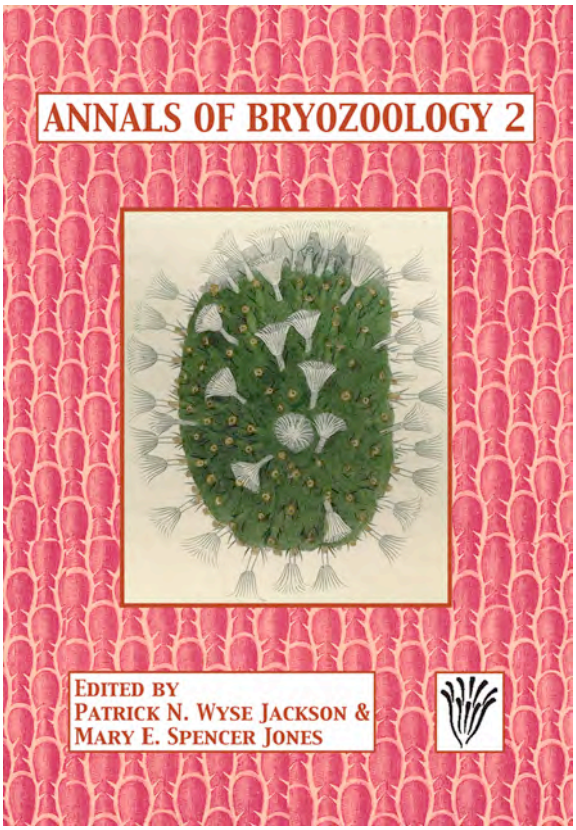

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Antarctic cyclostome bryozoans as paleotemperature proxies: historical background to early collecting expeditions

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1. Introduction
2. The expeditions
    2.1 British National Antarctic Expedition 1901–1904
    2.2 British Antarctic Expedition 1910–1913
    2.3 *Discovery* Investigations
        2.3.1 *Discovery* Expedition 1925–1927
        2.3.2 *Discovery* Expedition 1929–1931
        2.3.3 *Discovery* Expedition 1935–1937
    2.4 British, Australian, New Zealand Antarctic Research Expedition
3. Sample collection, sorting and storing
4. Hydrological data
5. Cyclostome bryozoans
6. Conclusion
7. Acknowledgements

1. Introduction

Geochemical proxies of ancient oceans have, to date, been obtained from low-Mg calcite from fossils, especially brachiopods and foraminifers. The search for additional reliable calcareous benthic organisms to use as environmental proxies has prompted an investigation of bryozoans from Antarctica. Bryozoans have been major contributors to carbonate sediments on polar and cool-water sea floors throughout the Cenozoic. Cyclostome bryozoans secrete their calcareous skeletal elements as low-Mg calcite,[1] are possible recorders of the geochemical conditions prevailing in their ambient seawater and thus may provide a proxy for the calculation of paleotemperatures.

Samples collected from Antarctic waters have been studied in order to investigate this possibility. A specific research cruise to collect bryozoans was not financially possible. Previous expeditions to these waters, though not designed to furnish bryozoan samples,

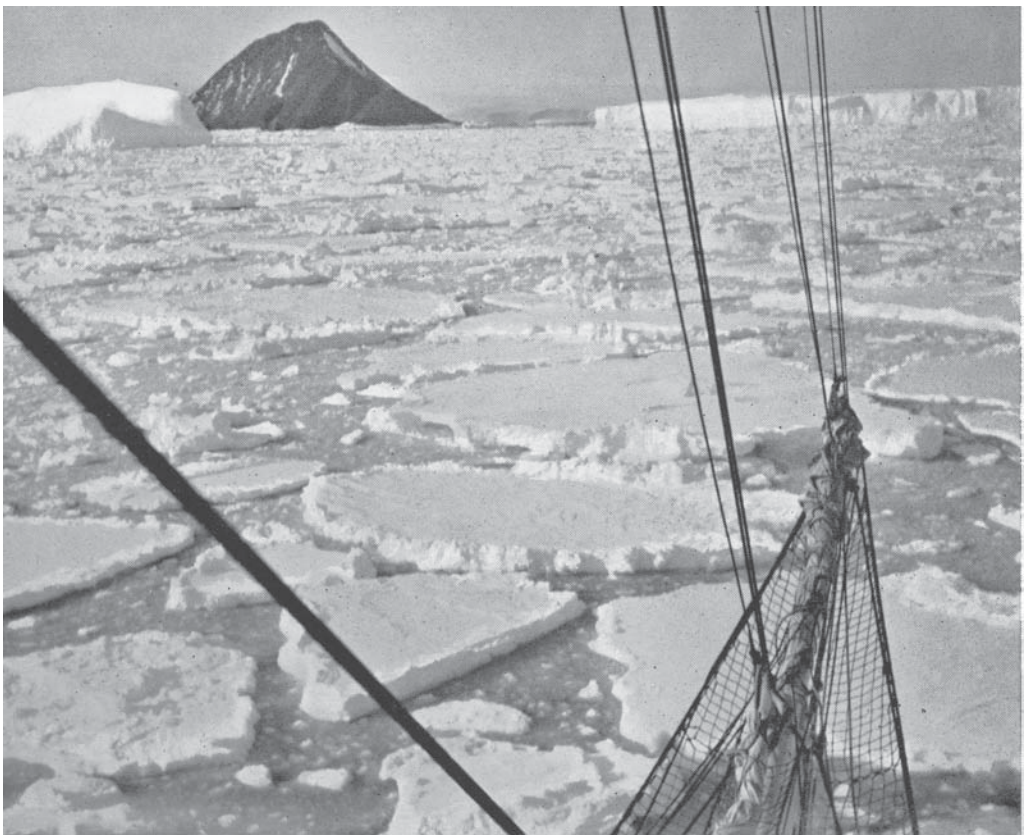

Figure 1. Proclamation Island from the sea, BANZARE. Note the dense sea ice. Photograph by J.F. Hurley (from Price 1963, see note 3).

nor even to study benthic invertebrates in general, have provided sufficient samples. Thus the far-reaching importance of the records of the early scientists, in what to them might have seemed of incidental significance, is demonstrated. Winzar[2] undertook a useful introduction to this study. She investigated cheilostome bryozoans collected by Sir Douglas Mawson on his British, Australian and New Zealand Antarctic Research Expedition (BANZARE), using samples stored in the South Australian Museum (SAM). The cyclostome bryozoans obtained from BANZARE samples from the SAM are included in the present study. The cyclostome bryozoans stored in the Natural History Museum, London (NHM) and collected from various Antarctic expeditions in the early twentieth century were also made available for the study. The Antarctic samples selected were all from south of latitude 60˚ south. It is possible that similar collections of material can be found in many museums around the world.

2. The expeditions

The Greeks, in ancient times, had postulated a New World of lush vegetation and a different race of people in the southern regions of the earth. It was not until the voyage of Captain James Cook in 1772–75, the first to cross the Antarctic Circle and observe the pack ice (Figure 1), that the true nature of the Antarctic continent was realised.[3] Numerous voyages were undertaken in the nineteenth century, mainly by Great Britain, France, the United States and Russia, for combined commercial (whales and seals) and scientific purposes as well as for empire-building and general exploration. James Clark Ross, for example, in 1840–41, led a British naval expedition to the Ross Sea area and in 1872–1876 the *Challenger* world-wide expedition gathered detailed observations of oceanographic phenomena, including the Southern Ocean.[4] By the end of the nineteenth century over-exploitation of whales in the Arctic forced a search for alternative hunting grounds. There was much discussion of the scientific benefits of expeditions to the Antarctic, but government support was lacking, indicating indifference to anything unlikely to result in a financial gain. It was a resolution passed at the 1895 meeting in London of the International Geographical Congress that prompted a new phase of Antarctic exploration and a growing interest among scientists.[5] Important achievements were made by many of these early expeditions, e.g. those led by Shackleton and Amundsen,[6] but only those expeditions from which cyclostome bryozoan samples were available for study are described herein. These expeditions are the British National Antarctic Expedition 1901–1904, The British Antarctic Expedition 1910–1913, Discovery Expeditions 1925–1927, 1929–1931 and 1935–1937 and the BANZARE 1929–1930 and 1930–1931 (Figure 2).

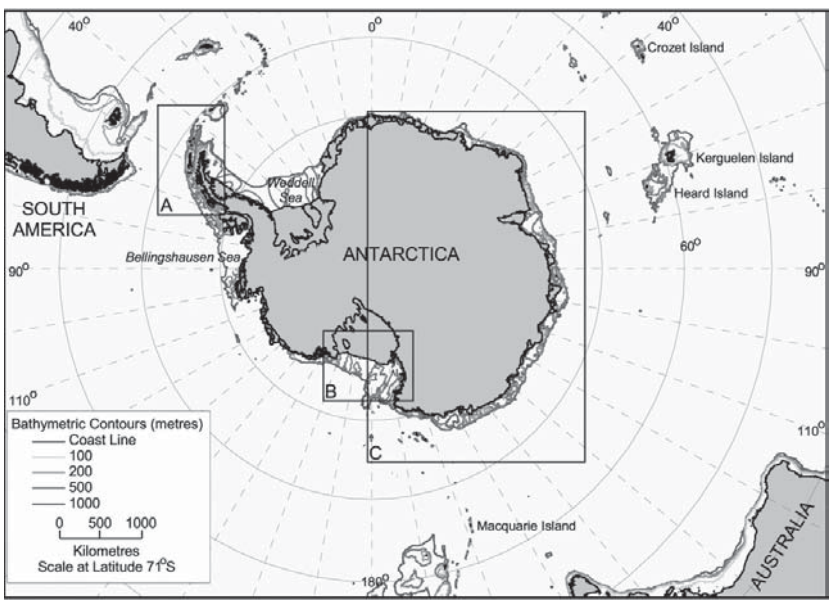

Figure 2. Antarctica: general location.

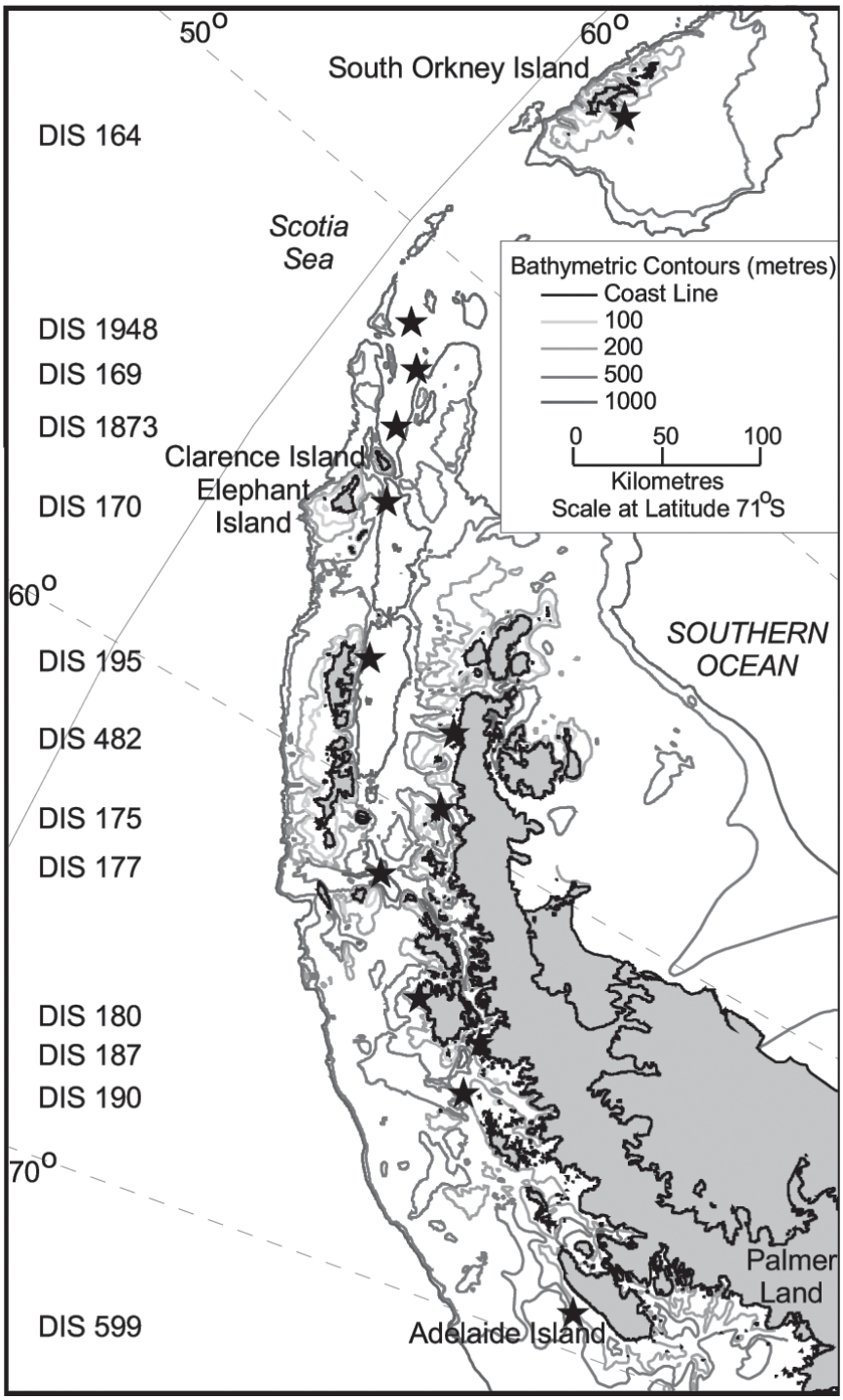

Figure 2A: Location of Discovery Investigation stations around the Antarctic Peninsula.

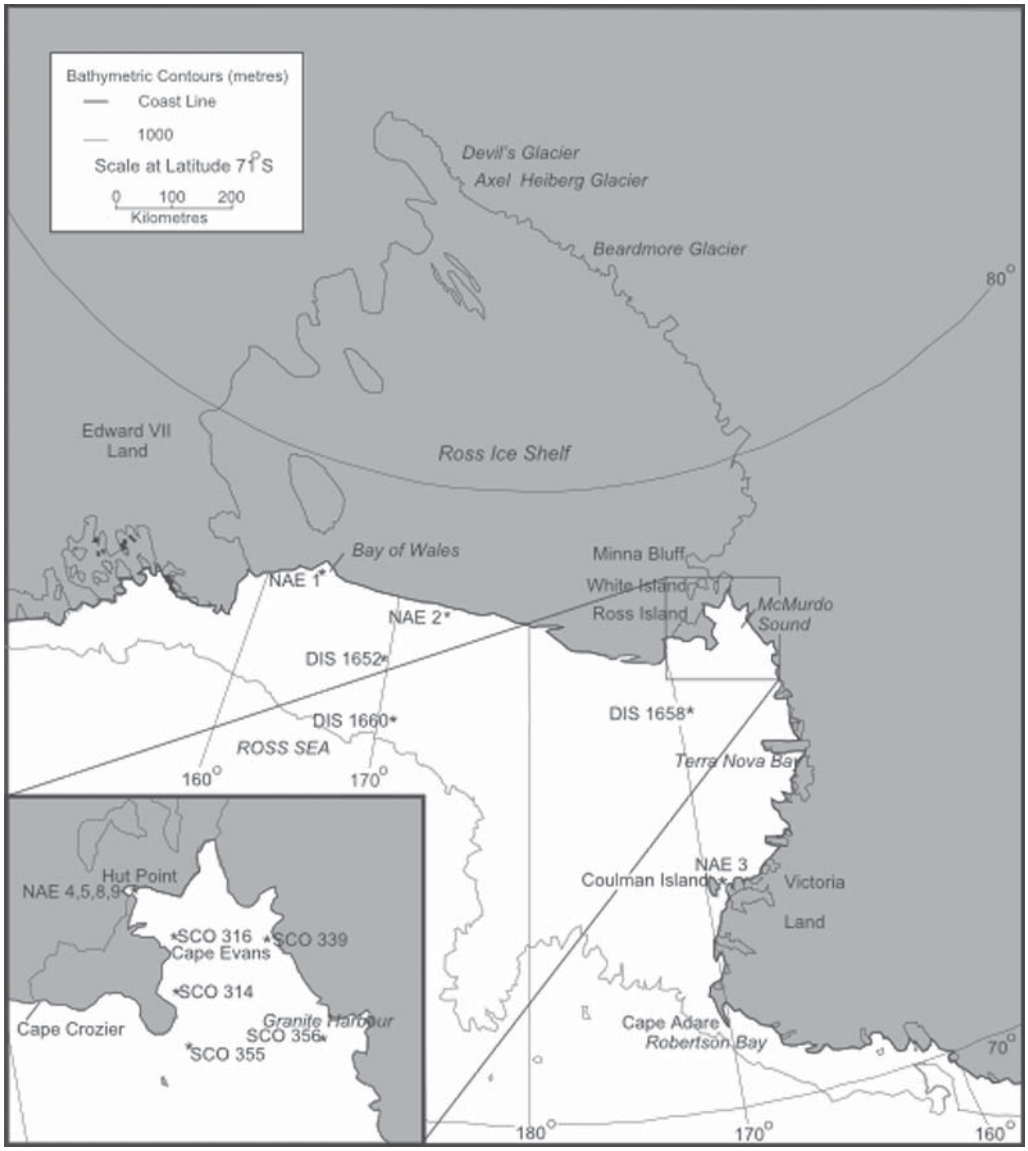

Figure 2B: Location of British National Antarctic Expedition, British Antarctic Expedition and Discovery Investigation stations in the Ross Sea.

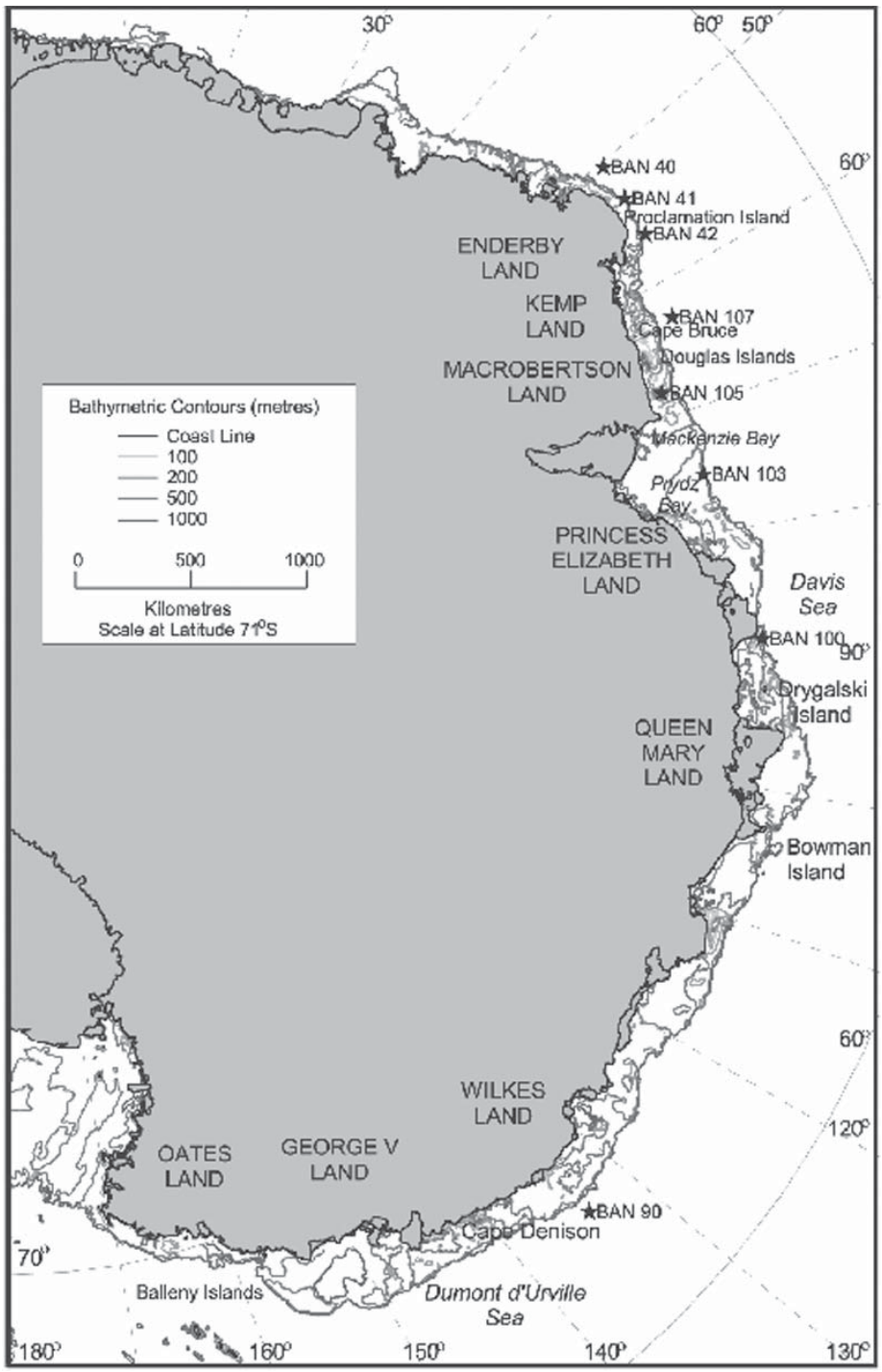

Figure 2C: Location of BANZARE stations in East Antarctica.

2.1 British National Antarctic Expedition 1901–1904

The British National Antarctic Expedition of 1901–1904 in the *Discovery* was one of four simultaneous expeditions arising from the 1895 International Geographical meeting. The president of the British Royal Geographical Society at the time was Sir Clements Markham, an explorer, geographer and author. Markham became obsessive about making the British navy the leader of polar exploration. He was responsible for raising funds and planning the expedition and was influential in choosing the personnel.[7] The Royal Geographical Society, the Royal Society, the government and private individuals gave financial support. The objects of the expedition were to determine the nature and condition of a portion of the South Polar regions, to make a magnetic survey to the south of the fortieth parallel and to carry out meteorological, oceanographic, geological, biological and physical investigations and researches.[8]

On the suggestion of Markham and judging that character was more important than experience in polar exploration, Robert Falcon Scott (1868–1912), an ambitious Lieutenant in the Royal Navy, was appointed to command the expedition. His second-in-command and navigator was Albert Borlase Armitage. Louis C. Bernacchi was the physicist and magnetic observer. Reginald Koettlitz, a botanist and bacteriologist, served as the senior surgeon. Edward Adrian Wilson was a medical doctor and also fulfilled a role as scientist, zoologist, artist and Scott's confidant.[9] Charles W.R. Royds was First Lieutenant and meteorological observer. Thomas V. Hodgson was a biologist who worked the dredge and trawl and the geologist was Hartley Travers Ferrar. Ernest Henry Shackleton was the Junior Executive Officer, in charge of holds, stores, provisions and deep seawater analysis. Only Armitage, Koettlitz and Bernacchi had previous polar experience. The total numbered forty-four (or forty-seven, depending on the stage of the voyage), with an average age twenty-five.[10]

The *Discovery* was a wooden sailing ship designed by W.E. Smith, with a 500 HP engine, built bythe Dundee Shipbuilders Company especially for the voyage.[11] *Discovery* left New Zealand on 24th December 1901 and crossed the Antarctic Circle (66˚ 30′S) on 3rd January 1902. The crew sighted Victoria Land (Figure 2B) on 8th January and landed at Cape Adare. They also landed at Coulman Island, Granite Harbour and Cape Crozier and then sailed eastwards along the edge of Ross Ice Shelf, then termed the Barrier, and landed at Balloon Bight (3rd February), near what became Shackleton's Bay of Whales (Figure 2B). A short sledge trip on the Barrier reached 79˚3′S and Scott and Shackleton made several flights in the tethered hydrogen balloon, *Eva*, to a height of about 210 m.

Discovery returned to McMurdo Bay (later McMurdo Sound) and Hut Point on Ross Island was chosen as the wintering site. They landed on 8th February and erected their hut for the winter. Sledge trips were made to White Island, Cape Crozier (Figure 2B) (on the return from which George Vince was lost when he slid off a sea cliff into the ocean) and south on the Ross Ice Shelf.[12]

Winter in Antarctica was spent collecting ice for water, fishing, killing seals and skuas for food and preparing for the spring activities. Scientific recordings of tides, meteorology

and magnetic observations continued. Reading, walking, debating, theatricals and arts and crafts of various kinds kept the crew entertained and the *South Polar Times* was published.[13]

Various sledging parties were undertaken beginning in September. An updated report was deposited at the previously designated post at Cape Crozier. A depot was established at Minna Bluff and later a support party supplemented the depot. The main southern sledging trip across the Ross Ice Shelf, of Scott, Wilson and Shackleton, with a support party ahead laying supplies, left on 2nd November 1902. Problems with skiing, rations, the dogs, especially when the support party was no longer ahead, and scurvy, particularly debilitating to Shackleton, meant they had to return short of their goal, having covered more than 1400 km and having reached 82˚17′S, the furthest south so far attained. They arrived at the *Discovery* on 3rd February 1903.[14]

The main western sledging trip, under Armitage, left on 29th November 1902. With support parties, their aim was to climb the mountainous Victoria Land and try to determine the extent of the Antarctic continent. They climbed the Blue Glacier and Ferrar Glacier (both west of McMurdo Sound) to the plateau and after 82 days returned to the *Discovery* on 19th January 1903.[15]

The relief vessel *Morning* was sent by Markham to report on the *Discovery*. On 18th January 1903, the *Morning* found the post left at Cape Crozier and by the 24th January was off Hut Point. Some supplies were left for the *Discovery* and some of the expedition, including Shackleton - reluctantly - because of scurvy, returned on the *Morning*. Although Scott was under orders to return to New Zealand, the *Discovery* was stuck in the ice and, despite various attempts, the ship was unable to move. This gave Scott and his party an opportunity to spend another year attempting to add to his achievements. The *Morning* departed Hut Point on 2nd March 1903.

Scott decided on two major sledging trips, each with a support team, and five smaller trips, for the spring and summer of 1903. Scott led a journey to the plateau via the Ferrar Glacier and found Taylor Valley, one of the dry valleys, later the subject of intensive geological work,[16] and Barne explored the large inlet south of McMurdo Sound. Local trips included a study of Emperor Penguins at Cape Crozier, led by Wilson.[17] Scott's party was the last to return, on 24th December 1903, to the *Discovery* where attempts were being made, by sawing and blasting, to free her from the ice.

Rising costs of the expedition meant the Royal Navy, rather than Markham, was given control. Two vessels, the *Morning* and the *Terra Nova* were sent to McMurdo Sound. They arrived there on 5th January 1904, with the orders that if the *Discovery* could not be freed from the ice, after all collections and valuable implements were transferred to the other two ships, the expedition must be abandoned. Transfer of the collections and instruments to the relief ships was begun and the date of 3rd March was set for abandoning the *Discovery*. After ineffectual ramming by the *Terra Nova* and blasting of the ice, large swell waves were finally successful in freeing the ship on 16th February. After much celebration and rearrangement of cargoes, a memorial service for Vince was held. Rising seas and a gale blew the *Discovery* onto a shoal but it was freed again and the three ships

headed north on 19th February and arrived at Lyttleton, New Zealand, on 1st April 1904.[18]

The NHM samples collected on the British National Antarctic Expedition, yielded sufficient cyclostome bryozoans for analysis from seven different stations in the Ross Sea (Figure 2B).

2.2 British Antarctic Expedition 1910–1913

Robert Falcon Scott's second Antarctic voyage, this time in the *Terra Nova*, was again supported by Sir Clements Markham, the Geographical Society and the Royal Society as well as by many individuals. The expedition consisted of 33 men drawn from all walks of life. The *Terra Nova,* built in 1884 by Alexander Stephens and Sons, Dundee as a whaler, was a sailing ship with auxiliary steam power. The steam engines were rated at 140 HP and provided power for the pumps and to melt ice for drinking water.[19]

The *Terra Nova* left London on 1st June 1910, called at Melbourne and departed from Lyttleton, New Zealand, on 29th November 1910. The pumps broke down on their way south in a storm and the ship was kept afloat by a bucket brigade. Attempts to land at Cape Crozier and Hut Point were unsuccessful due to the swell and to ice and Cape Evans was chosen as the wintering site. Stores were landed and the hut sufficiently completed to move in on 17th January 1911.

The main aims of this expedition were to reach the South Pole and to carry out scientific research, both as part of the polar journey and in Victoria Land.[20] Unknown to Scott, the Norwegian Antarctic Expedition, in the *Fram* and led by Roald Amundsen, set out in the same year, 1910, initially aiming to travel to the North Pole but changing plans to reach the South Pole. Amundsen's was a secretive, small and meticulously planned party, with each man highly skilled in polar travel. They made their base at Bay of Whales, landing on 14th January 1911, and set about transporting supplies to depots on the proposed route. Winter was spent making adjustments to equipment and ensuring that their dogs were fit and healthy. The weather prevented them departing until 20th October 1911. They crossed the Ross Ice Shelf and began their climb over the Transantarctic Mountains by way of Axel Heiberg Glacier and the Devil's Glacier (Figure 2B). Amundsen's party were the first to reach the South Pole under extreme conditions. They placed black marker flags and a small tent with supplies at the Pole on 14th December 1911. The journey of 2610 km took 99 days, ending on 25th January 1912. They returned via Hobart, reporting their success to the rest of the world.[21]

In early 1911, when Scott's sledging parties began transporting supplies to the depots across the Ross Ice Shelf in preparation for the polar journey, the *Terra Nova* departed with the eastern party under Campbell and Griffith Taylor's western geological party to the Royal Society Range, westward across McMurdo Sound. Taylor's party was landed at Butter Point, due west of Cape Evans, on 27th January 1911 from where they explored the Royal Society Range noting many geological features and the conditions of the ice. They returned to Hut Point on 14th March 1911.[22] The following year the second geological journey, again under Taylor, extended the work northwards to Granite Harbour (Figure

2B) and inland along Mackay Glacier from 7th November 1911 to 12th February 1912. Though most of the time was spent sledging and backpacking, they were able to collect and photograph rock samples, mainly granites, diorite and gabbro but also including coal and some fossils (age not given). They studied moraines and evidence of former ice action as well as making a detailed survey of the coast and hinterland.[23]

The *Terra Nova*, having landed Taylor's party, continued with the eastern party along the Ross Shelf, noting the ice shelf changes. Unable to land at Edward VII Land because of the ice they returned westward to the Bay of Whales where they saw Amundsen's ship, the *Fram*. Campbell discussed plans with Amundsen and, after sounding and dredging in the Bay of Whales, returned to Hut Point to inform Scott. The eastern party, now judged to be superfluous because of Amundsen's presence, became the northern party. They were landed at Cape Adare by the *Terra Nova*, where they spent the winter and, beginning on 28th July 1911, they began a series of sledging trips making an accurate survey of Robertson Bay and collecting geological, glaciological and meteorological data. They were picked up on 6th January 1912 and disembarked in Terra Nova Bay. Campbell and his party spent six weeks exploring the glaciers that emerge on the piedmont of the Bay. They were ready for the return of *Terra Nova* on 17th February 1912, but that proved impossible due to the ice and storms, though several attempts were made. Campbell's party had to fend for themselves. They dug a cave on the aptly named Inexpressible Island and during the winter overcame many domestic problems, such as heating, cooking, ventilation, lighting, diarrhoea and depression. They existed on seals and penguins and their meagre remaining food rations. They began their sledge journey back to Cape Evans on 30th September, relieved to find food at several depots on the return journey and arrived on 7th November 1912 to a hearty welcome.[24]

Two shorter journeys were made from Cape Evans. Around mid-winter 1911, under remarkably difficult conditions, three men journeyed from Cape Evans to Cape Crozier to collect Emperor Penguin eggs. Much was learned about the difficulties of winter journeys, though few penguins were observed.[25] A party climbed Mount Erebus in December 1912, spending two weeks on the upper slopes surveying the craters, calderas and fumaroles and collecting rock specimens.[26]

Scott's polar party set out from Cape Evans on 26th October 1911 for the South Pole. They reached Hut Point on their way across the Ross Ice Shelf to the Beardmore Glacier. The motor sledges broke down early in the journey, the horses were deteriorating rapidly and had to be shot, the dogs were turned back and the men hauled the sledges for the remainder of the trip. Blizzards held them up for four days. Five men made the last stage to the Pole arriving there on 18th January 1912 only to find that Amundsen had raced them by 34 days. They headed north on 19th January and for the first week made good progress, though they were all suffering from frostbite. Evans was the first to succumb, collapsing on 18th February never to regain consciousness. Oates, suffering from gangrenous feet, left the tent on 17th March saying "I am just going outside and may be some time".[27] He did not want to hinder their progress, his self-sacrifice improving the chances for the rest of the party. Scott recorded in his diary that his own feet were now frostbitten and would

necessitate amputation of the right foot if they made it back. Scott knew that they had little chance when a blizzard confined them to their tent. Awaiting death, Scott's last entry in his diary was made on 29th March only 17 km from a food depot.[28]

Winter prevented a search party until the end of October 1912. The party spotted Scott's tent on 12th November and found the three bodies (Scott, Wilson and Bowers) inside. They erected a cairn in remembrance of the three, and then searched for Oates, but found only his socks and boots. A cross was erected in honour of "a very gallant gentleman" .[29]

The remainder of the expedition returned to New Zealand on 11th February 1913. Scott and his team were hailed as heroes when the news reached the outside world.[30] In later years Scott and his men were regarded by some "not as stoic pioneers but as inept bumblers". Solomon[31] has researched the expedition from the point of view of contemporary scientific information and concluded that, with the knowledge available to them at the time, Scott and his men were as prepared as possible for the conditions they were to experience.

The British Antarctic Expedition samples stored in the NHM included cyclostome bryozoans sufficient for this study from five stations in McMurdo Sound (Figure 2B).

2.3 Discovery *Investigations*

Those nations who had been interested in Antarctic research were left with few resources to spare for expeditions after the First World War. One problem, that of regulation of whaling, however, was considered of great importance. Norway had established a whaling station at Grytviken on South Georgia in 1904. Great Britain, in 1908, recognising that this was the most profitable whaling ground, constituted the Falkland Island Dependencies covering islands around the Scotia Sea such as South Georgia, South Sandwiches, South Orkneys and South Shetlands and the tip of the Antarctic Peninsula (Figure 2A). Most had been discovered and claimed by British nationals. Regulations to restrain the slaughter of whales were introduced and in 1920 a report was published proposing research to be funded by taxation of the whaling and sealing industries. Scott's old ship, the *Discovery,* was purchased, reconditioned and renamed Royal Research Ship *Discovery* (Figure 3) thus giving its name to the whole program.[32] Stanley Kemp was made the Director of Research for the *Discovery* Committee.

Stanley Wells Kemp was born in 1882 and was educated at Trinity College, Dublin. His scientific career began as a naturalist in the Fisheries Branch of the Department of Agriculture for Ireland where he worked from 1903–1909. His next appointment, from 1910–1924, was as Superintendent of the Zoological Section of the Indian Museum and, later, the Zoological Survey of India. He was the Director of Research to the Discovery Committee of the British Colonial Office from 1924–1936. He was Secretary to the Marine Biological Association of the United Kingdom and Director of the Plymouth Laboratory from 1936. Kemp held a Doctor of Science and was a Fellow of the Royal Society. He published scientific papers on marine biology and geography. He died in 1945.[33]

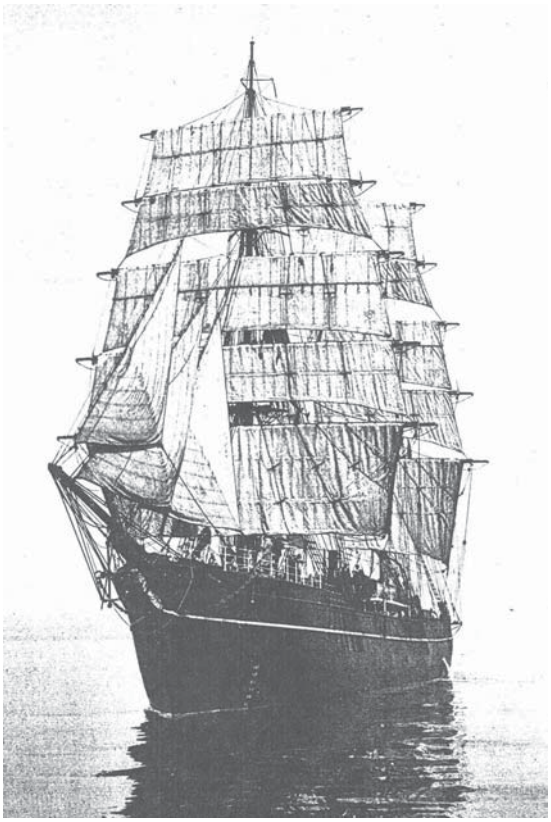

Figure 3. Royal Research Ship Discovery *under sail, Discovery Investigations (from Kemp & Hardy 1929, see note 11).*

The work of the *Discovery* Investigations, though designed for the benefit of the whaling industry, included basic studies in oceanography - physical, chemical and biological. It was recognised that in Antarctica the knowledge of whales and of the various factors that influence them, such as migrations, rate of growth, gestation period, nature of food, feeding habits, etc, was virtually non-existent. The charting of the waters was judged to be crucial for the safe passage of ships in the area. The biological work was planned around an environmental study of the major food of whales, krill (*Euphausia superba*), that feed on diatoms, the distribution of which is dependent on the physical and chemical constituents of the water. The amount of work required was enormous and the area immense, so limits had to be set based on economic needs. Most work was centred in the Scotia Sea and concentrated on plankton studies. Trawling and dredging of benthic organisms was considered less relevant and was undertaken only when circumstances allowed. The need for a high-speed vessel, similar to the ones used by the whale catchers, but also capable of carrying out work on plankton and hydrology, was met by the commissioning of the Research Steamship *William Scoresby*. It was launched in 1925 and apart from a brief return to England in 1927, worked almost continuously in the Antarctic.[34]

2.3.1 Discovery *Expedition 1925–1927*

The first of the *Discovery* Investigation expeditions in the *Discovery* was led by Dr Kemp. The major objective of the expedition was to conduct a preliminary oceanographic survey of the Scotia Sea area (Figure 2A,[35]). As a measure of the rate of work of these early investigations, the *Discovery* and *William Scoresby* between them obtained samples from 54 vertical stations (see page 26) at up to 17 depths all within 52 days in December 1926. Much of this expedition was to an area north of latitude 60 degrees south and so was not within the scope of this study.

Cyclostome bryozoans were collected from eight stations around the South Orkney and South Shetland islands and the Palmer Archipelago.

2.3.2 Discovery *Expedition 1929–31*

This was the first expedition of the Royal Research Ship *Discovery II* built in 1929, a steamship of 1036 tons made of strengthened steel, capable of greater speed and range of action than *Discovery* and thus more suited to extended oceanographic work. It was built by Ferguson Brothers at Port Glasgow and was launched on 2nd November 1929.[36] This expedition led by Stanley Kemp again concentrated on oceanographic work around the Scotia Sea whaling grounds, though exploration was extended to the South Atlantic Ocean and the west coast of the Antarctic Peninsula and the Bellingshausen Sea.[37]

Cyclostome bryozoans were collected from two stations off the Antarctic Peninsula.

2.3.3 Discovery *Expedition 1935–1937*

A circumpolar oceanographic voyage, led by George Edward Raven Deacon, was planned in *Discovery II* from 1935 to 1937. Plans were disrupted in December 1935 by the search for the American Lincoln Ellsworth in a plane piloted by Herbert Hollick-Kenyon, a Canadian. They had planned a flight across Antarctica from Dundee Island at the tip of the Antarctic Peninsula to the Bay of Whales in the Ross Sea. Problems encountered included a failed radio, poor visibility, a blizzard and shortage of fuel. After many unscheduled landings, they completed their journey to the Bay of Whales on foot. In response to a request for help, *Discovery II* was sent from Australia to the area to find them and transport them back to their base ship. The revised *Discovery II* program was limited to observations in the Ross Sea as well as the previously planned work in the Scotia Sea area.[38]

These *Discovery* expeditions furnished samples of cyclostome bryozoans sufficient for analysis from seven stations in the Scotia Sea and in the Ross Sea (Figures 2A, 2B). Cyclostome bryozoans were identified from additional stations but were in insufficient amounts for analysis.

2.4 British, Australian, New Zealand Antarctic Research Expedition 1929–1930 and 1930–1931

After the First World War interest in Antarctica was revived by the possibility of economic advantages, territorial claims and especially to take advantage of the profits in the whaling industry. Australia decided to undertake an expedition to raise the flag between Enderby and Oates lands (Figure 2C) i.e. between 45˚ and 160˚ east longitude and to expand on Douglas Mawson's Antarctic research. He had been a part of the 1907–1909 British Antarctic Expedition under Shackleton and also was the organiser of the Australasian Antarctic Expedition of 1911–1914. Mawson was appointed leader of this new expedition on 4th February 1929. Britain agreed to lend *Discovery*.

Mawson and the scientists (Figure 4) joined the *Discovery* in Cape Town and departed from there on the 19th October 1929. *Discovery* had already been refitted with wireless, electricity and other improvements and carried an aeroplane, a de Havilland Gypsy Moth. This expedition was to be confined to the sea, so dogs were not required for transport. They proceeded to Crozet Islands, Kerguelen Island and Heard Island in the southern Indian Ocean. Southeast of Heard Island they sounded a shallower region of the ocean, which they termed the Banzare Rise. They encountered floating ice and then pack ice from there southwards and the opportunities for aerial reconnaissance were limited as smooth seas free of ice were necessary to launch the plane. Eventually they launched the plane at 66˚10′S, 65˚10′E and discovered Douglas Islands (Figure 2C) and, at 60˚35′S, 61˚17′E,

Figure 4. Douglas Mawson and the scientific personnel on the BANZARE. Mawson is third from the right in the middle row. Photograph by J.F. Hurley (from Price 1963, see note 3).

they discovered part of the Antarctic continent, which was later named Mac.Robertson Land (Figure 2C) in honour of the chief patron of the expedition, MacPherson Robertson. They landed on an Enderby Land island, named it Proclamation Island (Figure 2C) and claimed Enderby, Kemp and Mac.Robertson lands for the Crown on 13th January 1930. Approaching the western limit of the assigned study area on 14th January, they met *Norvegia* off Enderby Land and soon after *Discovery* turned east. A continuous program of scientific observations was carried out on board ship, including meteorology, hydrology and biology. They made several short flights on 24th and 26th January 1930, during which numerous peaks rising from the Antarctic ice plateau were plotted. They then turned north, necessitated by dwindling coal supplies which were replenished at Kerguelen Island and departed for Australia on 2nd March, reaching Adelaide on 31st March 1930.[39]

The economic depression almost curtailed the second season, though the Norwegians, still actively exploring, gave the impetus. Mawson departed Hobart on 22nd November 1930, and called at Macquarie Island midway between Australia and Antarctica. They obtained coal and fresh water further south, from the Norwegian whaler *Sir James Ross Clark*. Mawson was unable to land at Balleny Island as planned because of pack ice. He obtained additional coal from the whaler *Kosmos* and continued to Cape Denison on the coast of George V Land (Figures 2C, 5) where he landed on 4th January 1931 and claimed it for the crown. Geomagnetic and other scientific observations were made. He then headed west, keeping well offshore to avoid the pack ice. Flying conditions were difficult and the aeroplane was nearly lost. The plane, nevertheless, enabled Banzare, Sabrina,

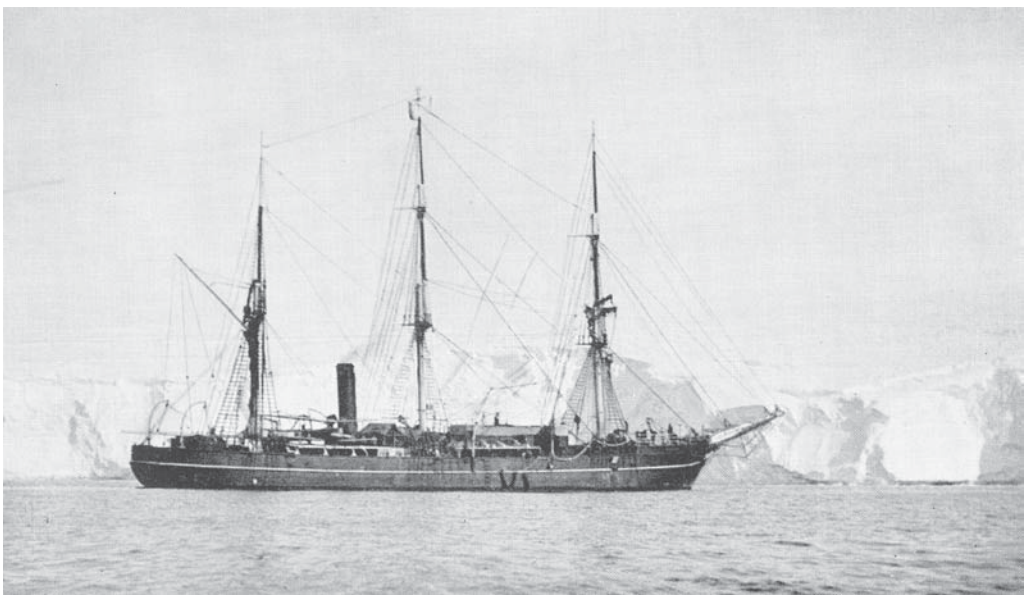

Figure 5. Discovery *off George V Land, East Antarctica, BANZARE. Photograph by J.F. Hurley (from Price 1963, see note 3).*

Budd and Knox lands to be sighted. Mawson saw Bowman Island on 28th January and noted that the Termination Ice Tongue that he had charted in 1911–1914 was no longer there. He was unable to land on Queen Mary Land, where they planned to visit the Emperor Penguin rookery, and continued further west. They obtained coal from a Swedish collier, *Lestris*, on 6th February and named Princess Elizabeth Land and Mackenzie Bay on 9th February. They passed Mac.Robertson Land, noting a great difference in ice conditions compared with the previous visit and were able to chart the coastline. They landed on the Kemp coast, claiming it at Cape Bruce at 61°30′E on 18 February and made bird and rock collections. They began their return to Australia on 19th February, passing over the Banzare Rise, which they had located on the previous voyage, and obtainied additional soundings. They completed their journey to Hobart arriving on 19th March 1931.[40]

A tremendous volume of data had been recorded and many specimens collected on these two voyages from Oates Land to Enderby Land and much of the coast was charted and claimed for the British crown. Oceanographic investigations were continued, principally off the continental shelf. Regular water samples were analysed and depth soundings made, enabling the plotting of the 500 and 1000 m submarine contours. Biological observations, especially of plankton, bacteria and bird life, at various vertical stations and from several sites on the mainland and on the Sub-Antarctic islands they visited, were made. Dredging was carried out to sample life on the sea floor and also to sample the glacially transported erratics from the continent. Rocks exposed on the shore were of particular interest to Mawson, the geologist, and these were collected. Meteorological data and magnetic and cosmic radiation studies were made. Hurley made a photographic record of all activities. The aeroplane, despite the difficult weather conditions, enabled many more areas to be examined than could have been seen from the ship alone.[41]

Cyclostome bryozoan samples sufficient for analysis and stored in the SAM were collected from eight BANZARE stations (Figure 2C).

3. Sample collection, sorting and storing

The adverse weather conditions experienced on these expeditions, including the low temperatures, strong winds, low visibility under foggy conditions and the worry of icebergs and pack ice (Figure 1) meant that the collection of biological samples was frequently curtailed in consideration of the safety of the ship. Working conditions were difficult at the best of times. The southern summer was the planned duration of Mawson's expedition, but Scott's expeditions and the Discovery Investigations continued throughout the year. The long hours of darkness in winter disrupted physiological rhythms but this was compensated to some extent by the longer days in summer. Rough weather resulted in the rolling of the ship. The low temperatures, and hence the freezing of stores and water samples, and the high humidity had to be overcome. Damage to the equipment, especially to the small trawls, by large boulders on the seabed caused delays.[42] The voyages of Scott and Mawson, in particular, were of an exploratory nature as few expeditions had been to these areas and the available charts of the coastline were incomplete if not non-existent.

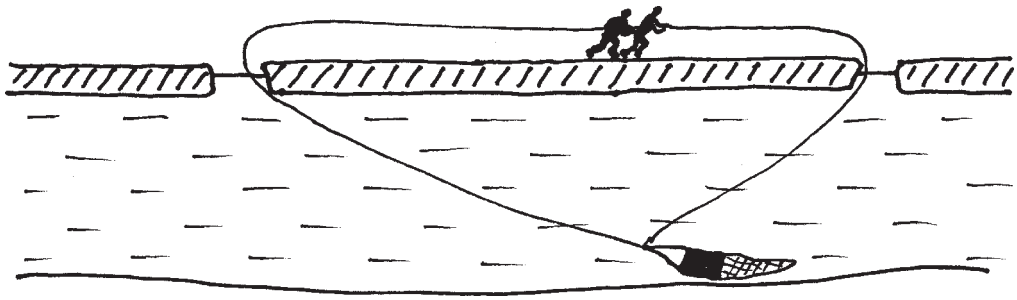

Figure 6. The method of dredging beneath the ice on British National Antarctic Expedition. (Redrawn from Wilson 1966, see note 56).

These two leaders were aiming to collect as much scientific information as possible, though Scott also held the attainment of the South Pole as a high priority. The Discovery Investigations in the early years had a more specific aim, that of gathering data on the whales and on the plankton on which they depended. Most of the stations from which biological data were collected on these expeditions were 'vertical' stations at which hydrological data were recorded and plankton nets of various types were towed at a range of depths down to several thousand metres.[43] Dredging and trawling of the ocean bed, by which bryozoans were collected, were considered of lesser importance and were mainly carried out in shallower waters (<1100 metres depth) and when weather permitted. For Mawson, the geologist, in addition to the benthic biota collected, there was the prospect of picking up ice-transported erratics derived from the south which, to Mawson, gave evidence of the continental nature of the land mass.[44] The biologist on the National Antarctic Expedition, Hodgson, even managed to dredge beneath the ice in the winter. In 1905 Scott described his method thus: "after a cold snap fresh cracks are formed in the ice-sheet across the straight, and these open out perhaps two or three inches. Before the space left has time to freeze thickly, Hodgson goes out with a long line and presses the bight down between the sides of the crack until it is hanging in a long loop between points two or three hundred yards apart. Then at each end of the loop he starts to dig a large hole."[45] A net is dragged along the bottom from the first to the second hole and then in reverse and the contents collected, sledged back to the ship, defrosted and preserved in jars for later study (Figure 6).

The dredges and trawls collected an amazingly rich and varied animal life on the Antarctic seabed (Figures 7 & 8). Hardy who was on the *Discovery* in 1927 later described in 1967 one of these exercises off the tip of the Antarctic Peninsula: "We made up to the lee of Clarence (island), for the weather, none too good, was freshening, and here we took a cast with the dredge in 343 metres depth. The life below appears to get richer and richer; I am only recording a few of these hauls we made. On this occasion our dredge was again on the bottom for just five minutes: yet such was the varied collection of animals it brought up that, with all of us working hard, we have only tonight, twenty-four hours later, got all the material sorted labelled and put away".[46]

Figure 7. A huge catch from a trawl, BANZARE. Photograph by J.F. Hurley (from Price 1963, see note 3).

Figure 8 . D.G. Lillie with some of the siliceous sponges obtained from the British Antarctic Expedition (from Scott 1913, see note 23).

The laboratory on the *Terra Nova* was small. Wright described it thus: "When we want to do some work in our lab. We have to take out a whole lot of boxes of apparatus and put them on the deck in order to get in ourselves".[47] The *Discovery, William Scoresby* and *Discovery II* were all provided with small laboratories and the efficient use of the limited space was meticulously planned.[48]

The biologists, on receiving a haul from a dredge or trawl, first separated the larger specimens for preservation, treating the different biota in different ways, which they developed by trial and error to allow the most beneficial result for later examination (Figures 9 & 10). All the specimens were stored in jars in 10% neutralised formalin or 70% alcohol preservatives. Smaller biota, caught in fine mesh nets fixed behind the trawl, were also included. The sand and gravel were sieved to examine the smallest forms and broken fragments. The water samples were analysed, as soon as possible after collection, for temperature, density, salinity, pH, phosphate and oxygen content. Some of these analyses for the Discovery Investigations were carried out on return to the whaling station at King Edward Point, South Georgia[49] and some of the analyses on the BANZAR Expedition were made at the University of Melbourne Chemistry Department. The methods used are described by various authors.[50] The species were partially identified, counted and recorded in a logbook by the biologists on board. Much later, specialists described and

Figure 9. Scientists sorting a trawl catch on the deck of the Terra Nova*, British Antarctic Expedition (from Scott 1913, see note 23).*

Figure 10. Sorting specimens dredged from the sea floor, BANZARE. Photograph by J.F. Hurley (from Price 1963, see note 3).

drew the groups which were their specialty and at least some systematic accounts were published in scientific reports.[51]

Bryozoans are benthic colonial invertebrates and were therefore only collected on the dredges and trawls of the Antarctic expeditions. They were not regarded as important objects of study, despite the fact that some of the samples examined contained a large number of bryozoan species and that many of the finer fractions were predominantly bryozoan fragments. Hardy in describing the 1927 expedition on *Discovery* mentioned polyzoans, the former name for bryozoans: "some possessed the finest stony skeletons, some branching and plant-like, others, even more beautiful, forming a lattice either in the shape of curved fans or complete cups of wavy outline like little baskets of delicate porcelain".[52] This is one of the few references to bryozoans found in the early Antarctic literature. The scientific reports on bryozoans from the expeditions described here include that of Hastings[53] (1943) which was concerned only with cheilostome bryozoans from various Antarctic expeditions and Winzar[54] (1998) who described cheilostome bryozoans from Mawson's expedition of 1929–1931. However, no report is known of cyclostome bryozoans from the expeditions described herein although in recent decades bryozoan studies from Antarctica have increased steadily.[55]

For this study the bryozoans from the BANZARE were selected from jars labelled either as 'Polyzoa' or 'Residue' and with the station number. The cyclostome bryozoans were selected from these jars using an Olympus binocular microscope. The samples of bryozoans stored in the natural History Museum, London had been sorted, given a Kemp number and stored in separate plastic containers. Some had been partially identified. The

Kemp number allowed the tracking of the station number and hence the hydrological details for any sample for which the station number was not directly recorded in each container.

4. Hydrological data

The reports of the Discovery Investigations and the BANZARE contain detailed descriptions of the equipment used for measuring the depth, temperature, salinity and chemical components of the water. The location of the stations is also accurately recorded. No such descriptions, however, have so far been identified for Scott's expeditions. The precise locations of the stations of Scott's first expedition, the British National Antarctic Expedition, are not known. The approximate location has been allocated by comparison of the descriptive location of the sample (e.g. Off Glacier Tongue about 8 miles north of Hut Point), the collection date shown on the sample, the diaries of Edward Wilson[56] and the dates on the routes shown on the charts of the expedition also published by Wilson in 1966.[57] The station numbers allocated are: 1 – East end of Barrier; 2 - Off Barrier; 3 - Off Coulman Island; 4 - Hut Point, which includes stations listed on the samples as Hut Point, WQ, McMurdo, Nos 4, 6, 10, 11 and 12 holes and Glacier Hole.

Depth measurements were made using Lucas or Kelvin sounding machines until the echo sounder became available.[58] The depth of collection varied from 0 to 1100 metres. The surface temperature at the collection site varied from –1.58 to +0.35°C. The temperature recorded even at the depth of collection was within this range, although the variation of temperature with depth is available for only a few stations (Appendix 1). There is a variation of only about one degree from the surface down to 1100 metres. Salinity varies between 32.87 and 34.51 ‰ at the surface and between 33.66 and 34.89 ‰ on the seafloor. The depth of collection, the surface temperature and salinity of the seawater (where available) are listed in Appendix 1.

The techniques and equipment used to obtain these data today are significantly modernised. Thus the information presented for these early expeditions may not be accurate. This is illustrated by a comparison of the depth of the BANZARE stations with the latest mapped depth at the positions recorded for each station. There are many possible reasons for this discrepancy, e.g. the position may be inaccurate, the depth of the station was measured by a length of wire which may have descended at a greater than expected angle resulting in an incorrect estimate of depth, and there may have been subsequent bull-dozing of the ocean floor by ice bergs. What are of importance are the relative depths – shallow, medium or deep – rather than the exact depth in metres.

5. Cyclostome bryozoans

The cyclostome bryozoans selected from the samples were sonic washed for two minutes, bleached in 20% sodium hypochlorite (household grade bleach), rinsed and then sonic washed again. Images of the specimens were made using a Field Emission Scanning

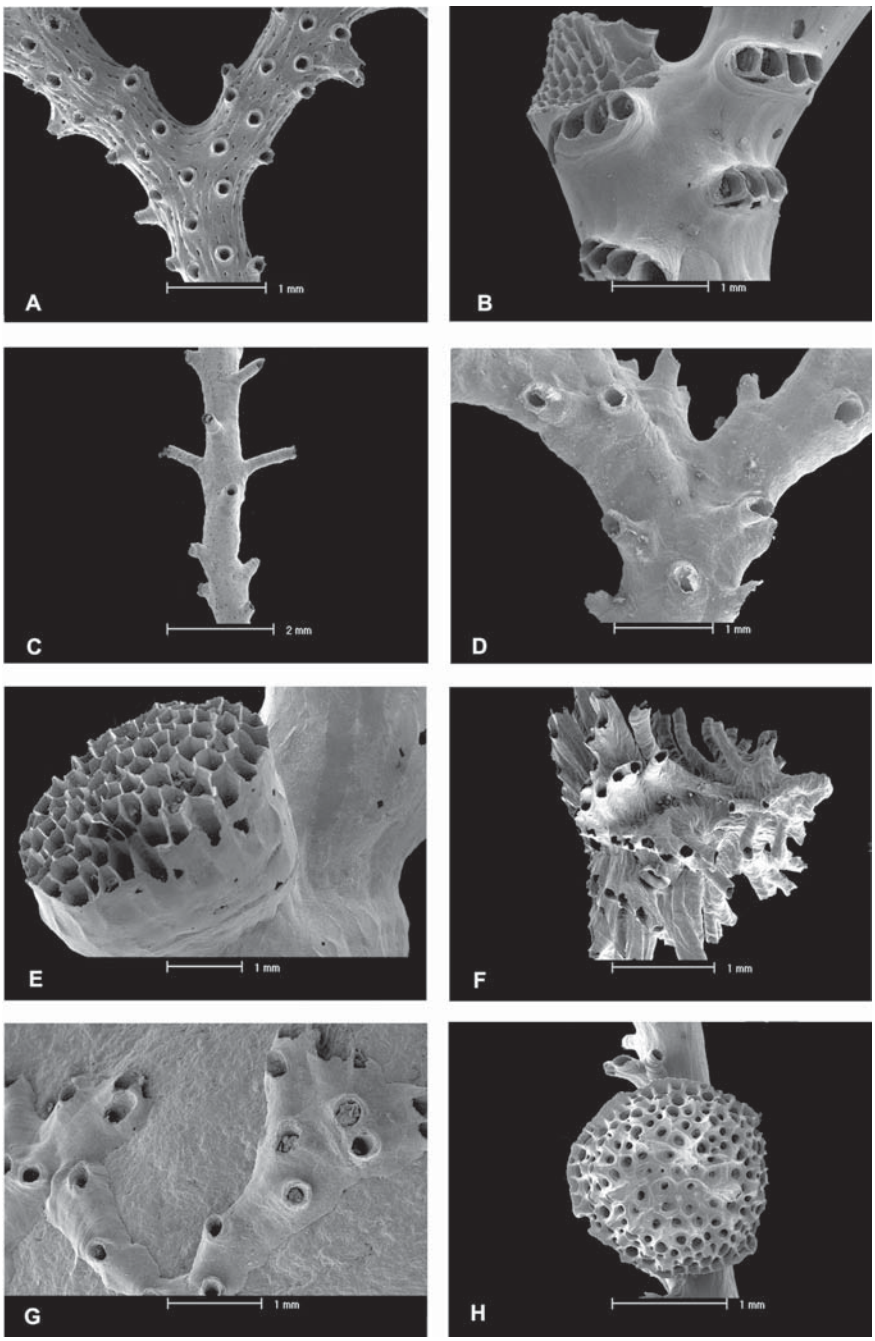

Figure 11. Some of the cyclostome genera identified from these Antarctic expeditions. A Hornera/Pseudidmonea. *B* Idmidronea/Exidmonea. *C* Entalophora/Mecynoecia/Diaperoecia. *D* Nevianipora/Tervia. *E* Fasciculipora. *F* Tubulipora/Liripora. *G* Oncousoecia. *H* Lichenopora/Disporella/Patinella.

Electron Microscope (Philips XL 30 with Edax) for identification and production of a catalogue. The genus of the cyclostome bryozoans was identified (Figure 11). Cyclostome bryozoans were recorded from 27 stations south of latitude 60˚S. As they were collected at high latitudes and at the beginning of the twentieth century before any significant influence of humans, the samples can be considered as close to pristine as possible. The number of cyclostome genera at each station ranged from one to four. The identification of the species must await further work. The cyclostome genera most commonly occurring were *Hornera*/*Pseudidmonea* spp., *Idmidronea*/*Exidmonea* spp., and entalophorids, with less common *Nevianipora*/*Tervia* spp., lichenoporids, tubuliporids, *Oncousoecia* spp., *Telopora*/*Supercytis* spp., *Fasciculipora* spp. and *Neofungell*a spp.

6. Conclusion

The research reported here on the expeditions to Antarctica in the early twentieth century represents the historical background to a wider study of the possibility of using cyclostome bryozoans as paleoenvironmental indicators.

We were able to use specimens stored in the NHM and in the SAM. There is the possibility that a vast store of bryozoans occurs in other museums throughout the world.

The importance of the records of data associated with the collection of these specimens is indicated, even though these data may have seemed irrelevant to the scientists on the expeditions. It is necessary to bear in mind the methods used on these early voyages, as the results may not be as accurate as those possible with the techniques and equipment available today.

These cyclostome bryozoans were collected at a time prior to the input of pollutants from human visitors to Antarctica and prior to nuclear, fluorocarbon and other global pollutants. Thus they represent modern biota from a pristine environment.

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Appendix 1: Antarctic stations from which cyclostome bryozoans were collected.[59] The latitude and longitude of some of the stations were estimated from the mapped position of the station.

Station	Location latitude/longitude	Depth metres	Temperature °C at surface	Temperature °C at collection	Salinity °/$_{oo}$ at surface	Salinity °/$_{oo}$ at collection
NAE 1	*78°20'S/163°15'W	183	n.a.	n.a.	n.a.	n.a.
NAE 2	*78°20'S/173°45'W	549	n.a.	n.a.	n.a.	n.a.
NAE 3	*73°15'S/169°E	183	n.a.	n.a.	n.a.	n.a.
NAE 4	*77°50'S/166°30'E	37-329	n.a.	n.a.	n.a.	n.a.
NAE 5	*77°50'S/166°30'E	238	n.a.	n.a.	n.a.	n.a.
NAE 8	*77°50'S/166°30'E	75	n.a.	n.a.	n.a.	n.a.
NAE 9	77°50'S/ 166°30'E	227-238	n.a.	n.a.	n.a.	n.a.
SCO 314	*77°34'S/166°10'E	222-241	n.a.	n.a.	n.a.	n.a.
SCO 316	*77° 51'S/166°28'E	348-457	n.a.	n.a.	n.a.	n.a.
SCO 339	77°5'S/164°17'E	256	n.a.	n.a.	n.a.	n.a.
SCO 355	77°46'S/166°08'E	547	n.a.	n.a.	n.a.	n.a.
SCO 356	*76°50'S/163°30'E	92	n.a.	n.a.	n.a.	n.a.
DIS 175	63°17'S/59°48'W	200	0.35	-0.48	34.04	34.34
DIS 180	*64°22'S/63°W	160	-0.02	0.00	33.26	34.16
DIS 190	64°56'S/65°35'W	93-130	-0.32	0.31	33.30	33.89
DIS 195	62°7'S/58°28.5'W	391	0.32	0.04	33.86	34.36
DIS 599	67°8'S/69°6.5'W	203	-0.71	-0.01	33.15	34.47
DIS 1652	75°56'S/178°35'W	567	-0.61	-1.90	34.07	34.85
DIS 1660	74°46'S/178°23'E	351	-0.09	-0.56	34.18	34.67
BAN 040	66°12'S/49°37'E	300	n.a.	n.a.	n.a.	n.a.
BAN 041	65°48'S/53°16'E	193	-0.70	-0.77	33.56	34.24
BAN 042	65°50'S/54°23'E	220	-0.24	n.a.	33.42	n.a.
BAN 090	66°21'S/138°28'E	640	-1.09	n.a.	34.28	n.a.
BAN 100	65°48'S/89°49'E	393	-1.58	-1.33	33.47	34.51
BAN 103	67°3'S/74°29'E	437	-0.83	n.a.	32.87	n.a.
BAN 105	67°46'S/67°3'E	163	-0.70	n.a.	33.84	n.a.
BAN 107	66°45'S/62°3'E	177-219	-0.21	-1.19	33.95	34.45

* Location approximate