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Two hundred years of Australian bryozoology

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1. Introduction

1.1 Development of Australian bryozoology

In the 18th and 19th centuries the southern seas remained one of the vast unknown areas of the world as explorers sought to discover new regions of the globe. Australia remained a largely poorly known region; its continental coasts unmapped except in the vaguest outline. Flinder's survey in 1825 in the small vessel 'Tom Thumb' succeeded in mapping the entire coast line. Early Australian bryozoan studies up until about 1850 parallel these explorations and are from collections that were returned to Europe by French and British



Figure 1.—Map of Australia showing various basins and 'basement' areas. Names of basins and outline of basins change with time so that a Cambrian-Ordovician basin may have a different shape and name than a Late Paleozoic or Cenozoic basins in roughly the same general geographic place. Some 'basement' areas, such as in eastern Victoria, eastern New South Wales, and eastern Queensland, are folded and faulted Paleozoic geosynclinal areas.

exploratory excursions (Dunmore, 1969) and studied there by European workers. After the 1850s, and until just after the turn of the century, Australians working on bryozoans had various backgrounds and most were 'amateurs' in that they had other work for making a livelihood. Some were medical doctors, many were clerics, and some had other work, but they all shared an excitment about the natural history of Australia and several had a great interest in bryozoans. Many had been formally trained in natural history and they formed local natural history study groups, helped each other through discussions and supported local and other publications with information and articles. Only a few were zoologists and paleontologists who occupied positions in the universities.

TWO HUNDRED YEARS OF AUSTRALIAN BRYOZOOLOGY

After about 1900 and through about 1950, zoologists and paleontologists were scattered at various institutions, universities, natural history museums, and at several strong state geological surveys, such as the geological surveys in New South Wales, Queensland, Victoria, Western Australia, and, to a lesser extent, South Australia, and they remained strong until the depression of the 1930s and the Second World War (1939-1946).

The Commonwealth of Australia was formed only in 1901 and, faced with strong state geological surveys, the federal government did not pursue a strong, organized, national geological and paleontological presence for a number of years. There were a succession of national Australian geological and paleontological surveys, often short term and created for specific purposes, but these were not organized into one cohesive organization until after the Second World War. In Canberra (Australian Capital Territory) the first of these included a 1945 Commonwealth Resources Survey and, in 1946, the Bureau of Mineral Resources, Geology, and Geophysics, and its successor, in 1992, the Australia Geological Survey Organisation. The book 'Geology of the Commonwealth of Australia' by T.W. Edgeworth David (1950) formed a detailed summary of Australian geology up to about the time of the initiation of a national geological effort. David died in 1934 with his text nearly complete at that time. The depression and World War II intervened and, after the war, W.R. Brown made changes to update the text and saw the three volume work through publication.

1.2 Stratigraphic Distribution of Studies

Studies about Australian bryozoans are conveniently grouped into two major categories: Cenozoic (Recent and Tertiary) studies and Paleozoic studies. The history of both Australian Cenozoic and Paleozoic bryozoans studies have taken similar paths. There are few, if any, Mesozoic bryozoans recognized from Australian outcrops because marine sediments of Mesozoic age are limited and poorly known and are unfavorable for bryozoans.

1.3 Geographic Distribution of Studies

Figure 1 shows the sedimentary basins of Australia including its continental shelves. At different times in the geologic past, the boundaries of these basins have changed to include more or less area and the names of the basins often are changed to reflect these differences. Also, separate names are often given to the shelf areas to distinguish them from the basins, particularly the Tertiary basins. Many of the basins in the center of Australia are late Precambrian to Devonian in age. 'Basement' areas in Figure 1 include some with Paleozoic sediments which have been deformed in geosynclinal fold belts, for example, the 'basement' in the Victoria-New South Wales-southern and eastern Queensland, includes lower and middle Paleozoic sediments, along with older rocks.

2. Tertiary and Recent Bryozoologists

2.1 Early Discoveries

Early exploration of the southern seas around the Australian continent led to extensive dredging and sampling of the oceans. Bryozoans were among the faunas that were harvested. The earliest bryozoan collections were made during the 1800-1804 French expedition of Captain Nicolas Baudin and subsequently described by J. B. P. A. de Lamarck (1816) and J. V. F. Lamouroux (1816). And d'Orbigny (1849) included some bryozoans from Australia. The material was collected from the southeastern and northwestern regions off the Australian coastline.

George Busk. George Busk at the British Museum of Natural History studied the 'Beagle' collections and other material that was gradually arriving at the British Museum. He published a series of fine papers on Recent Australian bryozoans between 1852 and 1884. Bryozoans collected during the H.M.S. *Rattlesnake* expedition of 1837 were also described by Busk (1852a, b, 1854, and subsequently in 1875). Busk was a leading bryozoologists with more than 40 publications. He possessed a good command of bryozoan systematics world-wide and extensively described many genera and species. P.H. MacGillivray (1859) also reported on samples collected by the H.M.S. *Rattlesnake*.

William Henry Harvey. Collections made by William Henry Harvey between 1854 and 1856 were subsequently described by Thomson (1858) at the British Museum. Harvey was an Irish Quaker, interested in seaweeds and he travelled to Australia between 1853 and 1856. He made numerous collections of Recent bryozoans in his collecting forays for seaweeds. His travels took him to Perth, Fremantle, and Albany in Western Australia, Point Fairy in South Australia, Melbourne in Victoria, Sydney in New South Wales, and Georgetown and Port Arthur in Tasmania (then known as Van Diemen's Land). Subsequently, the bryozoans in Harvey's collections were studied by numerous bryozoologists. Early in these investigations were detailed reports on the cheilostomes prepared by Wyville Thomson (1858, 1859). An updating on Thomson's species is discussed in Wyse Jackson and Spencer Jones (1996).

2.2 Second half of the 19th century

Paul H. MacGillivary. Beginning in 1858 (1859), working in Victoria, Paul H. MacGillivray, a medical doctor and naturalist, started publishing results of his studies on mainly Recent bryozoans along the southeastern portion of the Australian coast (Otway and Gippsland Basins) with a description of a new species of *Plumatella*. MacGillivray lived in Bendigo, Victoria, and many of his collections came from Queenscliff, Victoria. Some collections were sent to him or made by others, particularly J. Bracebridge Wilson, Maplestone, H. Watts, Baron von Mueller, Hincks, Waters and Miss Jelly. MacGillivray's

continued description of Australian Bryozoa. for more than forty years made him an important authority of southern Australian bryozoans until his death in 1895. He was in contact with the British zoologist and bryozoan worker Thomas Hincks (1884) to whom he sent collections. One of his prinicipal publication outlets was in M'Coy's [McCoy's] 'Prodromus of the Zoology of Victoria', a serial work in which about 300 species of bryozoans were described and illustrated between 1879 and 1895. This has been recently reviewed by Bock (2001). The following, extracted, paraphased, and summarized from two obituaries for MacGillivray notes the high regard his collegues had for his studies.

Paul Howard MacGillivray (1834-1895). A famous scientist and medical practitioner, he was born in Edinburgh, son of William MacGillivray and his wife Marion. Paul was educated at Marishal College (and King's College) at the University of Aberdeen (M.A.,1859), where his father had been appointed professor of Natural History in 1841. While still a student Paul, with some help from his father, published 'A Catalogue of the Flowering Plants and Ferns growing in the neighbourhood of Aberdeen' (1853). When his father died in September of 1852, Paul relinquished his studies of science and turned to medicine in London (Member Royal College of Surgeons, 1855). Later that year he migrated to Melbourne.

MacGillivray began to practice at Williamstown. Victoria, and joined the local volunteer naval brigade as a medical officer. From 1862 to 1873, he was resident surgeon of the hospital in Bendigo and then took up private practice there. Although his great love was still natural science, MacGillivray revealed an aptitude for surgery. His many papers on surgical matters included three works in 1865-72 on the management and treatment of hydatid cysts. In 1874 he was elected president of the Medical Society of Victoria.

MacGillivray was also well known as one of the foremost naturalists in Australia. In 1857 he was elected a member of the Philosophical Institute (later Royal Society) of Victoria and from 1859 began to publish in the society's *Transactions* a series of important illustrated papers on Australian and related representatives of the Phylum Polyzoa (Bryozoa), commonly known as 'sea mosses'. The fine description and figures from his own hand in Professor's McCoy's [q.v.] *Prodromus of the Zoology of Victoria* (1878-1890) are models of precision and clarity and remain, together with MacGillivray's 'The Tertiary Polyzoa of Victoria' (1895), standard bases for any research on Cainozoic Polyzoa. For the Royal Society of South Australia he also wrote on the fossil Polyzoa..

In December 1880, MacGillivray was elected a fellow of the Linnean Society of London. For publication by the Royal Society of Victoria, he had nearly finished a large monograph on the 'Polyzoa of Victoria' when he died on 9 July 1895 at his home in Bendigo. MacGillivray's collections and valuable library were bought by the government for the National Museum of Victoria.

In 1882, MacGillivray published descriptions of *Beania*, ten new species of *Membranipora*, and a check list of 29 species for Victoria. In 1883 he listed 24 news species in several genera, including *Microporella*, *Lepralia*, *Membraniporella*, *Schizoporella*, *Mucronella*, *Smittia*, and *Lagenipora*, many from Port Phillip Heads. In 1884 he reported on five species and two genera of cyclostomes and in 1885 and 1886 he recorded 21 more genera. He thanks Maplestone and Wilson for some of the collections. His 1887 paper contained bryozoans from all around Australia and nearby areas and listed seven genera and eight species. When publication of M'Coy's 'Prodromus' was delayed, MacGillivray assembled a series of publications on 'A Catalogue of the marine polyzoa of Victoria' and published it separately. His 1890, 1891, and

1894 (1895) papers continued the trend with 14 new species in different genera and 14 species in the genus *Amathia*.. MacGillivray's collections by this time had included all of Australia: Port Jackson, New South Wales; Cooktown, Queensland; Port Phillip Heads, Victoria; Maroubra Bay, New South Wales; Encounter Bay, South Australia; Sealers Cove, Westernport, Port Stephens, New South Wales. R. W. Bretnall (1921) renamed one of McGillivray's genera. [D.A.Brown]

C.M. Maplestone. Another Victorian, C. M. Maplestone, also added considerably to our knowlege of the Tertiary and Recent bryozoans in Victoria and the Tasman Sea in an impressive series of papers published between 1879 to 1911. Bale (1914) gives an accounting of Maplestone's interesting life which we summarize and paraphrase in the following.

Natural science in Victoria has sustained a severe loss by the death of Mr. Charles M. Maplestone (1835-1910), which occurred at Eltham on the 18th January 1910. Mr. Maplestone, who at the time of his death was 75 years of age, for the greater part of his life was an officer in the Victorian Postal Department, and was stationed at various seaside localities, where he devoted much of his leisure time to the study of marine natural history. About 1880 Mr. Maplestone began to concentrate his attention on the Bryozoa, of which he had been a student since 1866, and in 1881 he contributed to the Proceedings of the Royal Society of Victoria a paper entitled "Observations on Living Polyzoa', in which he described a number of species, including all the structures of the animal. About the same time he described several new species in papers read before the Microscopical Society of Victoria. Owing to the amalgamation of that society with the Royal Society, and the consequent discontinuance of its journal, some of his papers were not published, and one of his new genera-Dikista-lapsed, and was afterwards described by the late Dr. P. H. MacGillivray under the name *Maplestonia*. Many of Mr. Maplestone's notes were communicated to Dr. MacGillivary, and utilized by that gentleman, and by McCoy in his "Prodromus". After 1884 Mr. Maplestone's offical duties as an inspector necessitated constant travelling, and prevented his working at his favourite study, and all his undescribed material was handed over to Dr. MacGillivray.

In 1898 Mr. Maplestone, whose retirement from offical life then afforded him leisure to resume his scientific pursuits, undertook, at the suggestion of Professor Spencer, to furnish a series of descriptions of the Tertiary Polyzoa of Victoria, supplementary to the important monograph of the group contributed to the Transactions of the Royal Society of Victoria by Dr. MacGillivray, whose death had occurred before the appearance of his completed work. In May, 1898, Mr. Maplestone presented the first part of his "Further Descriptions of the Tertiary Polyzoa of Victoria" of which the twelfth and last part was read posthumously on the 12th of December, 1912. Interspersed with this series were several papers on recent species, the last of which was presented at the same meeting as the last paper dealing with the fossil forms. These papers concluded the series of over twenty communications to the Royal Society, all referring to the Bryozoa, for which group Mr. Maplestone had been recognized, since the death of Dr. MacGillivray, as the leading Australian authority. He also contributed to the Records of the Australian Museum in 1909-10 a couple of short papers on the Bryozoa collected by the Miner in the Tasman Sea. Few marine invertebrates of our shores are better known than the Bryozoa, thanks to the long series of patient investigations carried out by Dr. MacGillivray and later by Mr. Maplestone.

He became a member of the Field Naturalists' Club in November, 1895, and, though living so far away as Eltham, was a frequent visitor at the monthly meetings. During his official trips about the State he had made many observations relating to the flowering times of orchids, and, in October 1895, contributed an article on the subject to the *Naturalist* (vol. xii, p. 82); and at the December meeting read a useful and interesting paper entitled "Calendars, and Indexing Natural History Observations", which was published in the *Naturalist* in January, 1896, vol. xiii, p. 128. He was most methodical in his manner of dealing with his observations, and it is to be hoped his notes will pass into appreciative hands. Mr. Maplestone was laid to rest among others of his kindred in the little cemetery attached to Rose Chapel, St. Helena, near Eltham.— W.M.B. [W. M. Bale, 1914]

William Arthur Waters. The cheilostomes from South Australia and New South Wales were the primary subject of William Arthur Waters, an Englishman, who started publishing his early bryozoan studies in the *Proceedings of the Manchester Literary and Philosophical Society* in 1878. His subsequent papers appeared in the *Annals and Magazine of Natural History, Quarterly Journal of the Geological Society of London, Journal of the Linnean Society*, and *Journal of the Royal Microscopical Society*. In 1881 through 1889 he published a long series of extensive papers on cheilostome and cyclostome bryozoans from various localities in South Australia, Victoria, and New South Wales, as well as localities in New Zealand. One locality was Muddy Creek, in Victoria, which has a famous and diverse fossil fauna. He had the good fortune to work on the very extensive bryozoan material collection from the H.M.S. *Challenger* 1873-1876 expedition.

Other Bryozoologists. Fredrick Wollaston Hutton, who is perhaps better known for his studies of Mollusca and Polyzoa of New Zealand, presented descriptions of southern Australian bryozoans in the Tasmanian Royal Society proceedings in 1877 and 1878. Dendy (1868 [1869]) published an interesting paper identifying a Tertiary arenaceous bryozoan from Victoria, however, this should be rechecked as it seems a strange construction and we wonder if, instead, it is not an encrusting sessile foraminifera.

Several clerics are among these early bryozoologists. Well-travelled, well-educated, very observant of nature, and extremely interested in bryozoans, they were able to have a broad view of the world of bryozoans and they had extensive exchanges of bryozoan materials. Thomas Hincks (1880-1884) was such a cleric (others included F. W. Hutton (1876-1878) and J. E. Tenison-Woods (1879-1880)). Hincks was an early systematist who in the later part of the 19th century published a large number of papers on bryozoans from around the world. His 1881 through 1890's papers included articles describing bryozoans from Victoria, Bass Strait, New South Wales, Western Australia and other parts of Australia and New Zealand. His bryozan contributions were worldwide and their localities read like a travel log of British marine shipping of the day.

William A. Haswell also joined the investigation of Australian bryozoans along the eastern coast of Australia beginning in 1881, with four short, but informative, papers (1881-1883). In 1882, J.R.Y. Goldstein described bryozoans from Marion Island, Victoria. We have seen a single paper by the Queenslander, T. Whitelegge (1887) who

reported on some additional bryozoans to the Linnean Society of New South Wales. In 1888, R. Kirkpatrick reported on collections from Port Phillip and Port Western, Victoria, and, in 1890, some bryozoans from the Torres Straits, Queensland.

3. Twentieth Century

The Danish publication by G.M.R. Levinsen (1909) added considerable insight to cheilostomatous morphology and systematics and includes some Australia species. Both W.M. Bale (1922) and R.W. Brentall (1921,1922) further added to knowledge of bryozoans of Victoria. The Dutch East Indies *Siboga* Expedition (1899-1900) under the command of G. F. Tydeman produced some fine bryozoan collections which formed the basis for more thorough studies.

Sydney F. Harmer. Sydney F. Harmer at the British Museum studied these *Siboga* collections in a series of publications for more than forty years. His large monographic work of four bryozoan volumes (Harmer, 1915 to 1957), the last volume of which Anna Hastings shephered through publication after his death, were based in most part on *Siboga* collections and made significant and extensive contributions to our knowledge of East Indian and Australian bryozoans. In Harmer's excellent works, many of the bryozoan species he described also occur in the adjacent northwestern Australia Territory of Ashmore-Cartier Islands and the Western Australia coast. Further, Harmer (1957) included descriptions of many bryozoans from the southern coasts of Australia.

Leo W. Stach. During the 1930s, Stach, a research reader in Zoology at the University of Melbourne, published many thoughtful and enlightening papers on Catenicellidae and other bryozoans of the Victorian Tertiary (1933 to 1937). His work during these years was quite outstanding including his recognition that environmental conditions greatly influenced colony form and structures (see Stach, 1936). Stach also published additional papers on Antarctic and New Zealand bryozoan faunas. Later, Stach joined the petroleum industry and during World War II was a technical geological advisor to General MacArthur in the Pacific. He later became a successful explorationist, businessman, and spokesman for the petroleum industry to governments at the national and international levels, particularly in the United Nations. He retired to Victoria and died in 1998; he endowed several scholarship funds, one at the University of Melbourne, supporting students in geology in the mid 1990s (Collinson, 1999).

Canu and Bassler. In the 1930s, the famous pair of authors, Ferdinand Canu and Ray S. Bassler (1935), wrote on new species of cheilostome bryozoa from Victoria. Canu and Bassler had a long collaboration together studying many bryozoan collections world wide and this appears to be the only Australian collection on which they worked.

I. Vigeland. The National Museum of Victoria, in cooperation with the Fisheries and

Wildlife Department, from 1957 through 1963 conducted a systematic study of Port Phillip Bay, Victoria. National Museum of Victoria Memoir 27, published in 1966, treated the physical environment and some biology and Memoir 32 completes the publication of most of the results of the Survey. I. Vigeland, a visitor from the Zoological Museum in Olso, Norway, prepared the part on Byrozoa. He lists some 114 species of which 95 are named and 19 assigned to genus. He also lists the 300 species and their localities recorded by MacGillivray in his mongraph. One-hundred and fifty-three of these are recorded from Port Phillip Heads and 78 of them were found on the 1957-1963 Survey. The Bryozoa of the original Port Phillips Survey set up by the Royal Society of Victoria in July, 1888, were included in P. H. MacGillivray's monograph of the Victoria Bryozoa published in "McCoy's Prodromus of Zoology" between 1879 and 1889. Port Phillip Heads is a locality for 153 species listed by MacGillivray, and the only locality for 125 of these species; 81 species are from Queenscliff, 42 from Portland, and 22 from Warrnambool, in western Victoria. Vigeland presents a very helpful table of all of the species discussed by MacGillivray in "McCoy's Prodromus" with the authors, dates, currently accepted nomenclature, and localities.

David A. Brown. David A. Brown (1958) discussed the cheilostomous bryozoans from south west Victoria, and while a professor of Geology at Australian National University in Canberra, ACT, he published an exhausive study of Tertiary bryozoans from south west Victoria. He originally was from New Zealand and has published extensively on New Zealand bryozoans. In addition, he has aided bryozoologist in translating several important Russian studies in which new genera and generic revisions are discussed in detail. These translations are pertinent to Australian late Palaeozoic bryozoans.

A. E. Cockbain. A. E. Cockbain published a paper on the cheilostomes from the Tertiary Eucla Group in Western Australia (1969) and, in (1971), a paper on Tertiary cheilostomatous bryozoans from Victoria, in which he investigates a number of Brown's (1958) collections and localities and revised Brown's stratigraphic occurrences and zonal scheme. Cockbain, in the early 1960s, had written an extensive and detailed summary of the distributions and relations among Foraminifera and sediment types in the Straits of Georgia and Straits of Juan de Fuca for the Institute of Oceanography at the University of British Columbia, in Vancouver, Canada. He then joined the Geological Survey of Western Australia in Perth and, about 1970, joined industry in Western Australian.

Neil Powell. Neil Powell (1969) described the lunulitiform bryozoans from the collections made from southeast Australia by the *Endeavour* Expedition of 1909-1914. He subsequently worked for the Canadian National Museum in Ottawa, Canada for a few years, but then ceased his scientific studies.

Phil Bock. More recently, Phillip Bock (1982, 2001), who was at RMIT (Royal Melbourne Institute of Technology) for many years and currently is affiliated with Deakin

University in Victoria, has explored the details of the bryozoans of several Tertiary and Recent basins in South Australian and Victoria, commonly with coauthor Pat Cook (Bock and Cook, 1993 to 2002).

Phil Bock started his career in the Geological Survey of Queensland, and then moved to the Geological Survey of Victoria in 1960. There, John Talent introduced him to the Tertiary fossil bryozoan, Sphaeropora (which is still waiting for a major revision). Miocene sediments exposed in southwestern Victoria in road excavations showed several distinct bryozoan facies, which aroused his interest. In 1966 Phil obtained a position as Lecturer at the Royal Melbourne Institute of Technology, where he continued for 32 years until retirement in late 1997. Since then he has taken a position at Deakin University. While still at RMIT, and with the acquisition of a scanning electron microscope, his study of bryozoans was recommenced. He met Nils Spjeldnaes and Pat Cook at the International Geological Conference in Sydney in 1976, and subsequently became involved with the Zoology Section of the National Museum of Victoria (now Museum of Victoria). His early samples by SCUBA diving were supplemented by an extensive dredge survey of Bass Strait undertaken for the Museum. Sorting of these samples is still incomplete, but the samples already sorted are being described, as well as the samples obtained in 1995 on the RV Franklin, a survey under the direction of Yvonne Bone, and in the company of Steve Hageman.

As computer use started to become important, Phil moved into image processing, and he set up the computer as a webserver. The result was the first version of the Bryozoa Home Page, with a few bryozoan photos and SEM's. The site URL has not changed since, thanks to the cooperation of his former colleagues at RMIT. He retired from RMIT and accepted an invitation from Prof. Neil Archbold, at Deakin University, to take up a position as Research Fellow. Phil also continues as an Honorary Associate at Museum Victoria.

Patricia Cook. Between 1984 and 1987, Pat Cook and James Chimonides, at the British Museum (Natural History) (now Natural History Museum), investigated the Recent and fossil family Lunulitidae around most of Australia. After a life-long bryozoan career at the British Musem of Natural History, in the early 1990s, Cook retired to Melbourne, became associated with the Museum of Victoria, and has subsequently coauthored many bryozoan publications with Phil Bock, S.A. Parker and others (Bock and Cook, 1993-2002; Parker and Cook, 1994; see also Parker, 1989).

Robin E. Wass and J. J. Yoo. Although Robin Wass's work is discussed more extensively later because of his Paleozoic interest, Robin E. Wass, J. R. Conolly, and R. J. Macintyre (1970) recognized that the off-shore, deeper shelf sediments contained an extraordinary rich Tertiary and Recent bryozoan facies of cooler-water forms with interesting morphologies (Banta and Wass, 1979). Wass and J. J. Yoo (1973, 1975a, 1975b, 1983) greatly extended our knowledege of these various accumulations of deeper, cooler-water, shelfal forms. J.J. (Kim)Yoo was a science graduate from Seoul University

who obtained a MSc from the University of Sydney working with Wass. While at Sydney, and with funding from the Australian Research Council, Wass and Yoo sorted through and identified the many bryozoan species in Victorian and South Australian off-shore sediment samples

Dennis P. Gordon. In 1983, M. Bradstock and D. Gordon began a long term investigation of bryozoan bioherms in Tasman Bay and their importance in protecting fish habitats. Gordon has retained interest in Australian bryozoan and, in 1990, redescribed MacGillivray's Lower Miocene genus *Prostomaria* from Fossil Beach, Victoria, and, recognizing the uniqueness of the genus, used it to establish a new family Prostomariidae. An unusual thalamoporellid species that is epiphytic on sea-grass from the Yorke Peninsula, South Australia, and from the Esperance District, Western Australia, originally described by MacGillivray, was redescribed in much greater detail by Gordon and S.A.Parker (1991). Gordon and d'Hondt (1991) explored the relations of Miocene to Recent cribrimorphs including species from the Miocene and Recent of Victoria. Gordon and Brage (1994) identified a new catenicellid subfamily based on Oligocene and Miocene collections from Victoria. Gordon also published a summary of Tertiary bryozoans (1994) and a paper on the diversity of bryozoans (1999) of Australasia. Gordon is a profilic publisher on recent and fossil bryozoans through out the southern seas, particularly as they relate to New Zealand bryozoans.

3.1 Further Exploration of Coastal Seas

Great Barrier Reef Area. The Great Barrier Reef is the largest reef system in the world extending 2300 km north from 50 km south of Gladstone to Cape York and dissipating around the estuary of the Papua New Guinea's Fly River. It is a protected area and lies within the Great Barrier Reef Marine Park. It is difficult to access and its bryozoans have scarcely been explored.

Early work by R. Kirkpatrick (1890) reported on zoological collections made by A. C. Haddon, including bryozoans, from the Torres Straits between Queensland and Papua New Guinea.

A.A.Livingstone. Bryozoans from one major collecting expedition, the Great Barrier Reef Expedition, were investigated by Arthur A. Livingstone (1924-1926a,b [1927]), who was Assistant Zoologist at the Autralian Museum, and Anna B. Hastings (1932). These collections were made by Dr. W.E. J. Paradice on the HMAS *Geranium* and came from the reef tract between 12°-14°S latitude and 145°45' and 147°E longitude. More than 208 bryozoan species were reported from the Queensland Shelf. One hundred and sixty-seven were compiled by Livingstone (1927a,b).

Livingstone also had access to collections made off the East Coast of Australia. Until about 1924, a small fleet of trawlers was maintained by the New South Wales Government to make collections off the coast to aid the state trawling industry. The Australian Museum

in Sydney, where A. A. Livingstone was an Assistant in Zoology at the Museum, received all these collections. He worked with these many collections as well as making short cruises in the steamers to make some of the collections. Livingstone subsequently reported on bryozoan material from the Australasian Antarctic Expedition and Cheilostomes from New Zealand.

Lars Silen. Lars Silen (1943), a professor of zoology at Stockholm, Sweden, studied four collections from Heron Island on the southern part of the Great Barrier Reef made by J. Mauristzon in 1936 and, of the four species identified, one was considered new.

Dall and Stephenson (1953) compiled a bibliography of marine invertebrates of Queensland which laid the ground work for many later studies, such as Endean and others' (1956) study of rocky intertidal faunas in Queenlsand. Modern sedimentalogic studies on the Great Barrier Reef date from W.G.H. Maxwell's (1968) 'Atlas of the Great Barrier Reef' in which bryozoans were counted as major constituents making up the reef carbonate sediments.

June Ross. Several additional sets of collections from the Great Barrier Reef were made by June Ross; one set in the 1960s, a second during a 'Crown of Thorns' infestation survey in 1972 (Ross, 1974), and a third set on a 'Coral Reef Symposium' in (1974). In 1972, exploration of thirteen reefs on the inner and outer reef tracts northeast of Townsville, Queensland, from shallow subtidal localities ranging from 1 to 24 meters were carried out by June and Charles Ross (1974). The collections are housed in the Australia Museum in Sydney. Ten sites were on the outer reef tract on Coil, Bowl, and Shrimp Reefs and nine on the inner reef tract on Glow, Helix, Grub, Centipede, Davies, and Bowden Reefs and Wheeler Cay (see Figure 1) at 18°15' and 19°30' S latitude and 147° to 148° E longitude. At least two hundred species were identified from the collections and they were assignable to 51 genera and 27 families of cheilostomes and stenolaemates. Ascophorans, at least 33 genera, dominated the bryozoan fauna. Eleven anascan and six stenolaemate genera are other elements of this fauna. The ctenostomes were not included in the investigation.

On the reefs from both the inner and outer reef tracts and on both the windward and leewards sides of the reefs, species of the ascophorans *Celleporaraia, Rhynchozoon, Stylopoma, Coscinopis, Reptadeonella, Fenestrulina, Crepidacantha, Hippaliosina,* and *Arthropoma* and the anascans *Colletosia* and *Thalamoporella* are common. With worms, crabs, fishes, etc., grazing on the bryozoans, only a limited part of the bryozoan fauna is preserved after the ravages from other organisms on the reef, as well as the physical abrasion from waves and currents taking place on the reefs and chemical solution. We will return to June Ross in the section on Paleozoic bryozoans.

3.2 Western Australia

From Western Australia, Lars Silen (1954) also reported on 42 Recent species of

bryozoans collected by T. Gislen in 1951 and 1952 from near Rottnest Island, Warnbro Sound, near Rockingham, south of Garden Island, and other localities.

3.3 Introduced bryozoans

One aspect of Recent bryozoan occurrences which has interested many bryozoologists, but has not been widely studied, is the question of introduced bryozoan species brought to Australia by ships. Allen (1953), Hutchings and others (1987), and Furlani (1996) have explored this subject and other authors, for example, Silen (1954), mentioned that some Recent species recorded from Australia were likely of boreal (i.e. introduced) origin.

3.4 Bryozoan sediment facies

Another interesting aspect of the Tertiary record of bryozoans, which only has recently been studied, is their occurrence in Victoria, South Australia, and Western Australia, for example in the off-shore Lacepede shelf and associated sedimentary basins, such as the Eucla, Duntroon, St. Vincent, and Otway Basins. These bryozoans form local carbonate build-ups and sheets of carbonate sand aprons in the 'deeper' waters (below storm wavebase) of these cratonic marginal basins, and make up a 'cooler-water', marine carbonate environment or facies. Yvonne Bone and Noel James (1993), James and Bone (1994), Hageman and others (1996), James and Clarke (1997), Hageman and others (1998), James and others (2004), Schmidt and Bone (2004), and others have been writing on these as interesting sedimentary units and their involved diagenetic histories as carbonate sediments. James and Clarke (1997) edited a lengthy volume which summarized much of this and related work. The Recent bryozoan carbonate build-up in the Tasman Sea is typified by Bradstock and Gordon (1983) who looked at their ecological effects in fish habitats for commercial fisheries. Schmidt and Bone (2002) in their discussion on Eocene bryozoan assemblages of the St.Vincent Basin, South Australia, noted the rich bryozoan faunas in most of the Tertiary basins in Australia are "at least as diverse as the well studied Oligo-Miocene Victorian deposits".

4. Paleozoic Bryozoa

4.1 Late Paleozoic

Whereas the Tertiary and Recent studies of bryozoan in Australia have been mainly concerned with systematics and zoology, the Paleozoic studies have been concerned with using bryozoans to aid in identifying stratigraphic ages of rock units. Because of the extensive glacial deposits and marginal marine deposits of the PermoCarboniferous of eastern Australia basins and sandstones in the western Australia basins, a great deal of the effort was directed to establishing the ages and correlations of this time-rock interval.

Earlier Palaeozoic sediments are found within the fold belts of eastern Australia, but these are scattered, limited in outcrop, and have not been thoroughly investigated.

William Lonsdale. One of the earliest studies of Australian bryozoans is of Palaeozoic fossils collected by Darwin during the voyage of HMS *Beagle* from near Hobart, from Permian limestone deposits on Maria Island, on the east coast of Tasmania. These fossils were studied by William Lonsdale after Darwin's return to England and, in 1844, Lonsdale described the large distinctive bryozoan genus *Stenopora* in an appendix to Darwin's description and discussion of volcanic islands encountered during the expedition. In 1845, Lonsdale expanded on the description of the genus *Stenopora* in Strzelecki's Physical Description of New South Wales. These were the first reports of fossil bryozoans on this southern continent.

Other early bryozoologists. In 1877 de Koninck described and figured seven species and, in 1920, Chapman described three additional species, from the Lower Carboniferous of New South Wales. De Koninck's material was sent to him in Europe by Rev. W. B. Clarke and, when returned, was placed on display in the Exhibition in 'Garden Palace' in Sydney which burnt in 1882 along with these collections. G.E. Hinde (1890) published some brief notes on bryozoans from Western Australia. H.A. Nicholson and R. Etheridge, Jr. (1879) mentioned *Stenopora* from northern Queensland and, in 1885, also reviewed *Stenopora* in Tasmania and elsewhere in Australia. Nicholson and Foord (1885) described several new species of *Fistulipora*. Jack and Etheridge (1892) included bryozoans in their 768 page tome on the Geology and Palaeontology of Queensland and New Guinea.

In 1890, Arthur H. Foord wrote a few notes about fossils, including bryozoans, from the 'Kimberley District', northwestern Western Australia, that hinted at a possible larger fossil record there. Later, in Etheridge's (1878-1926) long career in geology and paleontology, particularly in Western Australia, he monographed the fossils of Western Australia, including some bryozoans. Also in 1926, R. W. Bretnall described some Western Australian Permian bryozoans in a bulletin of the Western Australia Geological Survey. Hosking (1931) described fossils, including bryozoans, from the Wooramel Distict, Western Australia, and Raggatt and Fletcher (1937) described faunas from the 'northwest basin', Western Australia.

Laseron (1918) described some species of Fenestellidae from the late Palaeozoic rocks in eastern Australia and made good use of fossil bryozoans in helping to establish geologic ages. In the southern part of the Sydney Basin, K. S. W. Campbell (1962) and Bruce Runnegar (1969) mention the occurrences of a number of Permo-Carboniferous bryozoans.

Joan Crockford. During and after the Second World War, Joan Crockford (1941-1962) authored many excellent and well illustrated papers on Carboniferous and Permian bryozoans, and a short paper on Silurian and Devonian bryozoans, mainly from New South Wales, Queensland, and Western Australia. Many of these studies were done under exceptional circumstances during the Second World War while alternating with her friends as an enemy aircraft observer on top of the Maclay Museum at the University of Sydney. She was an associate researcher at the University of Sydney. The number of older collections that Crockford located, subsequently examined, and described is very remarkable and her persistence in searching out information about the many collections, should have earned her a 'Bryozoan Merit of Honour'. She published, starting in 1941 (1941a, b, 1943c), a three part work on Bryozoa of eastern Australia which included several new species of bryozoans from the Permian Upper Marine Series of New South Wales, Queensland, and Tasmania. She also described the Silurian-Devonian fauna from Yass, Taemas and Tamworth in central New South Wales (Crockford, 1941c) and an Ordovician bryozoan species (1943b) from the central Australian Larapintine Series, in the Macdonnell Ranges, which was collected by the Horn Expedition (1895?) and which was not well located. She also reexamined the bryozoans of the Port Keats Bore (Crockford, 1943a) in what is now called the Bonaparte Basin in Northern Territory.

Crockford (1944a, b, c) also redescribed Bretnall's (1926) collections from the Permian of Western Australia. And she described the bryozoans from the Carnarvon Basin and Kimberley District in Western Australia (1944a, b, c). In 1945, Crockford made a detailed restudy of *Stenopora*, including material from Darwin's type locality from Tasmania. In 1946, 1947, and 1948, she gathered together the bryozoan material for the Lower Carbonifierous of Queensland (Part 1) and New South Wales (Part 2), redescribed it, and attempted to make age assignments. Crockford summarized her Australian work in a 1951 paper to the Linnean Society of New South Wales. Her monographic work on Permian Bryozoa of the Fitzroy Basin was published by the Bureau of Mineral Resources, Geology and Geophysics as Bulletin 34 (1957). In all Crockford published more than 16 excellent, detailed papers from 1941 to 1962.

June Ross (1963) also studied Permian bryozoans from the Permian Lyons Group of the Carnarvon (North-West) basin, Western Australia, and named three additional species of *Stenopora* along with a correlation chart suggesting relations to other parts of Australia. Irene Crespin (1964) took time out from her foraminiferal studies to compile a Catalog of Western Australian fossil material, including bryozoans, in the collections of the Geological Survey of Western Australia.

Robin Wass. Wass (publications 1962-1983) started his bryozoan studies at the Universityof Queensland by investigating the Permo-Carboniferous bryozoan faunas of the Cracow District, Queensland, and then extended the bryozoan part of his study to include bryozoans from the whole of the Bowen Basin in Queensland. As a lecturer at the University of Sydney, he and coauthors continued these studies on Palaeozoic bryozoans of the Warwick-Stanhope Region, Queensland (Wass and Dennis, 1977), South Marulan District, New South Wales (Wass and Gould, 1969), and a review of the bryozoans of the Sydney Basin (Wass and others, 1969). In 1970, he summarized the Permo-Carboniferous work by comparing these eastern Australian studies with Western Australia Permo-Carboniferous bryozoan studies. Wass also restudied the bryozoan faunas from the

famous Port Keats bore and nearby outcrops which had been studied previously by Etheridge (1906) and Crockford (1943a). This fauna is from the eastern side of the Bonaparte Gulf Basin, a mainly Late Palaeozoic basin that lies on the Australian cratonic edge south and west of the town of Darwin.

Brian Engel. Engel (1979), at the University of Newcastle, Newcastle, New South Wales, reported on fenestellid bryozoans from Carboniferous strata in Queensland. Engel and Ross (1993) in a thorough restudy of Crockford's, Ross's, and others findings reviewed the stratigraphic distribution of Permian bryozoans in Western Australia. They discuss the Carnarvon Basin, and the northern Canning Basin (=Fitzroy Basin). In comparing the eastern Australian and Western Australian faunas, they highlighted some interesting differences. The Order Cystoporata are a major component (32 species) of the Western Australian Permian fauna, whereas, this Order is almost unrecorded in the eastern states. In contrast the Order Trepostomata in Western Australian faunas is very sparse compared with the abundance of species and material in the eastern states. The Order Cryptostomata has numerous species in both regions, but the two regions have almost no species in common, a significant difference.

Catherine Reid. Reid's (2003) study of eastern states Permian bryozoans also shows few cystoporates and numerous trepostomes and cryptostomes. Reid (2003), from the University of Tasmania, published on Permian bryozoans from a number of stratigraphically well positioned localities in Tasmania and southern New South Wales. She described the bryozoan species and assemblages in stratigraphic detail and established an Early Permian faunal zone scheme which she was able to tie into other fossil zonal schemes.

Iraida Pavlovna Morozova. Following a visit to Australia, Morozova of the Paleontological Institute, Moscow published two papers on Permian bryozoans of Eastern Australia. In the first (2003) she erected the genus *Robinella*, named for Robin Wass, while in the second (2004) she described two new genera *Crockfordia* (named for Joan Crockford) and *Paramaychella* from the Bowen Basin of Queensland.

4.2 Lower Paleozoic

June Ross. We have mentioned June Phillips Ross earlier in discussions of the Great Barrier Reef and Late Paleozoic bryozoan studies. She started her studies of Australian Paleozoic Bryozoa at the University of Sydney and, after receiving her PhD, continued those and other bryozoan studies first at Yale University, then at the University of Illinois, and finally at Western Washington University, in the Department of Biology. Although she settled in the United States, she remained keenly interested in Australian bryozoans, taking many opportunities to travel there and make additional collections. After joining the Biology faculty, her interests broadened to include Recent bryozoans and their growth. Her Great Barrier Reef collections and work, mentioned previously, started at that time. **Ordovician.** Collections from eastern Australia (Ross, 1961; 1994; Ross in Talent and others, 2000; and Ross in Webby and others, 2000) relate to Ordovican, Silurian and Devonian bryozoans from various localities in the eastern Australian (Tasman) geosynclinal belt, in Tasmania, Victoria, and New South Wales, and from the Middle Ordovician strata in the Lachlan Fold Belt and the Amadeus Basin in central Australia. In the Amadeus Basin, bryozoans occur in the lower part of the Stokes Siltstone. They are part of a diverse Ordovician fauna of Darriwilian age (Ross, 1994) that occur in sand-size grainstones, conglomerates, and mudstones that represent very shallow intertidal facies. Distinctive are the cryptostome *Pseudostictoporella* and the bimuroporid trepostome 'proto-*Champlainopora*', a precursor to late Whiterockian forms of *Champlainopora* and arthrostylid crypostomes. This fauna is closely similiar to that from the Middle Ordovician, Whiterockian, Oil Creek Formation, Oklahoma, U.S.A.

At Cliefden Caves in central New South Wales, the Fossil Hill Limestone has faunas that include the trepostomes *Homotrypa* and "*Batostoma*" and the cryptostomes *Stictopora* and *Austraphylloporina* (Ross, 1961) of Eastonian age. To the west, the Quondong Limestone is a slightly younger Eastonian and has a more varied assemblage of *Stictopora* and *Homotrypa* species. In northern Tasmania, a thick succession of Eastonian age carbonates from the upper member of the Benjamin Limestone into the Westfield Beds contains abundant cryptostomes and trepostomes and sparse cystoporids. Rhabdomesines are common and locally dominant, ptilodictyoids, amplexoporines, eridotrypines, rhombotrypines, monticuliporines and constellariids comprise this fauna which shows close similarities to faunas of the Upper Ordovician Cincinnatian of North America (Ross, 1979). Farther west near Zeehan, a deeper-water limestone succession that contains the cryptosome *Stictopora* and the trepostomes *Batostoma* and *Amplexopora* is of Gisbornian/Eastonian age.

Silurian(?). Silurian(?) bryozoans are all extremely rare and questionable. In the early exploration of Silurian and Devonian of Victoria, the age of many units was uncertain. For example, a number of Silurian(?) and Devonian fossils, but not all, ascribed to bryozoans by Chapman (1903, 1907, 1914, 1917, 1919, and 1920) were determined to belong to other fossil groups or were too fragmentary to identify as determined by Ross (1961).

Devonian. Devonian bryozoans are less common than the Ordovician ones and most are endemic species in Australia (Ross, 1961; Ross, in Talent and others, 2000). A fairly thick section in the Fitzroy Basin, Western Australia, is a notable exception with *Fistulipora pillarensis* occurring in the upper part of the Givetian or lower Frasnian. Higher in the Frasnian, another species of *Fistulipora*, a *Fenestella*, and three species of *Nicklesopora* occur. The highest part of the Fitzroy Basin Devonian, upper part of the Famennian, has abundant, but an endemic, bryozoan fauna comprised of *Percyopora tubulata*, *P. occidentalis*, *Fitzroyopora oscarensis* and '*Granivallum*' *fistulosum* along with the cystoporate *Coelocaulis maculosa* and the cryptostomes *Nicklesopora crenulata*

and Fenestella pikerensis.

In eastern Australia bryozoans are reported from scattered sites in the Lachlan Geosyncline from Tasmania in the south to northern Queensland in the north. The Buchan-Taemas-Molong platform in Victoria and New South Wales has extensive areas of carbonate sedimentation, but bryozoans are generally sparse. Talent (1963) found an exceptional diverse Emsian bryozoan fauna of trepostomes, cyclostomes, and ctenostome from the Wentworth Group in northern Victoria. Other Emsian species from the Lilydale and Loyola areas in Victoria include a cryptostome Fenestella margaritifera and a cvstoporate Fistulipora victoriae (Ross, 1961) but the specimens are quite fragmentary. Other Middle Devonian bryozoans are Crockford's (1941c) Semicoscinium vallatum from near Taemas and nearby a trepostome Cyphotrypa(?) shearsbyi. Ross (1961) described a more diverse fauna of trepostomes, two species of Cyphotrypa, Sterotoechus, *Homotrypa*? and *Heterotrypa*; cryptostomes *Ikelarchimedes*, *Hemitrypa*, *Nicklesopora*; and the cystoporate *Fistulipora*. Pedder (1971) recorded a trepostome from the Lower Devonian (Pragian) in the Wellington-Molong District and farther north near Tamworth, Crockford (1941c) described the Eifelian cryptostome Fenestella mouara from the Moore Creek Limestone. In northern Queensland, from the Burdekin Basin, Wyatt and Jell (1967) report bryozoans from the Givetian Fanny River Group. Bigey (1985) included a brief account of eastern Australian Devonian bryozoans in her biogeographic analysis. The Lachlan Geosyncline bryozoans are a distinct fauna, not closely related to those in the Canning Basin fauna.

4.3 Current Knowledge

The outcome of all of these Paleozoic studies is that we have a reasonably thorough understanding of the Permian and some Carboniferous bryozoans and a fair understanding of the sparser earlier Palaeozoic bryozoans from eastern Australian and Western Australia.

5. Acknowlegdements

We have had the enthusiastic help of bryozoologists in Australia and those who have been associated with Australia bryozoology in one way or another in their studies. Foremost is Phil Bock, Deakin University, Victoria, who helped with much valuable material about Victorians, MacGillivray, Maplestone, and himself. Bock gave us two excellent obituaries about MacGillivaryand one extemely helpful obituary for Maplestone from the 'Victorian Naturalist' by W. M. Bale (1914). These concise statements of the stature and type of work done by MacGillivray, Maplestone, and many others, showed the kind of studies that were typical in the years before the First World War. Thanks also to Robin Wass who aided us with comments about Stach, Yoo, and Cockbain. For background information on place names, geography, ecological setting, and the environment of coastal Australia, the reader is referred to a thorough summary by Ohlsson and Barca (2004).

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