but managed to pass their time there smoothly and luxuriously! After their climb, Hugh Ruttledge, the expedition leader, was able to say of Wager and Wyn Harris that, ‘knowing these men as I do, they would not turn aside from a climb within the limits of the possible' (Brown 1966).

Meanwhile, Smythe and Shipton set out for the summit on June 1 but Shipton was forced to return early because of exhaustion. Smythe reached the same point as Wager and Wyn Harris by 10 AM but could not continue because a sprinkling of snow on these slabs made them unclimbable. He was mortified at having to turn back with success almost in view.

In the discussion of the expedition, Brigadier E.F. Norton who, as Colonel Norton, was the highest up Everest in 1924 having also reached the second step, pointed out that the monsoon in 1933 was the earliest of the century. As a result, he concluded that it was the weather, and nothing but the weather, which had cheated this party of the top that year (Ruttledge 1934).

On the long march out of Tibet beginning on July 13, Wager and Shipton opted to leave the main body of the expedition and crossed from the Lashar plain in Tibet to the Lhonak Valley in N.W. Sikkim (Hargreaves 1991). This was a very remote journey with porters. They crossed Lhonak La, which is over 18,000 ft in snow and poor visibility, but the trip was a great success. Wager left Shipton in Sikkim but met up with him again in Ceylon (Sri Lanka) where Shipton's mother had a tea estate. They came back to England together and arrived about 7 September. When he arrived home, he was obliged to present many lectures around the country to raise money for the Mount Everest Committee as well as to continue with his teaching and research at Reading. He was a busy man. During his time on the Everest expedition, Wager had become interested in the drainage pattern of the Arun River and its relation to the rise of the Himalaya based mainly on observations made during the trek into Tibet (Deer 1967) and the Lachi series of North Sikkim during his trek back from Everest through Tibet (Hargreaves 1991).

In December 1929, Wager met seventeen-year old Phyllis Worthington at a Morris and Folk Dancing Week in Sussex. In 1934, he contrived to meet her again through her sister by organizing a large picnic on Sunday 17 June 1934 on the Thames near Reading. At this time, he had become quite famous because of his exploits on Everest. On Saturday 30 June, he handed Phyllis the plans for his proposed expedition to Kanderlugssuak in 1935 during a train journey to Frinton and said 'You will need to know more about this'. At the half way stop, they had a long walk and just decided to marry. On 10 July, he left to go to Scotland to be picked up by the Pourquoi Pas to go to Greenland with the French explorer, Dr. Charcot. However, the Pourquoi Pas could only limp to Iceland and back. The Wagers married on 12 October 1934, and had five children between 1937 and 1945, of whom the fourth, Jane, went on to compile Wager's biography for the grandchildren he never knew (Hargreaves 1991). By all accounts, the Wagers were ideally suited.

Previous: Explorer | Next: Geologist (1929-1940)

Geologist (1929-1940)

In October 1929, Wager took up his position at Reading University. When he arrived, the Geology Department only had two rooms called 'The Hut' but they moved into new labs in 1931. Wager made a good impression on the students by being friendly, having a sense of humour and being able to make petrology seem fascinating (Hargreaves 1991). Geological excursions were considered very important at Reading and a lot of fun. Wager went on a week-long trip to the Isle of Man in March 1930 and to Skye at Easter 1932. However, in January 1930, after only one term at Reading, he was invited by Gino Watkins to participate in the BAARE Expedition of 1930-31 to East Greenland.

For the rest of his time at Reading, Wager was heavily involved in organizing and participating in expeditions and working up the results for publication (Hargreaves 1991). His time at Reading was therefore somewhat anomalous. With the students, Wager was at his best in the field unravelling geological problems before their eyes. He was not a natural lecturer but he managed to fascinate the students all the same. However, immediately after his lectures, he would stalk back to his room on the hour, bang the door shut and get on with the Skaergaard struggle. Nonetheless, the Wagers were good hosts to the groups of undergraduates they invited to their home.

On May 24, 1937, Wager was obliged to give an evening lecture to the Royal Geographical Society on the results of the 1935-1936 British East Greenland Expedition (Wager 1937). It was a black tie event with long dresses for the ladies. After the lecture, Phyl had to go up on the platform and say a few words. People thought that this was remarkable, as Jonathan had been born only three weeks earlier.

In 1936, E.A. (David) Vincent went up to read geology at Reading, a member of the first small group of students to enjoy the benefit of three years of continuous instruction from Wager (Hargreaves 1991, Vincent 1994). Vincent was to go on to become one of Wager's closest associates at Durham and Oxford and to succeed him as Professor of Geology at Oxford after his death.

In July 1938, the Wagers spent the whole month in Norway (Hargreaves 1991) and took the opportunity to visit V.M. Goldschmidt at his home in Holmenkollen in Oslo (Goldschmidt 1943). This was to be the only meeting between Wager and Goldschmidt but it was important in view of the attention that Wager's group at Oxford subsequently gave to testing the validity of the Goldschmidt Rules based on geochemical data from the Skaergaard rocks (Glasby 2006, 2007). On September 11, 1939, Wager wrote to Goldschmidt seeking his advice on the use of biotite as a substitute for the potassium imported from Germany for the manufacture of fertilizers. At that time, Wager was already aware of the possibility of a German blockade during the war to starve Britain out. In October, 1939, Wager visited the Macaulay Institute of Soil Research in Aberdeen to suggest to the Director, Dr. W.G. Ogg, that trace elements on the land would be an important topic in war time. He was already collaborating on trace element distributions in Skaergaard rocks with Robert Mitchell who was later to become director of the institute.

In December 1939, Wager bought Sawyersgarth in Littondale with the inheritance left by his father. This was to be Wager's refuge in Yorkshire for the rest of his life. In his obituary in the Times (Anon 1965), it mentions that Wager loved to spend some time at his farm in Litton, where he did much scientific writing, and would often go out with map, rucksack and hammer to map the local Yoredale rocks.

War Service

In March 1940, Michael Spender visited Wager in Reading and told him about the photogrammetric machine he had imported to England and how important it would be for interpreting air photographs (Hargreaves 1991). Wager knew Spender from the Mikkelsen Expedition to East Greenland in 1932 where Spender had made a fine map of 1,000 sq miles of Kangerdlugssuaq using the latest methods of stereo-photogrammetric surveying (Shipton 1945). Spender subsequently carried out a stereo-photogrammetric survey of the North Face of Everest during the 1935 reconnaissance expedition of Everest, which resulted in a large-scale map and accurate determination of prominent features for use on the 1936 Everest expedition (Ruttledge 1937). Spender pointed out that people were desperately needed in the development of photographic interpretation and, in late May, Wager was persuaded to join the Photographic Interpretation Unit of the Air Ministry initially as a civilian. Later he commissioned into the Royal Air Force Voluntary Reserve (RAFVR), firstly as a Pilot Officer and then promoted almost immediately to Flight Lieutenant.

In 1941, Wager was working in the Second Phase Room in charge of interpretation shifts under Michael Spender. They worked twelve hour shifts, twelve hours on and 24 hours off. Wager's job was to allocate sorties to the various interpreters, collate the results (over 500 photos from a run) and then write up the report on each sortie.

In 1942, Wager heard that a small photographic interpretation unit was scheduled to go to Murmansk in northern Russia to keep watch on the Tirpitz and to train their Russian counterparts. He decided he was the best man to lead this team and volunteered to go but then bitterly regretted his decision. By then, Wager was a Squadron Leader but he liked to describe himself as a Squadron Leader who never led a Squadron.

Their ship left the Britain on August 14 and arrived in Murmansk on August 23 with its complement of pilots, photographic interpreters and photographic personnel. Their brief was to seek out the Tirpitz and other units of the Germany Navy. Three long-range reconnaissance Spitfires were flown out in September to join them. The Tirpitz along with the Admiral Scheer was finally located by Mosquitoes on October 19 as winter was closing in. The detachment was then ordered to return home, leaving the three Spitfires behind as trophies for their Russian counterparts. Wager reckoned that his ship only got back to Britain because its captain was due to be court-marshalled over some alleged misdemenour and drove his ship so hard that he managed to outpace the German U-boats. Wager was very glad to get back on October 29. He had survived the notorious Murmansk run and was mentioned in Despatches. The Tirpitz was eventually sunk on November 1944, in Tromsø in southern Norway during an attack by 30 Lancaster Bombers.

In 1943, Wager applied for the Chair at Durham. He was given glowing testimonials by Professor Hawkins at Reading and E.B. Bailey, Director of the Geological Survey. He was granted leave to visit Durham and was appointed but the problem was to get his release from the RAFVR. This was only achieved after Lord Eustace Percy, Vice Chancellor of Newcastle University, had written to his friend, Sir Archibald Sinclair, Secretary of State for Air in the Wartime Government, saying that Durham must have this science professor. Wager went up to Durham in November and was offerred the Vice Chancellor's house, which the Vice Chancellor did not want, and Wager took it immediately. It was very grand. News of Wager's appointment appeared in the Daily Telegraph on November 15. Wager was given a splendid farewell from Z Section at Medmenham. He arrived in Durham with his family on January 1, 1944, to take up his chair as successor to Arthur Holmes.

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take up his chair as succesor to Arthur Holmes.

On April 3,1943, not long after he had been flown to Britain from neutral Sweden by Britain's Secret Intelligence Service (SIS), V.M. Goldschmidt had written to Dr. Wager to thank him for his offer of assistance (Goldschmidt 1943). On February 18, 1944, Goldschmidt wrote to now Professor Wager from the Macaulay Institute to congratulate him on his appointment to the Professorship at Durham (Goldschmidt 1944, Fig. 13). One senses a great deal of mutual respect between these two men but they were never to meet again. Wager was probably too preoccupied with his work in Durham and Goldschmidt became a semi-invalid after his near-fatal heart attack in December 1944.

Geologist (1944-1965)

When Wager became professor at Durham, there was only one other member of the teaching staff, Bill Hopkins. He therefore appointed Fred Stewart, who arrived in Durham in the autumn of 1943, and David Vincent, who took up his position in October 1946, as lecturers (Hargreaves 1991).

At Durham, Wager gave the introductory course of lectures for first years students, on igneous activity for the second year students and on igneous petrology for the third year students. He also gave a course on structural geology for the second year students concentrating on alpine tectonics. Wager was a somewhat nervous lecturer but his material was always superb and he did not duplicate what was in the textbooks. In these early post-war years, the students were mainly ex-servicemen who were marvellous to work with (Hargreaves 1991).

During his time at Durham, Wager played an important role in founding Geochimica et Cosmochimica Acta (Shaw 2003) and published his classic paper on the geochemistry of the Skaergaard intrusion with Robert Mitchell in the first volume (Wager and Mitchell (1951). In this study, the authors traced the strong fractional crystallization of the original basic magma by means of trace element analyses of separated minerals. This paper was novel at that time in presenting multi-element analyses of the samples as opposed to the single element approach preferred by V.M. Goldschmidt. Wager remained an editor of Geochimica et Cosmochimica Acta until his death.

Wager's star pupil at Durham was Malcolm Brown. Brown had come up to Durham in 1944 on a six month RAF course intending to read chemistry after the war but had been so impressed by Wager's course on physical geology that he had decided to read geology instead. He returned to Durham in 1947 and took first class honours in geology in 1950. Vincent (1998) has described Brown's three years as an undergraduate at Durham as a truly exceptional rate of intellectual and personal development. Wager always regarded Brown as by far the best pupil he ever taught. Like E.A. Vincent, Brown was to go on to become one of Wager's closest associates at Oxford.

In the period of austerity immediately after the war, continuing research in Greenland would have been out of the question. In his acceptance speech for the Bigsby Medal in 1945, Wager acknowledged this and pointed out that the time had come for reconnaissance work in distant places to be replaced by work of the same exactitude nearer to home (Wager 1945). Wager therefore began his investigations on the British Tertiary Igneous Province, firstly in the Western Red Hills Complex on Skye with Fred Stewart in the 1940s and later with E.A Vincent, G.M. Brown and J.D. Bell in the 1960s and on Rhum which was to provide the basis for Malcolm Brown's doctoral work at Oxford (Deer 1967, Vincent 1998). Vincent (1994) has described Brown's work on the layered ultrabasic complex on Rhum as remarkable for its meticulous detail, both in the field and in the laboratory work. Based on this study, Brown (1955) was able to characterize the Rhum and Skaergaard Intrusions as open and closed magmatic systems, respectively (Hargreaves 1991, Vincent 1998). However, Wager's research output in Durham was limited, doubtless a reflection of his heavy duties within the university.

During his time at Durham, Wager had the signal honour of being elected a Fellow of the Royal Society of London in 1946.

The Chair of Geology at Oxford was advertized in the University Gazette on 8 February 1950, and Wager's election to the Chair was announced on 6 April. Wager's time at Oxford has been described in meticulous detail by Vincent (1994). In going to Oxford, Wager was, in fact, taking over a rather moribund department which had been run down during the war years, although it was now housed in a new conversion of the Clarendon Department which had been financed by Royal Dutch Shell (Hargreaves 1991). Wager set himself the task of creating a modern, world-class geology department. This involved dealing with a number of problems on a step-by-step basis. However, his first duty when he arrived in Oxford was to sort out his huge collection of rocks which he had brought down from Durham!

In those days, Oxford was known as a 'soft rock' department biased heavily towards palaeontology and stratigraphy. It was therefore necessary to broaden the base of teaching in the department to include more emphasis on igneous geology and petrology. To do this, Wager had to broaden the base of the teaching staff in the department. Over the years, he managed to attract to the department the likes of L. H. Ahrens, S. R. Taylor, E. A. Vincent, G. M. Brown, R. St. J. Lambert, H. G. Reading. E. R. Oxburgh, J. D. Bell and J. Zussman amongst others. By 1960, the academic staff had grown to about a dozen. However, the number of students graduating with honours in geology remained low, although of a high standard. In 1956, for example, five students graduated with honours in geology of whom two, David Bell and Keith Cox, stayed on to become members of staff. The number of research students remained steady at about ten to twelve until about 1960. Many were engaged on petrological or geochemical topics.

By the late 1950's, Wager had managed to reestablish the Department of Geology and Mineralogy as a vigorous centre for research activity. He had acquired a good deal of new equipment for the laboratories and had imbued the department with a determined and enthusiastic research spirit, but he had not managed to increase the number of students graduating from the department to the level he considered necessary (Vincent 1994).

In research, Wager focussed on a number of new developments that he considered important. In particular, he became interested in geochemistry as pioneered by V.M. Goldschmidt. In the early 1950s, analytical methods were rather primitive and time consuming. Major elements had to be determined by gravimetric and volumetric analysis. Vincent (1994) reports that it took him a fortnight working very hard to generate three full analyses. As a result, sample selection became an important issue. Optical emission spectrography in Britain at that time had a precision of 30% when the standards were closely similar to those of the analyzed samples and element concentrations were greater than 1000 ppm. However, Wager and Mitchell (1951) more realistically assessed the accuracy of the method at that time at +/-50%. These levels of precision were much poorer than those obtained by V.M. Goldschmidt more than a decade earlier and Goldschmidt would never have achieved his success with such precision (K.-H. Wedepohl pers. comm.). X-ray fluorescence spectrography became an important method during this period, and was used for analyzing Skaergaard samples.

In addition, Instrumental Neutron Activation Analysis (INAA) was being developed at the Atomic Energy Research Establishment (AERE) at Harwell in the 1950s by Albert Smales and his Analytical Chemistry Group. This method gave previouly unattainable levels of sensitivity, precision and accuracy for a wide range of elements. As a result, a separate laboratory was set up at Oxford for handling and processing samples which had been irradiated at Harwell and led to an increase in the number of elements which could be investigated in Skaergaard material. The analytical work was often carried out in collaboration with Part II chemists. The joint studies with Harwell culminated in the publication of 'Methods in Geochemistry' edited by Smales and Wager (1960) which summarized recent advances in the principal analytical techniques used at that time. In this case, the editors followed the dictum of V.M. Goldschmidt that 'the primary purpose of geochemistry is on the one hand to determine quantitatively the composition of the earth and its parts, and on the other to discover the laws which control the distribution of the individual elements.' One of the principal objectives of geochemical research at Oxford at that time was to test the validity of the Goldschmidt Rules by applying them to the

Skaergaard Intrusion in East Greenland (Glasby 2006, 2007). INAA was the preferred method of analysis in many of these studies. Wager's main contribution in this regard was to get a group of very able scientists analyzing Skaergaard material with new analytical methods.

Interestingly, Paul Rosbaud played an important role in commissioning the Smales and Wager book for publication. Rosbaud was a close friend of V.M. Goldschmidt towards the end of his life and was instrumental along with Wager in setting up Geochimica Cosmochimica Acta on Goldschmidt's behalf (Glasby 2006, 2007). However, his main claim to fame is that he is reputed to have been 'the Griffin', Britain's top spy during the war. Wager and Rosbaud become good friends and Rosbaud's gnome-like figure, with his stooping shoulders, perpetual twinkle, and drooping cigarette, became a familiar sight around the department (Hargraves 1991, Vincent 1994).

In 1960, the Diploma in Geochemistry course was established at Oxford with three students in the first batch, one of whom, C.K. (Kent) Brooks, went on to become one of the leading experts on the Skaergaard Intrusion (Brooks 1985).

Wager also became very interested in geological age determination following his contacts with Arthur Holmes and Fritz Paneth in Durham and later with Louis Ahrens in Oxford (Vincent 1994). In 1957, the department acquired a spark source mass spectrometer with Stephen Moorbath who had graduated with an outstanding first in 1954 appointed as the first British Petroleum Research Fellow to run it. Moorbath was to provide much of the inspiration for the age dating work. Over the next decade, the isotope geochemistry laboratory, later to be renamed the Geological Age and Isotope Research Laboratory, expanded rapidly. In 1960, N.J. Snelling and his group from the Institute of Geological Sciences in London were seconded to take over all geochronological work for the Colonial (later Overseas) Geological Surveys at Oxford. The first provisional radiometric ages from Kangerdlugssuaq and Angmagsalik were published by Wager and Hamilton (1964). Wager put a lot of his own research energy and enthusiasm into the age dating and gave over-riding priority to the needs of the laboratory. This was rewarded by the high international esteem in which the laboratory came to be held and fully justified Wager's faith in this project.

Wager had therefore fulfilled his aim of equipping the department with the most modern apparatus for the chemical, physical and nuclear investigation of rocks and minerals and pushing the analysis to its ultimate limit to gain data for his petrological studies (Dunham 1966).

In 1955, Wager led the undergraduate field trip to the Lake District at Easter with Robin Oliver (Hargreaves 1991, Vincent 1994). On the way back, he felt pain in his left arm and side and was diagnosed as having had a coronary thrombosis (heart atack). He was told to be careful for the rest of his life, never to walk up hills and never to dig energetically in the garden. He went on sick leave for all of Trinity (summer) term. It must have been very galling for a man as energetic and active as Wager to have to accept these constraints. Despite this, he was forced to put in a lot of effort to convince the university authorities that he needed a new lecturer in igneous petrology to reduce his heavy teaching load and to supervize his research students, especially in Skye and Rhum, but eventually Malcolm Brown was appointed in late 1955. At this time, Louis Ahrens resigned from the Readership in Mineralogy and left what he thought was a sinking ship to take up the Chair of Chemistry at the University of Cape Town. He was replaced by E.R. Vincent. In the following summer, Wager was able to visit his students in the field in Skye but did not undertake any hard walking.

In 1958, Wager was President of Section C (Geology) of the British Association when it held its annual meeting in Glasgow (Hargreaves 1991; Fig 14). It was therefore a high priority for him to attend this meeting. For his Presidential lecture, he chose the topic 'beneath the earth's crust', which was of considerable interest at that time because it had already been proposed to drill a bore hole through the Earth's crust and into the mantle (Wager 1958).This lecture indirectly went on to form the basis for the 1966expedition to East Greenland.

In 1958, Wager was also involved in discussions with T.F.W. Barth, C.E. Tilley and P. Rosbaud about the establishment of a new journal of petrology (Anon 1966). In spite of many initial setbacks, the first volume was published in 1960 with L.W. Wager on the editorial board and G.M. Brown as one of the managing editors. Wager stayed an editor until his death by which time Brown had been promoted to senior managing editor. E.A. Vincent joined the editorial board in 1967. Wager was able to publish two major papers in the first volume of the journal in 1960 (Wager 1960, Wager et al. 1960).

By 1957, Wager and Brown had already begun discussing the possiblity of writing a book on layered igneous rocks (Wager and Brown 1967, Hargreaves 1991, Vincent 1994). The classic Wager and Deer (1939) memoir was already out of print and there was a large body of chemical and mineralogical work carried out over the preceding two decades that needed to be considered. Writing this book was to be a huge task which would take up the next ten years. In order to prepare themselves, Wager and Brown visited the Bushveld complex in South Africa and the Great Dyke of Southern Rhodesia (Zimbabwe) for two months in the summer of 1958. Wager then took the only sabbatical at his academic career. From the end of March 1959, he spent six months at Le Mazot, a chalet in one of the side valleys of the Rhône valley, where he could immerse himself in writing the book. He also spent a little time in Italy visiting some volcanic centres he had not previously seen.

With the help of Geoff Robson, one of his former students from Durham who was working at the Seimic Research Centre in Trinidad, Wager then spent the final third of his sabbatical in the West Indies where he visited a number of volcanoes including Mount Misery in St. Kitts, Soufrière volcano on St. Vincent and the calc-alkaline volcanism on Montserrat. These volcanoes were all to be studied by doctoral students under the supervision of Wager and Brown over the next few years. The sabbatical was a great success and Wager returned to the department refreshed in January 1960. When the book was finally published in 1968, about 45% was devoted to the Skaergaard Intrusion and the rest to the Rhum, Stillwater, Bushveld and other types on basic layered intrusions. Wager wrote most of the chapters on the Skaergaard and Brown most of the other chapters.

In August 1962, Wager was invited to the Soviet Union for two weeks as a Royal Society Visiting Professor to lecture in Moscow and Leningrad (Hargreaves 1991). His big disappointment was that he did not get permission to visit the intrusion in the Kola Peninsula and do field work there. During his stay in Murmansk in 1942, travel had been totally restricted.

On November 20, 1965, Wager was in London with Phyl to buy a camera and attend the wedding of Jack Longland's son. When he returned to his club, the Farmers Club in Whitehall Court, he had a second coronary and died almost immediately. That evening, Malcolm Brown rang up David Vincent with tears in his voice, saying 'David, Prof's died.' In the department on the following Monday, the news was like a thunderbolt. Later that week, I asked Malcolm Brown, 'What did Professor Wager die from?' 'A heart attack. He strained his heart on Everest.' Following his funeral, Wager's ashes were scattered at Sawyersgarth.

When Wager died, the Wager and Brown book was almost complete apart from chapter 19 which had to be finalized for publication by Malcolm Brown. It was published in 1968 (Wager and Brown 1968). The book sold quickly and became a standard text. It was translated into Russian in 1970. Wager's scientific legacy is now based mainly on his two major publications (Wager and Deer 1939, Wager and Brown 1968).

In 1967, Malcolm Brown was appointed to the Chair in Durham to succeeed Sir Kingsley Dunham. In 1979, was appointed director of the Institute of Geological Sciences, subsequently renamed the British Geological Survey, again succeeeding Sir Kingsley Dunham, and was knighted in 1985. He was elected a Fellow of the Royal Society in 1975 (Vincent 1998).

The Wager Prize was instituted by the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) at the instigation of David Vincent in 1974 and was funded in part by a capital sum provided by Phyllis Wager and in part by the surplus from a Symposium on Volcanoes held in Oxford in 1969. The first prize was awarded in 1973 and then every four years. It was replaced by the Wager Medal in 1994.

In 1985, C.K. Brooks wrote an article on L.R. Wager and the geology of East Greenland summarizing Wager's major achievements in Greenland. Brooks was subseqently involved in assessing the economic potential of the Skaergaard Intrusion (Nielsen and Brooks 1995; Brooks 2002). Brooks (1985) considered that Wager had two outstanding characteristics which led to his success as a leader, researcher and explorer. He was both a thinker and a perfectionist, and these two were inextricably mixed and prominent in all his doings.

In 1989, the Journal of Petrology published a Special Commorative Issue 'dedicated to L.R Wager on the fiftieth anniversary of publication of his landmark study of the Skaergaard Intrusion of East Greenland. The remarkable interpretative insights provided by that work made the Skaergaard a classic example of igneous differentiation' (McBirney 1989). The editor of that volume was Alexander McBirney of the University of Oregon who made numerous studies of the Skaergaard Intrusion between 1975 (McBirney 1975) and 2003 (McBirney and Creaser 2003) and, in particular, provided an excellent analysis of the various mechanisms of differentiation in the Skaergaard Intrusion (McBirney 1995).

Following Wager's death, David Vincent wrote that Wager had left a very different department from the one he had inherited 15 years earlier. He had achieved his aim of putting Oxford back on the map in research and had created a department of world standing which, although still very much smaller than Cambridge, was, in its way, equally distinguished. His greatest service was to imbue the department, from top to bottom, with the spirit of research (Hargreaves 1991).

Wager was the subject of a large number of obituaries in which his integrity and the high esteem in which he was held by his colleagues shine through (Anon 1965, 1966, Brown 1966, Dunham 1966, Longland 1966, Shipton 1966, Adie 1967, Deer 1967, Vincent 1968). Table 1 lists the major awards Wager received during his life time.
When he died, Wager left a large collection of rocks from East Greenland, Skye, Rhum, and other parts of the Hebridean Tertiary Igneous Province, including the remote island of St. Kilda, as well as from the Bushveld Complex in South Africa and the 1933 Everest expedition. These are now held at the Oxford University Natural History Museum (OUNHM) located next door to the Geology Department together with a collection of his letters.

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Conclusions

As an explorer, Wager had all the necessary ingredients for success. These include mental toughness and courage, meticulous planning, careful selection of the targets for investigation and ensuring their implementation, knowing the strengths and weaknesses of his colleagues and finally presenting the results of the investigations to the wider scientific community. Wager consistently satisfied all these criteria but most importantly, on the British East Greenland Expedition 1935-1936, he and his junior colleague, W.A. Deer, achieved results of landmark significance in igneous petrology.

As a mountaineer, Wager was indeed 'highest up Everest before the war'. However, he was foiled in his attempt to climb Everest in 1933 by the second step, which he considered unclimbable, the unfavourable weather conditions for the time of year and his failure to use oxygen. Even Reinhold Messner, the hardest of the hard, was pushed to his absolute limits in climbing Everest without oxygen in 1978. Had he been climbing on the more favourable Nepal side of Everest in favourable weather conditions with oxygen, Wager's chance of reaching the summit of Everest would undoubtedly have been much greater. Nonetheless, Wager was, without a doubt, one the select few top climbers in Britain at that time.

As a geologist, Wager had the supreme good fortune to discover the Skaergaard Intrusion in the first phase of his first expedition to East Greenland and to realize its significance immediately. His work on the Skaergaard was the dominant theme of the next 34 years of his life, and led to the publication of the classic work on the petrology of the Skaergaard Intrusion with W.A. Deer in 1939, and culminated in the publication of his book 'Layered Igneous Rocks' with his protégé, Malcolm Brown, published shortly after his death. Wager's studies on the Skaergaard with his colleagues were of the first rank. Wager is also remembered as an excellent field geologist and teacher, as the man who revitalized the Oxford Geology Department after the war and as as a cofounder of two major international scientific journals. However, it is for his Skaergaard work that he is mostly remembered today.

Lawrence Wager was a very modest man. He went on his expeditions, did what was necessary and moved on. He was a dedicated man and not one to blow his own trumpet. However, based on the evidence presented here, I believe that Wager's achievements in East Greenland and on Everest in the 1930s rank him in the top half dozen British explorers of the 20th century, alongside Scott, Shackleton, Fuchs and Fiennes. His classic work on the Skaergaard Intrusion has stood the test of time and remains highly regarded. Wager seemed to pack more into his life than anybody else. He was a very tenacious man with a shrewd scientific brain. He was totally dedicated in all he did and was an outstanding geologist.

Acknowledgements

I thank Professors K-H. Wedepohl and G. Wörner of the University of Göttingen for their helpful comments and support during the writing of this article.

Professor L. R. Wager: Major Awards and Honours

1933	Polar Medal
1935	Mungo Park Medal of The Royal Scottish Geographical Society
1939	Lyell Fund of the Geological Society of London
1941	Awarded degree of Doctor of Science (Sc.D.) by Cambridge University
1945	Bigsby Medal of the Geological Society of London
1946	Elected Fellow of the Royal Society
1948	Spendiarov Prize of the Russian Academy of Sciences (presented at the Albert Hall during the International Geological Congress in London)
1951-53	Vice President of the Geological Society of London
1952	President of Arctic Club
1958	President of Section C (Geology) of the British Asssociation for the Advancement of Science
1960-63	President of the Mineralogical Society of Great Britain and Ireland
1962	Lyell Medal of the Geological Society of London
1974	The Wager Prize of the IAVCEI was instituted in 1974 (renamed the Wager Medal in 1994)

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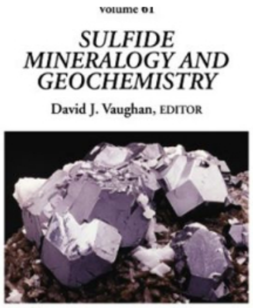

RIMG v.61 Sulfide Mineralogy and Geochemistry

BOOK REVIEW

Sulfide Mineralogy and Geochemistry
Reviews in Mineralogy & Geochemistry Volume 61
David J. Vaughan, editor

Much has been written about sulfide minerals since the publication of Volume 1 of the Reviews in Mineralogy (and Geochemistry) series. As one of the authors of that volume, I look back and realize that although we told what we knew about sulfides at the time, there was a lot we didn't know and it is exciting that a lot more has been discovered in the following 20+ years. Since then, the techniques and theories have advanced remarkably, especially in the development of advanced analytical instrumentation and the use of computers for display and analysis of crystal structures, chemical bonding, ab initio calculations, control of apparatus, construction of maps and diagrams, and storage and manipulation of data. I am very much impressed by David Vaughan's influence on sulfide mineralogy and geochemistry, and congratulate him for producing so much useful information over the years and also for his efforts in organizing and editing this Volume. In Chapter 1, David reviews the reasons for producing a volume focused on sulfides, the relevant literature, and its scope and content. Although the emphasis is on sulfides, selenides and tellurides are mentioned in a few of the chapters, and there is also some discussion of the roles of arsenic, antimony, and sulfates.

Chapter 2, Crystal Structures of Sulfides and other Chalcogenides, by Emil Makovicky contains a remarkable review of sulfide structures, with many illustrations of crystal structures and related information. In reading this chapter, I thought to myself how nice it would be to have an index to locate sections on specific minerals of interest -- this is a comment I have also seen in other book reviews. However, I then realized that this is not so important today if text is available in electronic form. I downloaded several chapters in pdf format via GeoScienceWorld, a service that is available through our Library at the University of Arizona. Then, using Adobe Reader 7, I was able to search with ease for any mineral name or other topic of interest. The answers appear in the context in which they were written, so this is really better than looking up words and relevant pages in a printed index. Chapter 3 is on Electrical and Magnetic Structures of Sulfides by Carolyn Pearce, Richard Patrick, and David Vaughan. Virtually all industrial applications related to sulfides depend on their electrical and/or magnetic structures. This includes not only uses of sulfides in electronics and as nanoparticles, but also in exploration for ore deposits and extraction of sulfides from bulk material. Chapter 4 is Spectroscopic Studies of Sulfides by Paul Wincott and David Vaughan. This chapter reviews a range of spectroscopies useful for investigations of sulfides, including infrared to ultraviolet, x-ray emission and absorption, Mössbauer, nuclear magnetic resonance, and a number of other techniques. Mössbauer studies at high pressure have been especially important for understanding phase changes in iron sulfides. Chapter 5 is Chemical Bonding in Sulfide Minerals by David Vaughan and Kevin Rosso. Chemical bonding is sulfides is much more complex than in oxides and it has taken a long time for useful bonding theory to be incorporated into sulfide studies. However, the authors demonstrate that substantial progress is being made in both qualitative and quantitative calculations to interpret and predict sulfide crystal structures.

Chapter 6, Thermochemistry of Sulfide Mineral Solutions by Richard Sack and Denton Ebel, begins with a discussion of phase relations and solid-solution thermochemistry, and continues with examples of equilibria and non-equilibria of a range of sulfide systems. It also covers experimental methods in sulfide research. This chapter is followed by a complementary discussion in Chapter 7, Phase Equilibria at High Temperatures, by Michael Fleet. This chapter covers primarily systems containing first-row transition-metal sulfides, and includes a short section on Fe-S at high pressures. Chapter 8 is Metal Sulfide Complexes and Clusters by David Rickard and George Luther, III. The emphasis here is on sulfides in aqueous systems and the role of clusters and complexes. This is, in fact, a very complex part of sulfide research because, as the authors note, it is often difficult to determine the actual molecular structure and composition of a sulfide complex in a dilute solution, so geochemists often just focus on measuring the stabilities of

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complexes. The chapter ends with an interesting discussion of the relationship between complexes, clusters, and solid phases. The next two chapters are both by Kevin Rosso and David Vaughan with Chapter 9 describing Sulfide Mineral Surfaces and Chapter 10 the Reactivity of Sulfide Mineral Surfaces. Surface studies have benefited enormously in the past 20 years or so by the development of a variety of techniques for characterizing surface structures and their reactivity with their environment. Among the techniques mentioned are EXAFS, XANES, the scanning tunneling microscope (STM) and atomic force microscope (AFM). Surface studies involve identifying the crystallographic orientation of the fractured or cleaved surface, the presence of vacancies, and the atoms or ions exposed at the surface. Chapter 10 discusses surface reactions with gaseous species such as O2, H2O, H2S, and CH3OH, catalysis, and metal ion uptake at sulfide surfaces. Computational analysis requiring supercomputers is also a developing field. Chapter 11, Sulfide Mineral Precipitation from Hydrothermal Fluids by Mark Reed and James Palandri, explores how sulfides dissolve or precipitate in fluids with varying temperature, pH, and chemical composition.

Chapter 12 is Sulfur Isotope Geochemistry of Sulfide Minerals by Robert Seal, II. Seal provides basic understanding of stable isotope geochemistry, analytical methods, and factors controlling sulfur isotope fractionations. Seal then provides a number of examples showing how knowledge of sulfur isotope variations aid in the understanding of systems containing sulfide minerals, such as meteorites, marine sediments, igneous rocks, ore deposits, and seafloor hydrothermal systems. Chapter 13 is Sulfides in Biosystems by Mihály Pósfai and Rafal Dunin-Borkowski. Two concepts described here are very interesting, biologically controlled mineralization (BCM) and biologically induced mineralization (BIM). The authors relate that while only a few examples of BCM are known, iron sulfides form in vast quantities by BIM and affect the global cycling of iron, sulfur, oxygen, and carbon. Of particular interest are magnetotactic bacteria that contain intracellular magnetic iron oxide or sulfide minerals. Some magnetotactic bacteria contain pyrite, mackinawite, or greigite. This area of research is very promising and many scientists believe that sulfides may play a significant role in the origin of life

In conclusion, I recommend this Volume very highly as an authoritative presentation of current knowledge and understanding of sulfide minerals' chemistry, physical properties, and geological importance. Although there was no Short Course associated with production of the Volume, I think it has great potential for being the foundation of one or more international research symposia on the role of sulfides in the geosciences and related areas of science and technology.

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The Neighbor: Gliese 581c

Artist's impression of the pl...

Midday, Muspell Scablands, Gliese 581c (Planet Ymir)

A bloated sun hangs at high noon above a worn rockscape. Dark blemishes twist gradually across the sun's face, coiling out messages in magnetic ink like the handwriting of Apollo. Sunspots recede toward the solar east limb at unnatural speed, while similar blemishes rotate into view in the solar west, both clearly defining the sun as a sphere. The dark magnetic storms dot the sun's face like islands in some vast solar ocean of blood. The sunlit sky is a brilliant crimson at zenith, shading to a lurid claret horizon, the whole unmarked by a single cloud. A tiny amber coin slides out of the western solar limb, its shape rippling in the brutal atmospheric heat. In hours the disk is at half phase, already doubled in apparent size. In a few more hours it is a large crescent, then a wide black circle crossing the sun like a vast pupil from west to east. Electric arcs wind across the planet's outer face, stitches of incandescent sodium ten thousand kilometers long. In hours the nearby world will disappear once again, orbiting east behind the sun.Artist's impression of the planetary system in Gliese 581 (Credit: European Southern Observatory)

Below the gleaming sky is a dazzling, shadowless plain of rhyolite sand and lumpy granite cliffs. Fluted ventifacts decorate the rocky terrain. There are perched boulders shaped like gigantic horizontal teardrops, their scalloped ridges sweeping artfully toward leeward knife edges. Weird arches penetrate the beige granite, themselves pocked with thousands of meter-sized hollows once occupied by white feldspar blocks that weathered away to dust long ago. No birds nest in the sheltering hollows. No lizards burrow in the ashen sand. No sturdy lichens encroach the sunburnt cobbles. The scablands are lifeless.

And yet, nothing is still. A constant gale bellows across the beaten plateau. The heavy wind scrubs rock into sand, sand into dust, and dust into the burgundy horizon. Pounding updrafts howl constantly from the deeper canyons, driven by the endless noon heat, sending hot dry air into the stratosphere and out in all directions from the noon pole. The brutal gusts grind steadily at the granite hills, ablating the massif with fifteen atmospheres of carbon dioxide and nitrogen shrieking at three hundred kilometers per hour. Not a breathe of oxygen freshens the searing air, and there is only the thinnest trace of water vapor. Farther from the pole deep shadowed canyons hide briny lakes and bitter acid springs, but no moisture can survive the shadeless glare of the polar noon.

A low rumble travels from over the horizon. Mount Surtur, at 2,300 meters the tallest rocky peak on the planet, vents a burst of sulfur dioxide and water vapor into the barren hyperbaric winds. Mountains are modest on this world. Twice the gravity of Earth makes for a subdued topography. Volcanoes are commonplace, despite the planet's miserly portion of iron and heavy metals. A small core provides for only the weakest of geomagnetic fields, but what this world's mantle lacks in uranium heat is amply compensated for by its insulating bulk - five Earth masses - and generous supply of warm, radioactive potassium to drive mantle convection.

Time passes, and midday persists. The sun never moves in the ruby sky. Beneath the sculpted rock arches, permanent shadows form a fixed patchwork of light and murk. Slowly, almost imperceptibly, the shadows deepen. The ruby glare intensifies. This sun is a variable star, intermittently doubling in brightness, and doubling again, before eventually dimming back to its normal sullen glow. The cycles are random, and are the only seasons known to this massive, tidally-locked world.

As the torrent of solar photons reaches its peak, fresh waves of heat coil through the air. A diorite boulder shatters with a deafening report as its upper side expands in the quadrupled heat faster than its underside. Thermal drafts blaze skyward with renewed intensity, creating a vacuum pull. Cooler air masses rush in from the high latitudes, carrying dark cyclones thousands of kilometers wide to spiral in toward the noon pole, veering and skittering like droplets on a stove. Most of these storms evaporate before they reach the sunlit polar highlands. But today is special. One powerful cyclone, the first in many sun-cycles, has momentum enough to touch the pole before burning away. Its hurricane winds power across the hillsides, lifting sand and gravel that weigh twice what they would on Earth. The humid vortex lashes across the plateau, through arches, over ventifact cliffs, bringing rare moisture to work eroding alchemy on the parched minerals. A rippling staccato blast echoes over the dead scablands. Like bullets from the gods, billions of heavy drops impact the parched rock and flash instantly to steam. It is a rainstorm, the first and last in an epoch. Springtime has come to the sunward pole.

Midnight, Niflheim Expanse, Gliese 581c (Planet Ymir)

A spinning vault of stars glimmers above crystalline peaks. The constellations wheel across the heavens in a vertiginous rush. A lone azure world coasts silently through the sky, at times large enough that its banded disk is plain, if there were eyes here to see it. Thin frozen clouds stream through the night sky at supernal speed, thinning further as they reach the midnight pole and dissolve into hurtling snow. Flakes like diamond caltrops impact the glaciers at lacerating velocity, forming squalls of snow that pound the icy heights. A chaotic vista of sundered glacial peaks recedes into the foggy distance. Toward the horizon in all directions, dark cloudbanks scud through the

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gelid night, spiraling toward the midnight pole and shedding weight on their approach. The polar mountains are composed entirely of ice, accumulated age upon age, building in weight and height with each new squall. Forty kilometers thick and eight thousand kilometers across, the polar cap buckles bedrock down to the mantle, where geothermal warmth lubricates the ice with meltwater. Hundreds of darkling lakes perforate the belly of the ice continent, deep saline lenses sealed below the frigid crust, some as large as seas. All are sterile and still.

The ice massif extends nearly to the equator. Its mass encompasses two thirds of the available water on this planet's surface, and near the pole the frozen peaks reach 5,000 meters above the datum, almost to the edge of the compressed troposphere. The polar heights are the ultimate moisture shadow; cold and tall, no cloudbank can pass over them. On this world ice is twice as heavy, and glaciers crawl twice as quickly. As the massif builds it spreads outwards under titanic pressure, creeping and flowing in slow rivers toward the equator, toward the dawn. The polar cap is a permanent conveyor belt, accumulating moisture driven in high altitude winds from the sunward pole, and dispensing it slowly into cool and misty seas at the edge of night.

Dawn, Ginnunga Ocean, Gliese 581c (Planet Ymir)

Hulking glacial cliffs calve loudly into a pellucid violet sea. The blast of each cracking stack of separating ice echoes across tens of kilometers. In one direction purple ice floes extend in a crevassed march between black rocky hills, back to the shadowy horizon. Behind each jagged vertical thrust of ice, fixed shadows a kilometer long shelter narrow frozen ridges straight as lasers. At the opposite horizon a lurid half-sun crouches like a livid dome at the edge of the world. Incandescent beams of ruby, coral and apricot coruscate through the claret sky above gaps in the pregnant cloud cover. In the middle distance, indigo rain squalls glide over wine-dark waters. A fresh breeze with the momentum of a locomotive pushes magenta icebergs lazily about. Vast chunks of rotten ice pile up onto a gravel beach between the glacial toes. The heavy air is laden with salt, and the sour stench of sulfur.

At the water's edge, among the granite pebbles and broken quartz boulders, there is slime. Stringy coal-black filaments permeate the slime. The filaments form a continuous tangle, like matte cobwebs dusted in soot, occupying every square millimeter of space on every particle of wet sediment exposed to the tenuous dawn light. There are no filaments on the shadowed sides of the rocks, only occasional gray flakes of dried stringy matter where a pebble once faced the sun, but was tumbled by some random flake of falling ice or windborne grit. Where water meets beach, dark viscous clots float in the wind-chopped foam. Millions of miniscule bubbles decorate the slimy filaments and floating clots. As each bubble pops a whiff of brimstone is released; hydrogen sulfide, exhaled from billions of tiny globules growing upon the glistening rafts of mucus. The slime is alive.

Eons ago, where ice met dawn warmth, a world-circling ocean formed here. A necklace of seas marks the equator of this world, in the temperate middle where cool moist airs flow sunward, pulled by the rising thermal gales of the noon pole. In return, high warm currents flow toward the terminator into night, where their thin moisture condenses to snow and adds to the vast polar cap. As the ice spreads sunward under its hypergravitic weight, it feeds the necklace of seas with melt, nutritious rock flour, and yellow volcanic sulfur from subglacial volcanoes. At the juncture of light and fertile waters, life has formed colonies. In some windless coves the steady sunlight fosters vast fields of knobby growth below the water line, where microbial slime catches silt to erect mineral fortresses with a living skin. Claret light is greedily devoured by the colonists, who use every precious erg to build their insulating ooze. The photosynthesizers feed on volcanic sulfur dioxide, and bitter hydrogen sulfide exhaled by other colonists who feed on their waste. It is a simple ecosystem, but a robust one.

At the boundary of land and sea, crude bacteria find linked cell membranes offer strength, and exploit that strength to weave bodies into cobwebs to catch every infrared joule. Clever proteins capture heat as well as light, driving cellular machinery to assemble and proliferate onto every sunlit surface. Lurking among the filaments are other colonists; manipulative eaters of the dead, who scavenge the webs for every molecule of discarded carbohydrate and hungrily drink from the bath of oceanic sulfate.

In the largest of the fibrous marine mats, away on the sunward coast, there is a novelty. A race of the microscopic sulfate-breathers has developed a new ploy. One of its proteins acts as a camouflage, allowing it to penetrate the membrane of a living light-gatherer, and continue to feed from within the unwary host. As it feeds it pumps out sulfide waste, which is greedily absorbed by the photosynthesizing host. New vigor galvanizes the host, for now nestled inside its own cellular sheath is a personal dynamo that absorbs its waste sugars and exudes precious sulfide into its plasm. Host and invader are now one hybrid, and their union gives them clout. The hybrid multiplies faster than its neighbors, and shadows them to death with new layers of growth. It begins to spread.

As it multiplies through the necklace of seas, it diversifies into a wealth of alternate forms and chemistries. Each seeks more light, more warmth. The bizarre hybrid reaches the furthest sunward edge of the world-sea, and can go no further. It is blocked by heat, and by desiccation, and by simplicity. But it continues to struggle, dividing and replacing its progenitors with ruthless efficiency at each new chemical innovation. Eventually, in a quiet backwater in a placid purple bay at the sunward edge of the girdling sea a stray neutron, coasting at half the speed of light from an exploding sun many light years away, ricochets through the genes of a hybrid host cell. There is damage. There is also a lucky accident. One of the neutron's blunders flips a gene fragment the wrong way, and ribosomes begin to manufacture a weird new light-gathering protein. This protein can contract in sunlight, coiling like a spring and then releasing in darkness. As the new protein infiltrates the microbe, the cell begins to move. Plasmic springs contract with each warming photon, pulling the cell with amoebic grace toward the distant dawn.

The hybrid microbes have a new future. As each replicating blob drags itself over each mountainous pebble, a myriad of futures are forged. It has taken the hybrid, and the other colonists, four billion years to get this far, to emerge from their source in stygian volcanic fountains at the bottom of the world-sea and diffuse to the colder surface. It will take many billions of years more to gather themselves into shapes and geometries capable of dominating their world. But there is ample time. Their world is in its infancy, and their sun will burn for a trillion years.

Afterward

The preceding work of fiction is dedicated to the discoverers of Gliese 581c (Udry et al., 2007), who announced last month their find of the first known terrestrial extrasolar planet within the habitable zone of its star, Gliese 581, a red dwarf only 20.4 light years away. The Gliese 581 system has three known planets, all of which are mentioned in this fictional narrative. Planet "c", the middle planet between a massive inner neighbor that catapults around its star every 5.4 days and an outer Neptune-sized world with an 83.6 day orbit, is only five times as massive as the Earth and is likely to have a blackbody surface temperature somewhere between -3 and +40° C, depending on its (unknown) albedo.

This planet, which I've taken the hubristic liberty of nicknaming "Ymir", after the old Norse god whose corpse formed the world, is probably about 1.5 times the diameter of the Earth and has about twice Earth's gravity at its surface. The diameter is educated guesswork, of course, and depends largely on its assumed bulk composition. I took place names on Ymir also from the Norse creation myth: in the old sagas Muspell was a hot southern region and Niflheim a chilly northern, and where they met at the Ginnunga Gap life was engendered.

In my imagining of this planet I've assumed a few things. First, I've assumed that Ymir is tidally locked to its star, as our Moon is toward the Earth. Gliese 581c is close enough for liquid water to exist at its surface, but its sunward side should be searing hot while its night side should be sheathed in ice. On Ymir, water ice would be almost twice as heavy, but would be no stronger mineralogically, and so the icecap should undergo continuous viscous relaxation toward the sunlit side. The resulting hydrologic cycle I've envisaged is speculative, but I think it is entirely plausible if one assumes an Earth-like supply of surface water (or perhaps a little more).

Second, I assumed that because Gliese 581 is a low-metallicity red dwarf, it ought to have condensed planets with somewhat lower metal contents but substantially higher volatile contents than the inner worlds of our own star system. Terrestrial planets orbiting Gliese 581 probably have small to negligible iron cores, and ought to have mantles and crusts composed of silicates that are richer in the lighter elements sodium and magnesium, but poorer in heavier elements such as iron and calcium, compared to our world. Thus my depiction of a quartz-rich, granitic and probably high albedo crust.

Third, I've assumed that because calcium would be scarce, planktonic bacteria probably wouldn't crystallize calcite, leaving most of the planet's original complement of carbon dioxide in its atmosphere through geologic time. This would help to warm the planet and distribute enough heat around the globe to prevent the atmosphere from completely freezing out on the permanent dark side.

As far as life is concerned, what I've imagined here is entirely speculative, of course. However, if life does exist on Ymir (and no, I don't seriously expect anyone else to start calling the planet that) it will have evolved in a very low energy environment constrained by a weak sun and a geographic range limited by where water can stay wet. My assumption of an ecology built around sulfide-oxidizing phototrophs and sulfate-reducing heterotrophs, with incipient motility evolving first in endosymbiotic phototrophic hosts, is based on analogy with the evolution of complex life on Earth, but leaving out the evolution of oxygenic photosynthesis. On Earth only one branch of the Eubacteria ever evolved the latter trick, and green plants exist today only because they endosymbiotized (or were invaded by) photosynthesizing Eubacteria. I created what I imagine to be a plausible route to complexity on a world without oxygen but with ample sulfur (there is little iron to lock it away) and plenty of time.

And time they do have. Gliese 581 is a slow-burning red dwarf with sufficient hydrogen fuel to last long into the distant geologic future. If the orbits of Gliese 581's planets are stable over such time scales, Ymir might really have around a trillion years in which to play out its evolutionary drama. That should be more than enough time for us to take a trip there and back again, to see what mischief our neighbor is really up to.

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