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GEOLOGICAL CURATORS' GROUP
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GEOLOGICAL CURATORS' GROUP

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The Group is affiliated to the Geological Society of London. It was founded in 1974 to improve the status of geology in museums and similar institutions, and to improve the standard of geological curation in general by:

- holding meetings to promote the exchange of information
- providing information and advice on all matters relating to geology in museums
- the surveillance of collections of geological specimens and information with a view to ensuring their well being
- the maintenance of a code of practice for the curation and deployment of collections
- the advancement of the documentation and conservation of geological sites
- initiating and conducting surveys relating to the aims of the Group.

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Cover: Three women palaeontologists: Gertrude Elles (top left), Ethel Wood (bottom left), and Dorothy Hill (right) [see papers by Rickards and Simpson].

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GEOLOGICAL CURATORS' GROUP - November 1999

THE WORK AND TYPE COLLECTIONS OF THE AUSTRALIAN PALAEONTOLOGIST, PROFESSOR DOROTHY HILL (1907-1997).

by Andrew Simpson

Simpson, A. 1999. The work and type collections of the Australian Palaeontologist, Professor Dorothy Hill (1907-1997). *The Geological Curator* 7(2): 51-69.

The outstanding Australian palaeontologist, Professor Dorothy Hill, is renowned for her pioneering work on fossil corals and Palaeozoic biostratigraphy. During her long association with the University of Queensland she achieved much in the fields of science and education. Her working life has left an invaluable legacy of scientific papers and numerous specimens in the collections of the Geology Museum at the University of Queensland. These include 186 type specimens of 107 taxa. A comprehensive listing is given. Short biographical notes on her working life highlighting her more significant scientific achievements, particularly in relation to collection development at the University of Queensland, are also given as contextual information.

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World renowned palaeontologist and highly respected Australian educator and tertiary administrator Emeritus Professor Dorothy Hill passed away on the 23rd of April 1997 aged 89 years. A display commemorating her work was prepared in the Geology Museum, University of Queensland, and was available to the public during 1998.

Professor Hill is best known in palaeontological circles for her pioneering work on Palaeozoic corals and archaeocyathids and their application to the study of stratigraphy. During her working life she contributed thousands of specimens to the collections of the Department of Earth Sciences (then Department of Geology and Mineralogy). A large number of these are type specimens due to the considerable volume of taxonomic work undertaken. As such this material is in demand by modern researchers for comparative studies and to refine our understanding of evolutionary principles.

Dorothy Hill was born in Brisbane in 1907. She won an Open Scholarship to the University of Queensland after attending Brisbane Girls' Grammar School. Dorothy Hill was a gifted sportswoman representing both the University and Queensland in hockey. One anecdotal story suggests she originally chose geology instead of chemistry as it didn't interfere with hockey practice. Campbell and Jell (1998) indicate a more likely reason was her desire to broaden her general knowledge of science. After her first year of science at University she was inspired to continue to study geology by Professor H.C. Richards (1884 - 1947), the Foundation Professor in the Department of Geology and Mineralogy.

For her Honours project in geology she mapped the district from Bellevue to Linville in the Brisbane Valley on horseback, seeking coal deposits and collecting Triassic fossil plants. For her efforts she graduated in 1928 with First Class Honours and a University Gold Medal, the first woman to receive this highest undergraduate award. This was the first of many firsts. She was later described by Professor Malcolm Thomis, in his history of the University of Queensland as "the most distinguished scholar of all of Queensland's graduates" (Thomis 1985, p. 287).

Soon after graduating, while visiting friends, she was shown a Carboniferous limestone with fossil corals in the Mundubbera district (Jell 1997). So began a lifetime passion for the study of these Palaeozoic fossils. Fossil corals are studied by examining their internal structure with the use of oriented thin slices of rock through the fossil (thin sections). The study is relatively inexpensive requiring only a rock saw, a microscope and photographic equipment. Another reason for pursuing this academic discipline was because, at the time, the regional geological mapping of Queensland was imperative for the development of the state's natural resources (Runnegar and Jell 1983).

Dorothy Hill undertook Ph.D. studies at the University of Cambridge, England, supported by a Foundation Travelling Scholarship to the Sedgwick Museum (Campbell and Jell 1998). She was awarded the degree in 1932. No Ph.D. programs were available in Australia at that time. From 1932 to 1937 she was a Fellow of Newnham College, Cambridge, supported

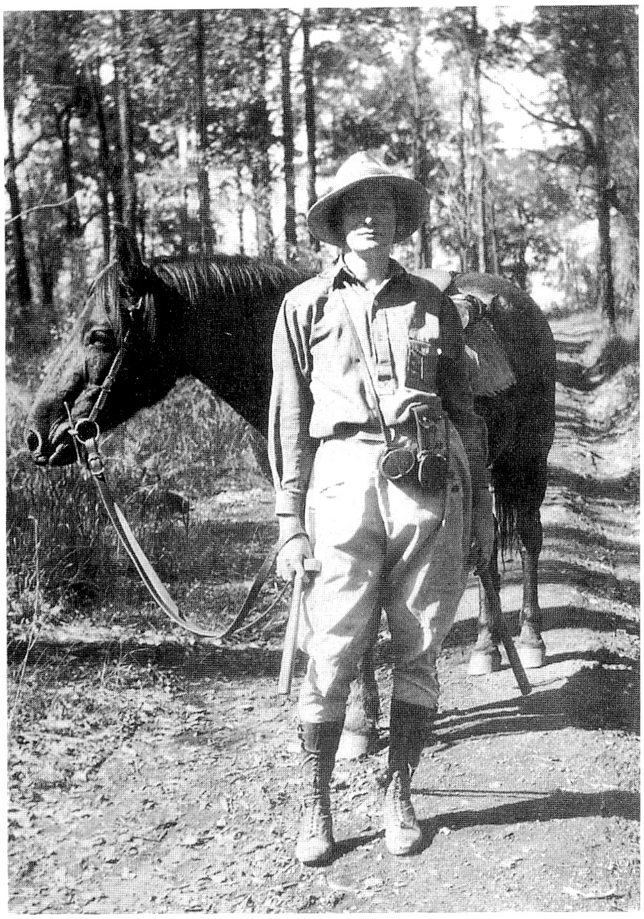

Figure 1. Dorothy Hill in the Brisbane Valley *circa* 1929 with typical mode of transport for field geologists at the time. Photo from the Fryer Library Collection, the University of Queensland.

by research scholarships. During this time she completed her study of Lower Carboniferous corals of the Mundubbera area (Hill 1934), undertook a revision of the terminology used in the study of fossil corals (Hill 1935) and worked towards a major monograph in four parts, on fossil corals from Scotland (Hill 1938*a*, 1939*a*, 1940*a*, 1941). Her experiences at Cambridge had a profound effect, developing her understanding of the scientific research methodology, the need for a good scientific library, the need for scientific collections and the value of collaboration with colleagues. Campbell and Jell (1998) have outlined how she maintained her sporting interests and broadened her cultural horizons during these Cambridge years.

In 1937 Dorothy Hill obtained one of the new Australian Commonwealth Research Fellowships and returned to the University of Queensland where she continued to collect and study fossil corals. Her palaeontological interests expanded to cover coral studies throughout Australia and encompassing all Palaeozoic time periods. Soon after her return to Brisbane, for example, she had published on the Permian of Western Australia (Hill 1937), the Devonian of Queensland (Hill 1939*b*), the Devonian of Victoria (Hill 1939*c*) and the Silurian of New South Wales (Hill 1940*b*), amongst others. Apart from these solo efforts there was also significant, and often innovative, collaboration with staff members of the then Department of Geology at the University of Queensland. W.H. Bryan (1891 - 1966), a geologist with broadly diverse interests had studied the development of spherulites; collaboration with Hill allowed his knowledge and scientific instincts to encompass her palaeontological interests (Bryan and Hill 1941). This prolific output was rewarded in 1942 when she was awarded a Doctorate of Science, the first woman at the University of Queensland to achieve this. Between 1938 and 1942 she served as Secretary of the Royal Society of Queensland. This period also saw the beginning of Hill's involvement with the Great Barrier Reef Committee under the chairmanship of H.C. Richards. Richards and Hill (1942) published the results of early drilling on the Reef. Campbell and Jell (1998) outlined her considerable contribution to the development of the Great Barrier Reef Committee and her later commitment to documenting its early history.

The Fellowship was interrupted by the Second World War when she enlisted in the Women's Royal Australian Naval Service in 1942. She worked on codes and ciphers in the office of the naval officer in charge of the port of Brisbane, Captain E.P. Thomas (Campbell and Jell 1998). This was an important position as much war material for Allied forces was passing through eastern Australia. The war did not halt her research activities which she pursued in her spare time. In her history of the Department of Geology and Mineralogy at the University (Hill 1981, p. 28-29), she noted an unusual example of her assistance to the war effort. Hill happened to be studying collections at the Australian Museum when the Curator of Palaeontology (O.H. Fletcher) was called up for service. She assisted the Museum authorities by selecting the type specimens from the collection and packing them for transportation to a safe site in the country in case Sydney came under attack from Japanese forces. In 1939 and the early 1940s she was also in touch with the Chief Government Geologist of Queensland asking that the Survey's collections be kept safe during the war (Campbell and Jell 1998). At this time she also extended her knowledge of the Palaeozoic of Queensland by investigating the fossil coral collections of the Geological Survey of Queensland and identifying the fossil floras and faunas collected by the Shell (Queensland) Pty Ltd company.

After the war she was appointed lecturer in historical geology, specialising in palaeontology. Hill (1981) noted that the offer of a permanent lecturing position

Figure 2. Professor Dorothy Hill in the field with students *circa* 1965. Photograph courtesy of Dr J.S. Jell

in Queensland came after an approach from Sir Douglas Mawson (1882-1958) then head of the Geology Department concerning a lecturing post at the University of Adelaide. This was the beginning of a highly productive career as a researcher and teacher at the University of Queensland that lasted until the mid 1980s. Her experiences with the Shell collection during the war convinced her the Brachiopoda constituted the most prolific group in the Australian Palaeozoic (Hill 1981). She also believed the Permian would be the most likely System to yield oil in Queensland. For this reason she started many of her research students on Permian and Carboniferous stratigraphy and faunas, as well as publishing on the topic herself (Hill 1950*a*).

She was also convinced of the need to update the geological map of Queensland and set about this task, gathering published and unpublished data in collaboration with the Geological Survey of Queensland. There were many practical outcomes from her research that contributed greatly to our understanding of eastern Australian geology. Her compilation of the Geological Map of Queensland (Hill *et al.* 1953) provided the basic knowledge for much subsequent economic activity. These efforts culminated in the publication of the "Geology of Queensland" by the Geological Society of Australia (Hill and Denmead 1960) commonly referred to as the "green bible" by explorationists in the 1960s because of the distinctive colour of the cover (Hill 1981). Fifty two geologists contributed to this undertaking, its timeliness underscored by the discovery of the first commercial oil field in Queensland (Moonie) one year later.

During the post-war era she produced a continuous stream of high quality scientific literature that saw her international reputation as an outstanding researcher grow. Some highlights from this period include her contributions to the Anglo-American production, the Treatise of Invertebrate Paleontology. Late in the 1940s (Hill 1981) she was approached by the editor of the Treatise, R.C. Moore, and asked to produce the section on Palaeozoic corals. In 1954 the Department of Geology hosted the Fulbright Visiting Scholar, Professor John W. Wells (1907-1994); Hill and Wells collaborated on various bridging sections of the Coelenterata volume of the Treatise. She contributed three and a half volumes, more than any other author has achieved (Coelenterata, (with Wells) in 1956, Archaeocyatha in 1972 and the revised edition of Coelenterata (rugosa and tabulata) in 1981 (2 volumes)).

During this phase of her career, Dorothy Hill also developed an outstanding reputation as a teacher. She was described by her colleagues as a "born teacher" (Denmead 1969). She believed that good research and good teaching went hand in hand, and inspired generations of students with her passion for geology and the natural sciences. She perceived the role of the teacher as the development of inquiring minds (Campbell 1997). This was done by confronting students with real problems, then providing them with the intellectual tools to seek appropriate solutions. She supervised many Honours and higher degree students. These students would consult with her every day to help advance their projects, a practice rarely equalled in modern times.

Many of her students went on to take up positions of leadership and responsibility in commercial and community spheres. On the occasion of her 75th birthday, the Australasian Association of Palaeontologists, an organisation she was instrumental in establishing, held a symposium in her honour and dedicated a volume of papers (Roberts and Jell 1983) to her. Twenty eight companies and government instrumentalities contributed financially to this endeavour; almost all were headed by her former students or colleagues. This was the third major collaborative work to carry Professor Hill's name as a mark of honour and respect from her peers and former students. An earlier volume (Campbell 1969) consisted of 20 contributions from 24 authors outlining and reviewing developments in palaeontology and stratigraphy. Another volume (Denmead *et al.* 1974) concentrated on recent developments in knowledge of the Tasman Fold Belt.

Whilst acquiring the best intellectual practices from her time at Cambridge, she is attributed with effectively "decolonising" the science of palaeontology in Australia (Runnegar and Jell 1983). She encouraged students to take up studies at Australian universities, working on Australian geological problems. This was done at a time when Australia urgently needed accurate appraisal of its geological resources.

The large volume of work undertaken by Dorothy Hill directed towards the stabilisation of the taxonomy of Palaeozoic corals meant rapid growth of the collections at the University of Queensland. In 1948 the Department of Geology appointed its first "Keeper of the Collections", Stan Colliver. He was a Fitter and Turner with the Victorian State Railways who had strong amateur natural history interests. He had met Hill during her war service in Melbourne (Jell pers. com. 1998). Colliver worked under the direction of Hill to ensure adequate international standards of curation for the fast growing collection (Campbell and Jell 1998). Although curatorial practices based on the Sedgwick Museum were already in place prior to Hill's return from Cambridge (Jell pers. com. 1998), her experiences in Cambridge helped reinforce the need to maintain these high standards. Her influence in establishing the collections as a major research resource for international scholarship was considerable. She was particularly keen to ensure the appropriate care of type specimens, outlining her thoughts on the subject in a communication to the fledgling Geological Society of Australia at an early stage (Hill 1954*a*). She noted that it was the responsibility of authors to ensure that type material was housed in an appropriate institution with a clear policy on type specimens and a staff member dedicated to making such material available to future researchers. She also believed that, where possible, Australian material should be housed in Australian collections in close geographic proximity to their origin. Furthermore, as a type fossil coral specimen may consist of a number of thin sections, she believed it was appropriate to deposit types in different collections, and where replicas (such as casts) could be made these may also be deposited in alternative collections. As a result of her decades of dedication,

Figure 3. Grotesque of Professor Dorothy Hill from the Richards Geology Building at the University of Queensland clearly depicting her affection for the main objects of her scientific interest, the rugose corals. The grotesque and all the cladding of the Great Court Buildings of the University of Queensland consist of Jurassic Helidon Sandstone. Hill's early mentor H.C. Richards, the first Professor of Geology at the University was responsible for selecting the Helidon Sandstone for this purpose. Photograph courtesy of Media and Information Services at the University of Queensland.

the collections of the Geology Museum at the University of Queensland contained approximately one third of all the type palaeontological material housed in the tertiary education sector in Australia.

In 1962 Dorothy Hill was instrumental in establishing the Queensland Palaeontographical Society, this local organisation was a forerunner of the Australasian Association of Palaeontologists. From 1962 to 1969 this group was responsible for publishing a series of booklets on index fossils of Queensland (Hill and Woods 1964*a*, 1964*b*; Hill, Playford and Woods 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972*a*, 1972*b*, 1973). The original purpose was to publish images and brief explanatory notes of index fossils to enable those engaged in regional mapping to make preliminary identifications and biostratigraphic inferences (Pridmore *et al.* 1994). This remarkable series, unmatched by any comparable endeavour elsewhere in Australia, did much in a quiet, unintentional way to popularise the science of palaeontology in Queensland. At the second annual meeting of the Society a membership of 57 was recorded (Pridmore *et al.* 1994). Although being out of print for many years the publications are still actively sought by amateur and professional collectors.

Her scientific interests were not just restricted to geology and palaeontology. She was also active in support for the Great Barrier Reef Committee (Campbell and Jell 1998). During her career she also shouldered a significant slice of administrative responsibility. In 1971 she became president of the University of Queensland's professorial board, the first woman to hold such a position in any Australian university. This was a difficult job, involving responsibility for research funding and staffing during a time of substantial social change on campus (Campbell and Jell 1998).

She was the first woman elected a fellow of the Australian Academy of Science (1956), the first woman elected president of the geology section of the Australian and New Zealand Association for the Advancement of Science (ANZAAS) in 1956, the first woman appointed to a Professorial position at an Australian university (1959), the first woman elected a Fellow of the Royal Society of London (1965, the only Australian woman to achieve this distinction). She was awarded a CBE in 1971 and an AC from the Australian government in 1993. Some of her many other awards included the Lyell Medal of the Geological Society of London (1964), the Clarke Medal of the Royal Society of New South Wales (1966) and the ANZAAS Mueller Medal for distinguished service to science (1967). She was an Honorary Life Member of the Geological Society of Australia, Patron and Honorary Life Member of the Association of Australasian Palaeontologists and served on the Council of the Australian Academy of Science from 1968 to 1971, as Vice President (1969), and President (1970).

One of Dorothy Hill's most outstanding achievements at the University of Queensland, for which she was held in high regard by the geological fraternity, was the development of the Geology Library. Her recognition of the need for a good research library stemmed from her earlier experiences at Cambridge. During the 1950s she was the officer-in-charge of the departmental library which undertook spectacular growth under her guidance. Many obscure serials, new titles and back numbers were collected by various means, including through exchanges with the Department's own series of papers. The library was internationally recognised as a benchmark of best practice for specialist scientific libraries. In 1985 the library was named the Dorothy Hill Geology Library in honour of her considerable efforts in developing the collection of scientific literature. Unfortunately, due to financial pressures, the University amalgamated the library with the collections of the Physical Sciences and Engineering Library two months before her death. University Senate readily agreed to rename the combined holdings the Dorothy Hill Physical Sciences and Engineering Library.

Figure 4. Charcoal sketch of Professor Dorothy Hill by Lola McCausland, 1976. This was the basis for Professor Hill's portrait now part of the University of Queensland's Art Collection and presently hanging at the entrance to the Dorothy Hill Physical Sciences and Engineering Library at the University of Queensland. The sketch was also used as the frontispiece of the Dorothy Hill Jubilee Memoir.

Dorothy Hill did much to advance the position of women in Australian science and society without ever seeking to be a champion of this cause. She recognised the existence of in-built inequalities and believed the best way to combat this was through outstanding performance (Campbell and Jell 1998). The historical context and difficulties faced by women seeking careers in palaeontology in Australia during the early half of the twentieth century has been outlined elsewhere (Turner 1998). Hill was an outstanding success and unintentional role model. During her career she travelled Queensland encouraging people to send their daughters as well as their sons to the University of Queensland. In a recent obituary, Ken Campbell, a retired Professor of Geology from the Australian National University, and one of Hill's first Ph.D. students, ranked her amongst the most eminent women Australia has produced (Campbell 1997).

The life and work of Professor Dorothy Hill was celebrated in a 1997 exhibition at the Queensland Museum entitled "Brilliant Careers", which highlighted the work of 33 women collectors and illustrators in Queensland. Elements of this display were subsequently incorporated in the Geology Museum display at the University of Queensland.

The Geology Museum display included Professor Hill's binocular microscope with which she pursued much of her research. The microscope was built by the Carl Zeiss company in 1910, and was one of the most advanced instruments of its time with a revolutionary advantage of separation of the microscope stage from the fittings that carry the optical components. The microscope was one of the first purchased by the fledgling Department of Geology and Mineralogy. It has been painstakingly restored to its original condition by the Curator of the University of Queensland's Microscope collection, Mr Windsor Davies. Today, the microscope is one of the 180 historic instruments in the Microscope collection.

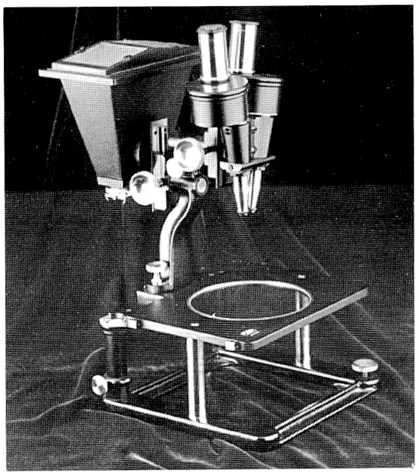

Figure 5. Professor Dorothy Hill's stereo-binocular microscope, Carl Ziess *circa* 1910, as restored by Mr Windsor Davies. Photograph courtesy of Windsor Davies.

The display also featured a reproduction of Professor Hill's portrait painted in 1972 by Lola McCausland that for many years hung in the Geology Library at the University of Queensland. The original portrait, now part of the University of Queensland Art Museum collection, is now hung at the entrance of the Dorothy Hill Physical Sciences and Engineering Library at the University of Queensland. The display also included some of her more significant scientific publications, fossil corals and archaeocyathids and some of the thin sections from the Geology Museum's reference collections.

Dorothy Hill's passion for Palaeozoic corals was commemorated by an inset of *Xystriphyllum* sp., from the Broken River region of north Queensland, as part of her headstone (Jell pers. comm. 1998). Dorothy Hill's influence on Australian science will reverberate for generations.

List of Professor Dorothy Hill's type specimens from the collections of the Geology Museum, University of Queensland

The following is a listing of the type specimens (Archaeocyatha, Brachiopoda and Coelenterata) submitted into the collections of the Geology Museum at the University of Queensland by Professor Dorothy Hill. In this listing the term type specimen is restricted to specimens designated as holotype, paratype, neotype, lectotypes and syntypes. Figured and mentioned specimens have not been included.

Genera and species are organised alphabetically within their broader taxonomic groupings. Generic and specific names are listed as originally designated. Reference to any subsequent taxonomic reinterpretation is also given. Other references to the specimens in the literature are also noted. In most cases only the Australian literature has been checked and the listing is therefore not comprehensive. I would certainly welcome advice on other references to these specimens in the scientific literature. Locality, rock unit and age have been revised where possible, but in all cases the original published locality has also been given. Any statement following an equivalence sign or within brackets indicates revision or reinterpretation.

Since commencing this listing, the University of Queensland has donated all its research collections to the Queensland Museum in early 1999. The author publishes with the permission of the Queensland Museum. There are no plans to change the designated prefix or number of any specimens formerly belonging to the University of Queensland.

The prefix UQL indicates a University of Queensland Locality and UQF a University of Queensland Fossil. The following institutional abbreviations are used throughout the listing:-

AM - Australian Museum, Sydney.

BMR, CPC - Bureau of Mineral Resources (now the Australian Geological Survey Organisation), Commonwealth Palaeontological Collection, Canberra.
GSQ - Geological Survey of Queensland, Brisbane.
GSV - Geological Survey of Victoria, Melbourne.
GSWA - Geological Survey of Western Australia, Perth.
MU - Melbourne University, Melbourne.
NM - National Museum of Victoria, Melbourne.
NZGS - New Zealand Geological Survey, Lower Hutt.
SU - Sydney University, Sydney.
TAE - Trans Antarctic Expedition (specimens in the British Museum of Natural History, London)
UT - University of Tasmania, Hobart.
UWA - University of Western Australia, Perth.

ARCHAEOCYATHA

Formosocyathus antarcticus Hill, 1964
Paratypes* UQF 44348 [ex An 62/1a],UQF 44352 [ex An 62/1C], UQF 44355 [ex An 62/1B].
From loose block An 62, Plunket Point, near head of Beardmore Glacier, Antarctica.
Stratigraphy unknown, Early Cambrian.
* Duplicate slides of unfigured paratypes.
Hill 1964, p. 616, figs 1(3-10).

Ladaecyathus pratta Hill, 1965
Holotype* UQF 44322.
From an erratic in moraine on Whichaway Nunataks, Antarctica.
Stratigraphy unknown, Early Cambrian.
* Portion of Holotype TAE 22(S8410) in British Museum (Natural History).
Hill 1965, p. 86, pl. 5, fig. 3.

BRACHIOPODA

Horridonia mitis Hill, 1950
Holotype UQF 10772.
From white limestone in the ridge 400 m to 800 m north west of Cracow Homestead, near the base of the marine "Kamilaroi".
= Buffel Formation; Asselian Stage, Permian.
Hill 1950*a*, p. 17, pl. 8, fig. 17.

Terrakea pollex Hill, 1950
Holotype UQF 16758.
From white limestone in the ridge 400 m to 800 m north west of Cracow Homestead, near the base of the marine "Kamilaroi".
= Buffel Formation; Asselian Stage, Permian.
Hill 1950*a*, p. 20, pl. 9, fig. 6.

COELENTERATA

Acanthophyllum asper Hill, 1940
= *Embolophyllum asper* (Hill) Pedder, 1967
Holotype UQF 4270 A-F [B and C are slides].
From Cave Flat road, Wee Jasper, Goodradigbee River, New South Wales.
= Taemas Limestone; Emsian Stage, Devonian.
Hill 1940*c*, p. 252, pl. 9 fig. 3.
Strusz 1966, p. 549, pl. 85, figs 2a-b.
Pedder 1967, p. 11.
Hill 1978, p. 16.

Acervularia chalkii Chapman, 1931
= *Prismatophyllum chalkii* (Chapman) Hill, 1939
Holotype portion* UQF 69906 A-D [A and D are slides].
From Cave Hill, Lilydale, Victoria.
= Lilydale Limestone Member, Cave Hill Formation; Early Devonian.
* Ex Holotype 1877 MU
Chapman 1931, p. 94, text-fig.
Hill 1939*c*, p. 232.
Hill 1978, p. 18.

Alveolites caudatus Hill, 1954
Holotype portion* UQF 14778.
From high (= about 366m-396 m above base) in the Gneudna Formation, 1.6 km north of traverse north of Gneudna Well, Carnarvon Basin, Western Australia.
Gneudna Formation; Frasnian Stage, Devonian.
* Ex holotype CPC 765 BMR.
Hill 1954*b*, p. 32, pl. 1 fig. 10.
Hill 1978, p. 18

Amygdalophyllum conicum Hill, 1934
Holotype UQF 2951.
Paratypes UQF 2434-2437, 2439, 2441, 2444-2446, 2498, 2504, 2942, 6353, 13093-13095, 13097.
From Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
Riverleigh Limestone; Visean Stage, Carboniferous.
Hill 1934, p. 70, pl. 8 figs 14-21 (Holotype), 22-31 (UQF 2437), 32-33 (UQF 2498), 34-36 (UQF 2436), 37-40 (UQF 2445), 41-48 (UQF 2942), text-fig. 1, p. 70 (UQF 2435).
Hill 1978, p. 19.
Webb 1990, p. 42.

Amygdalophyllum vallum Hill, 1934
Holotype UQF 2950 A-G [A, C, E and F are slides].
Paratype UQF 2453 A-D [all slides].
From Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
Riverleigh Limestone; Visean Stage, Carboniferous.
Hill 1934, p. 72, pl. 8 figs 9-11 (Holotype), figs 12, 13 (UQF 2453).
Hill 1978, p. 33.

Aphrophyllum foliaceum Hill, 1934
= *Merlwoodia foliaceum* (Hill) Jull, 1969
= *Merlewoodia foliacea* (Hill) Webb, 1990

Holotype UQF 2396*.
From Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
= Riverleigh Limestone; Visean Stage, Early Carboniferous.
*Wrongly given as F 2430 in text by all subsequent authors.
Hill 1934, p. 74, pl 9 figs 9, 16 (UQF 2955) fig. 11 (UQF 2956), fig. 12 (UQF 2957), figs 13, 14 (UQF 2502), fig. 15 (UQF 2958); text-fig. 2, p. 74 (Holotype).
Jull 1969, p. 130.
Hill 1978, p. 22.
Webb 1990, p. 73.

Aphyllum salmoni (Hill)
See *Yabeia salmoni* Hill, 1942

Argutastrea hullensis (Hill)
See *Hexagonaria hullensis* Hill, 1954

Aulina simplex Hill, 1934
Holotype UQF 2939 A-I [B-I are slides; A is missing].
Paratypes UQF 2416, 2418, 2424, 2448, 2508, 2535, 2940, 45564-45566 [UQF 2508 and 2940 are missing].
From Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
Riverleigh Limestone; Visean Stage, Carboniferous.
Hill 1934, p. 93, pl. 11 figs 13-29 (Holotype); text-fig. 4 (UQF 2940).
Hill 1978, p. 31.

Aulopora recta Hill, 1954
Holotype portion* UQF 15090 A-C.
From the Mount Pierre Group, Bugle Gap, West Kimberleys, Western Australia.
=? Virgin Hills Formation; Fammenian Stage, Devonian.
*Ex Holotype CPC 559 BMR.
Hill 1954*b*, p. 34, pl. 3 fig. 20.
Hill 1978, p. 30.

Bajgolia contigua (Hill)
See *Eofletcheria contigua* Hill, 1955

Bajgolia gracilis (Hill)
See *Eofletcheria gracilis* Hill, 1957

Bajgolia(?) *ida* (Hill)
See *Eofletcheria ida* Hill, 1955

Barrandeophyllum cavum Hill, 1954
Holotype portion* UQF 67161 [slide].
From the Mount Pierre Group, Old Bohemia Homestead vicinity, Margaret River area, West Kimberleys, Western Australia.
= Virgin Hills Formation; Frasnian Stage, Devonian.
*ex Holotype CPC 548 BMR.
Hill 1954*b*, p. 8, pl. 3 fig. 3.

Billingsaria banksi Hill, 1955
Holotype portion* UQF 17764.
From Ida Bay, Tasmania.
= Gordon Limestone; Middle-Late Ordovician.
*Ex Holotype 2113 MU.
Hill 1955, p. 246, pl. 3 fig. 40.
Hill 1978, p. 17.

Campophyllum recessum Hill, 1940
= *Chalcidophyllum recessum* (Hill) Pedder, 1965
Holotype portion * UQF 21625.
From Devil's Elbow, Murrumbidgee River, opposite island, Bloomfield's station, New South Wales.
= Currajong Limestone (approximately 40 m above the base); Emsian Stage, Devonian.
* Ex Holotype F16343 AM.
Hill 1940*c*, p. 254, pl. 9 fig. 7.
Pedder 1965, p. 204.
Hill 1978, p. 29.

Caninia rudis Hill, 1954
Paratype Portion* UQF 15073 A-B, UQF 15074 A-F [C and E are slides].
From the Mount Pierre Group, Bugle Gap, West Kimberleys, Western Australia,
= ?Virgin Hills Formation; Frasnian Stage, Devonian.
* Ex R340 BMR.
Hill 1954*b*, p. 28.

Carcinophyllum patellum Hill, 1934
Holotype UQF 2534 A-E [D and E are slides].
Paratypes UQF 2386, 2431-2433, 2446, 2460, 2505, 2960, 2961, 45558-45563, 46087.
From Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
= Riverleigh Limestone; Early Carboniferous.
Hill 1934, p. 80, pl. 10 figs 1-2 (Holotype), figs 3, 4 (UQF 2386), fig. 5 (UQF 2432), figs 6, 7 (UQF 2505), figs 8-11 (UQF 2960), figs 12, 13 (UQF 2961), figs 14-17 (UQF 2460).
Hill 1978, p. 28.
Webb 1990, p. 86.

Catactotoechus irregularis Hill, 1954
Paratypes UQF 15066-15068.
From Oscar Hill, one mile south of Oscar Homestead, West Kimberleys, Western Australia.
Bugle Gap Limestone; Fammenian Stage, Devonian.
Hill 1954*b*, p. 10.

Catactotoechus tenuis Hill, 1954
Paratype UQF 15062.
From Oscar Hill, one mile south of Oscar Homestead, West Kimberleys, Western Australia.
Bugle Gap Limestone; Fammenian Stage, Devonian.
Hill 1954*b*, p. 12.

Chalcidophyllum recessum (Hill)
See *Campophyllum recessum* Hill, 1940

Charactophyllum (*Spinophyllum*) *trochoides* (Hill)

See *Disphyllum* (or *Macgeea*) *trochoides* Hill, 1942

Chlamydophyllum expansum Hill, 1942
Holotype UQF 5220 A-F.
From the foot of Mt Etna, near Rockhampton, Queensland.
= Mt Holly Beds; Emsian Stage, Devonian.
Hill 1942*a*, p. 18, pl. 1 figs 8 a, b.
Hill 1978, p. 22.

Coccoseris ramosa Hill, 1955
Holotype portion* UQF 17776 A-D
From Ida Bay, Tasmania.
= Gordon Limestone; Middle-Late Ordovician.
*Ex Holotype 2119 MU.
Hill 1955, p. 249, pl. 3 fig 41.
Hill 1978, p. 29.

Coccoseris speleana Hill, 1957
Holotype portion* UQF 23263.
From the "Large Flat Limestone", Large Flat, near Mandurama, New South Wales.
= the upper part of the lower shaly limestone unit of the Cliefden Caves Formation; Late Ordovician.
* Ex Holotype F46754 AM.
Hill 1957, p. 101, pl. 3 figs 13 a, b.
Hill 1978, p. 31.

Coelostylis compactum (Hill)
See *Streptelasma compactum* Hill, 1953

Coenites expansus de Koninck, 1876
Neotype* UQF 4269.
From the Sponge limestone of Cavan, New South Wales.
= Cavan Limestone; Emsian Stage, Devonian.
De Koninck 1876, p. 74, Atlas pl. 2 fig. 3.
*Erected Hill 1950*b*, p. 146, pl. 6 figs 19 A-C.
Hill 1978, p. 22.

Coenaphrodia lonsdaloides (Hill)
See *Orionastrea lonsdaloides* Hill, 1934

Cyathophyllum pannosum Jell & Hill, 1969
Holotype UQF 52798 A-G [C and E are slides].
From B84F (field number) 3.2 km slightly north of west of Hidden Valley Homestead, Ukalunda district, south western part of the Bowen 1:250 000 sheet area, Queensland.
Ukalunda Beds; Emsian-Eifelian Stages, Devonian.
Jell and Hill 1969, p. 6, pl. 2 fig. 12.
Hill 1978, p. 28.

Cyathophyllum sentum Jell & Hill, 1969
Holotype UQF 52710 A-E [C and E are slides].
From B84F (field number) 3.2 km slightly north of west of Hidden Valley Homestead, Ukalunda district, south western part of the Bowen 1:250 000 sheet area, Queensland.
Ukalunda Beds; Emsian-Eifelian Stages, Devonian.
Jell and Hill 1969, p. 5, pl. 1 fig. 8.
Hill 1978, p. 30.

Cyathophyllum subcaespitosum Chapman, 1925
= *Lyrielasma* (*L.*) *chapmani** (Chapman) Hill, 1925.
Holotype portion** UQF 4195 A-B.
From Cave Hill, Lilydale, Victoria.
= Lilydale Limestone Member, Cave Hill Formation; Early Devonian.
* *C. subcaespitosum* Chapman is a junior homonym of *C. subcaespitosum* Meek, 1873. Consequently Pedder (1967, p. 5) proposed the nomen specificum "chapmani" for this species.
** Ex Holotype P1731 NM & P14065 NM.
Chapman 1925, p. 112, pl. 13 fig. 15.
Hill 1939*c*, p. 244.
Hill 1978, p. 32.

Disphyllum curtum Hill, 1954
Holotype portion* UQF 13184 A-D
From section south of Mount Wilson in the lower part of the Amphipora Limestone, lowest Disphyllum horizon of Mount Wilson, West Kimberleys, Western Australia.
= Pillara Limestone; Givetian-Frasnian Stages, Devonian.
*Ex Holotype F33518 UWA.
Hill 1954*b*, p. 22, pl. 2 fig. 8.
Hill 1978, p. 20.

Disphyllum intertextum Hill, 1954
Holotype portion* UQF 14165 A-L
From Paddy's Spring, north side of Emmanuel Range, West Kimberleys, Western Australia.
= Sadler Limestone; Frasnian Stage, Devonian.
* Ex Holotype F33517 UWA.
Hill 1954*b*, p. 22, pl. 3 fig. 1.
Hill 1978, p. 24.

Disphyllum repansum Jell & Hill, 1970
Holotype portion* UQF 59427 A-H.
Paratype portion** UQF 59426 A, B.
From Sanctuary Bay, Point Hibbs, Tasmania.
Point Hibbs Limestone; Early Devonian.
* UQF 59427 ex Holotype 52085 UT.
** UQF 59426 ex Paratype 52206 UT.
Jell and Hill 1970a, p. 5, pl. 2 fig. 8 (Holotype), fig. 9 (52206 UT).
Hill 1978, p. 30.

Disphyllum (or *Macgeea*) *trochoides* Hill, 1942
= *Charactophyllum* (*Spinophyllum*) *trochoides* (Hill) Zhen and Jell, 1996
Holotype UQF 4557 A-E [C and E are slides].
From Fanning River Station at Windmill about 4.8 km east southeast of Homestead, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 249, pl. 8 fig. 5.
Hill 1978, p. 33.
Zhen and Jell 1996, p. 76.

Disphyllum virgatum var. *densum* Hill, 1954
Holotype Portion* UQF 15076 A-B.
From Hull Range Section, 165-195 m above the basal

contact with the Precambrian, 3.2 km south of Shady Creek Gap, north of Margaret River, West Kimberleys, Western Australia.
Pillara Limestone; Givetian-Frasnian Stages, Devonian.
*Ex Holotype CPC 497 BMR.
Hill 1954*b*, p. 19, pl. 2 fig. 7.
Hill 1978, p. 20.

Disphyllum virgatum var. *variabile* Hill, 1954
Holotype portion* UQF 14779.
From the Gneudna Formation 590-900 m along traverse (i.e. approximately 360 m above the base of the formation) south of Gneudna Well, near Williamsbury Station, Carnarvon Basin, Western Australia.
Gneudna Formation; Frasnian Stage, Devonian.
*Ex Holotype CPC767 BMR.
Hill 1954*b*, p. 20, pl. 1 fig. 2.
Hill 1978, p. 33.

Dohmophyllum clarkei Hill, 1942
Holotype UQF 4531 A-E [B and D are slides]
From the base of the Fanning River Limestone, about 3.2 km upstream from Fanning River Homestead, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 236, pl. 5 fig. 6.
Hill 1978, p. 18.
Zhen and Jell 1996, p. 54.

Embolophyllum asper (Hill)
See *Acanthophyllum asper* Hill, 1940

Endophyllum abditum var. *columna* Hill, 1942
= *Endophyllum columna* (Hill) Zhen and Jell, 1996
Holotype UQF 4275.
From top of limestone, Fanning River, 2.4 km upstream from Fanning River Homestead, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 252, pl. 9 fig. 1.
Hill 1978, p. 19.
Zhen and Jell 1996, p. 47.

Endophyllum banksi Jell & Hill, 1970
Holotype portion* UQF 59438 A-K.
Paratype portion** UQF 59437 A-B.
From the southern shore of Sanctuary Bay, north side of Point Hibbs, Western Tasmania.
Point Hibbs Limestone; Early Devonian.
* UQF 59438 ex Holotype 52091 UT.
** UQF 59437 ex Paratype 52084 UT
Jell and Hill 1970a, p. 7, pl. 2 fig. 1 (Holotype).
Hill 1978, p. 17.

Endophyllum columna (Hill)
See *Endophyllum abditum* var. *columna* Hill, 1942

Eofletcheria contigua Hill, 1955
= *Bajgolia contigua* (Hill) Webby, 1977
Holotype portion* UQF 17729.
From the Smelters Limestone, core number 2 Oceana Mine, Zeehan, Tasmania (believed to be from 28.2 m).
= Gordon Limestone; Middle-Late Ordovician.
* Ex Holotype 23527 UT.
Hill 1955, p. 251, pl. 1 fig. 6.
Webby 1977, p. 172.
Hill 1978, p. 19.

Eofletcheria gracilis Hill, 1957
= *Bajgolia gracilis* (Hill) Webby, 1977
Holotype UQF 23253A-D [B and C are slides; C is missing].
From the, Portion 289, Parish of Bowan, County Ashburnam, north of Cargo, New South Wales.
Bowan Park Limestone = Quondong Limestone; Late Ordovician.
Hill 1957, p. 105, pl. 4 fig 17b.
Webby 1977, p. 173.
Hill 1978, p. 23.

Eofletcheria Ida Hill, 1955
= *Bajgolia* (?) *ida* (Hill) Webby, 1977
Holotype portion* UQF 17766.
From Ida Bay, Tasmania.
= Gordon Limestone; Middle-Late Ordovician.
* Ex Holotype 2128 MU.
Hill 1955, p. 252, pl. 3 fig. 44.
Webby 1977, p. 172.
Hill 1978, p. 24.

Eofletcheria irregularis Hill, 1953
Holotype portion* UQF 14197 A-C
From the Encrinite Limestone north side of Skjellbukta, Frierfjorden, Gjerpen-Langesund district, Norway.
Hill 1953, p. 155, pl. 2 fig. 12.

Eoflectheria subparallella Hill, 1953
Holotype portion* UQF 14208 [slide].
From the, Loddvik, Helgoya, Mjosa, Norway.
Mjosa Limestone; Middle Ordovician
*Considered by Hill to be part of Holotype 66294 Palaeontology Museum, Oslo.
Hill 1953, p. 156, pl. 3 fig. 15.

Eridophyllum immersum Hill, 1942
Holotype UQF 5612 A-J* [B and C are slides].
From Wellington Caves, New South Wales.
= Garra Formation; Early Devonian.
*Portions E-I in the Australian Museum.
Hill 1942*c*, p. 186, pl. 5 figs 6a, b.
Hill 1978, p. 24.

Euryphyllum reidi Hill, 1938
Holotype UQF 3243 A-D.
Paratype UQF 3244.
From UQL 237, Upper Dilly Stage, Cabbage Creek, Springsure district, Queensland.
= Cattle Creek Formation; Sakmarian Stage, Permian.
Hill 1938*b*, p. 23, pl. 1 fig 1 (UQF 3244), figs 2, 3 (Holotype).
Hill 1978, p. 30.

Fasciphyllum murale (Hill)

See *Spongophyllum murale* Hill, 1950

Fasciphyllum ryani Hill, 1942
Holotype UQF 5018.
From the anabranch of the Burdekin River, near Big Rocks, Burdekin Downs Station, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 253, pl. 9 fig. 4.
Hill 1978, p. 30.

Favosites caryei Jell & Hill, 1970
Holotype portion* UQF 59433 A-B.
Paratype portion** UQF 59431 A-B.
From the southern shore of Sanctuary Bay, north side of Point Hibbs, Tasmania.
Point Hibbs Limestone; Early Devonian.
* UQF 59433 ex Holotype 51781 UT.
** UQF 59431 ex Paratype 51785 UT
Jell and Hill 1970*a*, p. 11, pl. 5 fig. 4 (51785UT), fig 5 (Holotype).
Hill 1978, p. 18.

Favosites nitidus Chapman, 1914
= *Squameofavosites nitidus* (Chapman) Jell & Hill, 1969,
Lectotype portion* UQF 27876 A-C [slides].
From Coopers Creek, Walhalla, Gippsland, Victoria.
= Limestone lenses in the Coopers Creek Formation; Early Devonian.
* Ex Lectotype P12919NM
Chapman 1914, p. 309, pl. 55 fig 25.
Jell and Hill 1969, p. 20.
Hill 1978, p. 27.

Grypophyllum compactum Hill, 1942
Holotype UQF 5317 A-E [B is a slide].
From Portion 8IV, Parish of Wyoming, lower part of limestone, Reid Gap, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 255, pl. 10 fig. 1.
Hill 1978, p. 19.

Grypophyllum curvatum (Hill)
See *Lyrielasma curvatum* Hill, 1942

Gurievskiella abyssus Jell & Hill, 1970
Paratype portion* UQF 59421 A-C.
From Sanctuary Bay, Point Hibbs, western Tasmania.
Point Hibbs Limestone; Early Devonian.
* Ex Paratype 51734 UT.
Jell and Hill 1970a, p. 4.

Gurievskella talenti Jell & Hill, 1969
Holotype UQF 52775 A-E [C and E are slides].
From B84F (field number) 3.2 km slightly north of west of Hidden Valley Homestead, Ukalunda district, south western part of the Bowen 1:250 000 sheet area, Queensland.
Ukalunda Beds; Emsian-Eifelian Stages, Devonian.
Jell and Hill 1969, p. 11 pl. 3 fig. 7.
Hill 1978, p. 32.

Halysites brevicatenatus Hill, 1954
= *Hexismia brevicatenatus* (Hill) Hill, 1978.
Holotype portion* UQF 14956.
From 274 m northwest of Cooinbil Homestead, Long Plain, near Kiandra, New South Wales.
Limestone lenses in the Peppercorn Beds (= BMR locality 1a); Wenlock or Ludlow Stage, Silurian.
*Ex Holotype CPC1032 BMR.
Hill 1954*b*, p. 38, pl. 4 figs 5a-b.
Hill 1978, p. 17.

Hexagonaria allani Hill, 1956
Holotype portion* UQF 17192 A-M [H-M are slides].
From limestone, Lankey Creek, near Reefton, New Zealand.
= Reefton Limestone; Emsian Stage, Devonian.
* Ex Holotype CO1248 NZGS.
Hill 1956, p. 8, pl. 1 figs 1a-b.

Hexagonaria gneudnensis Hill, 1954
Holotype portion* UQF 13182.
From between 239 m and 792 m on the traverse south of Gneudna Well (308 m to 311 m above the base of the Gneudna Formation) Carnarvon Basin, Western Australia.
Gneudna Formation; Frasnian Stage, Devonian.
*Ex Holotype CPC 766BMR.
Hill 1954*b*, p. 18, pl. 1 figs 1a-b.
Hill 1978, p. 23.

Hexagonaria hullensis Hill, 1954
= *Argustastrea hullensis* (Hill) Hill & Jell, 1970
Holotype portion* UQF 15081.
Paratype portion** UQF 15080 A-C.
From grey massive limestone in the Pillara Limestone 259-265 m above the base which rests on Precambrian, Hull Range, 3.2 km south of Shady Creek Gap, West Kimberleys, Western Australia.
Pillara Limestone; Givetian-Frasnian Stages, Devonian.
* UQF 15081 ex Holotype CPC 501 BMR.
** UQF 15080 ex Paratype BMR R157K1.
Hill 1954*b*, p. 16, pl. 1 fig. 20 (Holotype).
Hill and Jell 1970*a*, p. 53.
Hill 1978, p. 24.

Hexagonaria playfordi Hill & Jell, 1970
Holotype portion* UQF 46438 A-F.
From the Sadler Limestone, southeastern end of Hull Range, Kimberley Division, Western Australia.
Sadler Limestone; Givetian-Frasnian Stages, Devonian.
*Ex Holotype F5922/GSWA.
Hill and Jell 1970*a*, p. 46, pl. 10 fig. 5.
Hill 1978, p. 28.

Hexismia brevicatenatus (Hill)
See *Halysites brevicatenatus* Hill, 1954

Holmophyllum multiseptatum Hill, 1940
Holotype UQF 1023 A-D [B and D are slides].
Paratype UQF 46134.

From Cliftonwood near Yass, New South Wales.
= Cliftonwood Limestone; Ludlow Stage, Silurian.
Hill 1940*b*, p. 397, pl. 11 figs 14 a, b.
Hill 1978, p. 26.

Lekanophyllum fultum (Hill)
See *Mesophyllum (Dialithophyllum) fultum* Hill, 1942

Lipora tenuis Hill, 1953
Holotype portion* UQF A-E.
From the Encrinite Limestone of the quarry at Skjellbukta, Frierfjorden, Gjerpen-Langesund district, Norway.
Middle Ordovician.
Hill 1953, p. 161, pl. 5 fig. 23.

Lithostrotion (Diphystrotion) mutabile Hill, 1934
= *Aphrophylloides mutabile* (Hill) Jull, 1974
Holotype UQF 2387 A-H [E and H are slides]*.
From the Lion Creek limestone, (GSQ L363), 10.9 kms north of Stanwell, 16 kms west of Rockhampton, Queensland.
= Lion Creek Limestone; Visean Stage, Early Carboniferous.
Marginirugus barringtonensis Zone.
* Portion of Holotype is A5492 Sedgwick Museum, Cambridge.
Hill 1934, p. 89, pl. 11 figs 3, 4.
Jull 1974, p. 18.
Hill 1978, p. 27.

Lyrielasma curvatum Hill, 1942
= *Grypophyllum curvatum* (Hill) Zhen and Jell, 1996
Holotype UQF 4423 A-D [A and C are slides].
From the base of the Fanning River limestone, Fanning River, about 3.2 km above Fanning River Homestead, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 238, pl. 5, fig. 12.
Hill 1978, p. 20.
Zhen and Jell 1996, p. 57.

Lyrielasma(?) *lophophylloides* Hill, 1942
= *Nadotia*? *lophophylloides* (Hill) Zhen and Jell, 1996
Holotype UQF 5129 A-C [B is a slide].
From Burdekin Downs limestone at dam.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 238, pl. 6 fig. 1.
Hill 1978, p. 25.
Zhen and Jell 1996, p. 45.

Martinophyllum densum (Hill)
See *Prismatophyllum densum* Hill, 1940

Martinophyllum latum (Hill)
See *Prismatophyllum latum* Hill, 1940

Michelinia dendroides Hill, 1934
Holotype UQF 2941.
Paratypes UQF 2968 - 2972 [UQF 2968 is missing].
From UQL 1203, Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
Riverleigh Limestone; Visean Stage, Carboniferous.
Hill 1934, p. 97, pl. 11 fig 30 (UQF 2968), fig. 31 (UQF 2969), fig. 32 (UQF2970), figs 33,35 (UQF 2971) & fig. 34 UQF 2972; text-fig. 5 (Holotype).
Hill 1978, p. 20.

Michelinia progenitor Chapman, 1921
= Roemeripora progenitor (Chapman) Hill & Jell, 1970
Holotype portion * UQF 27873 [slide].
From Cave Hill, Lilydale, Victoria.
= Lilydale Limestone Member, Cave Hill Formation; Early Devonian.
* Ex Holotype P13189 NM.
Chapman 1921, p. 220, pl. 9 fig. 7.
Hill and Jell 1970*b*, p. 179.
Hill 1978, p. 29.

Mictophyllum cresswelli var. *cylindricum* Hill, 1954
= *Chalcidophyllum discorde fide* Pedder, 1965
Holotype portion* UQF 17166 [slide].
From Bell Point, Waratah Bay, Victoria.
= Bell Point Limestone; Emsian Stage, Devonian.
* Ex Holotype MU P4.
Hill 1954*c*, p. 109, pl. 7 figs 9a-b.
Pedder 1965, p. 206.

Merlewoodia foliaceum (Hill)
See *Aphrophyllum foliaceum* Hill, 1934

Mesophyllum collare Hill, 1942
Holotype UQF 4395.
From bed c near top of the Fanning River limestone on Fanning River, about 2.5 km upstream from Fanning River Homestead, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 246, pl. 7 fig 2a.
Hill 1978, p. 19.

Mesophyllum (Dialithophyllum) fultum Hill, 1942
= *Lekanophyllum fultum* (Hill), Zhen and Jell, 1996
Holotype UQF 4535 A-E [B and D are slides].
From by the cow paddock tank, Fanning River Station, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 247, pl 7 fig. 3.
Hill 1978, p. 22.
Zhen and Jell 1996, p. 38.

Nadotia? *lophophylloides* (Hill)
See *Lyrielasma*(?) *lophophylloides* Hill, 1942

Nyctopora stevensi Hill, 1957
Holotype UQF 23214 A-F [E and F are slides]
From the lowest part of the Cliefden Caves Limestone, Fossil Hill, Cliefden Caves, near Mandurana, New South Wales.
Cliefden Caves Limestone; Late Ordovician.
Hill 1957, p. 100, pl. 3 figs 6a-b.
Hill 1978, p. 31.

Nyctopora zeehanensis Hill, 1955
Holotype portion* UQF 17732 A-B.
From the Smelters Limestone, sample 11 at 27.7 m in core number 2, Oceana Mine, Zeehan, Tasmania.
= Gordon Limestone; Middle-Late Ordovician.
* Ex Holotype 23531 UT.
Hill 1955, p. 247, pl. 1 fig 3.
Hill 1978, p. 34.

Orionastrea lonsdaleoides Hill, 1934
= *Coenaphrodia lonsdaleoides* (Hill) Jull, 1974.
Holotype* UQF 2938 A-E [B and E are slides; A is missing].
Paratypes UQF 2515-2510, 2524, 2529, 2533, 5776.
From UQL 1203, Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
Riverleigh Limestone; Visean Stage, Carboniferous.
* Portion of Holotype is A5485 in Sedgwick Museum.
Hill 1934, p. 91, pl. 11 fig. 5 (UQF 2529), figs 6-8 (Holotype), fig. 9 (UQF 2533), figs 10 11 (UQF 2524).
Jull 1974, p. 21.
Hill 1978, p. 25.

Palaeoporites serratus Hill, 1957
Holotype UQF 23226 A-C [B is a slide].
From Regan's Creek Limestone, 4.8 km southeast of Cargo, New South Wales.
Regan's Creek Limestone; Late Ordovician.
Hill 1957, p. 102, pl. 4 fig. 24.
Hill 1978, p. 30.

Peneckiella teicherti Hill, 1954
Holotype portion* UQF 13185A-C.
From Atrypa beds in the reef about 10.6 km from Mount Pierre Well on Old Bohemia road Kimberley Division, Western Australia.
= Sadler Limestone; Frasnian Stage, Devonian.
* Ex Holotype 33515 UWA.
Hill 1954*b*, p. 25, pl. 2 fig. 29.
Hill 1978, p. 32.

Phillipsastrea carinata Hill, 1942
Holotype UQF 5206 A-E [B and D are slides].
From the Mt Etna limestone, foot of Mt Etna, Rockhampton, Queensland.
= Mt Holly Beds; Emsian Stage, Devonian.
Hill 1942a, p. 16, pl. 1 figs 6a-b.
Hill 1978, p. 18.

Plasmophyllum magnivesiculatum Jell & Hill, 1969.
Holotype UQF 50902* A-F [C-D are slides].
From the Ukalunda Beds, 3.2 km slightly north west of Hidden Valley Homestead, Ukalunda district, south-western part of the Bowen 1:250 000 sheet area, Queensland.
Ukalunda Beds; Emsian-Eifelian Stages, Devonian.
* Previously figured in Hill *et al.* 1967 as *Plasmophyllum* (*P*) sp., pl. D10 fig. 8.
Jell and Hill 1969, p. 15, pl. 4 fig. 6.
Hill 1978, p. 25.

Plasmophyllum tasmaniense Jell & Hill, 1970
Paratype portions * UQF 59419 A-E [E is a slide], ** UQF 59420 A-E [E is a slide].
From Sanctuary Bay, Point Hibbs, western Tasmania.
Point Hibbs Limestone, Early Devonian.
* UQF 59419 ex Paratype 52028 UT.
** UQF 59420 ex Paratype 51491 UT.
Jell and Hill 1970a, p. 9.

Plasmopora cargoensis Hill, 1957
Holotype UQF 23238 A-B [B is a missing slide].
From near the top of the Cargo Creek Limestone, Cargo Creek, New South Wales.
Cargo Creek Limestone; Late Ordovician.
Hill 1957, p. 104, pl. 4 fig. 25.
Hill 1978, p. 18.

Plasmoporella inflata Hill, 1957
Holotype UQF 23237 A-D [B and C are slides].
From near the top of the Cargo Creek Limestone, Cargo Creek New South Wales.
Cargo Creek Limestone; Late Ordovician.
Hill 1957, p. 104, pl. 4 figs 26a-b.
Hill 1978, p. 24.

Prismatophyllum densum Hill, 1940
= *Martinophyllum densum* (Hill) Jell & Pedder, 1969
Holotype UQF 3416 A-C [B and C are slides].
From the "Large Tryplasma Horizon", Silverwood. This is either Morgan Park, Limestone Siding or Lomas North (probably Lomas North), Queensland.
= Unnamed limestone lens in the Silverwood Group; Early Devonian.
Hill 1940*d*, p. 154, pl. 2 figs 5a-b.
Jell and Pedder 1969, p. 737.
Hill 1978, p. 20.

Prismatophyllum latum Hill, 1940
= *Martinophyllum latum* (Hill) Jell & Pedder, 1969
Holotype UQF 3417 A-E [B and C are slides].
From Barne's quarry, near Morgan Park, Silverwood, Queensland.
= Limestone lens in Silverwood Group; Early Devonian.
Hill 1940*d*, p. 153, pl. 2 figs 4a-b.
Jell and Pedder 1969, p. 738.
Hill 1978, p. 25.

Propora mammifera Hill, 1957
Holotype portion* UQF 23249 A-C.
From the lowest part of the Cliefden Caves Limestone, Fossil Hill, Cliefden Caves near Mandurama, New South Wales.
Cliefden Caves Limestone; Late Ordovician
* Ex Holotype P9227 SU
Hill 1957, p. 102, pl. 3 figs 9a-b.
Hill 1978, p. 25.

Rhizophyllum ukalundense Jell & Hill, 1969

Holotype UQF 53087 A-L [B, D, F, and H-J are slides].
From B76F (field number), in Mary Creek, "Hidden Valley", 12.8 km north-northeast of Mt. Wyatt, Ukalunda district, southwestern part of the Bowen 1:250 000 Sheet area, north Queensland.
Ukalunda Beds; Emsian - Eifelian stages, Devonian.
Jell and Hill 1969, p. 18, pl. 5 fig. 12.
Hill 1978, p. 33.

Sinospongophyllum abrogatum Hill, 1942
Holotype UQF 5211 A-E [D and E are slides].
From the Mt Etna limestone, foot of Mt Etna, near Rockhampton, Queensland.
= Mt. Holly Beds; Emsian Stage., Devonian.
Hill 1942*a*, p. 20, pl. 1 fig. 9.
Hill *et al.* 1967, pl. D7 fig. 8.
Hill 1978, p. 15.

Sociophyllum irregulare (Hill)
See *Stringophyllum irregulare* Hill, 1942

Spongophyllum halysitoides var. *minor* Hill, 1940
Holotype UQF 3423 A-E [D and E are slides].
From Limestone Siding, near Silverwood, Queensland.
= Limestone lens in the Silverwood Group; Early Devonian.
Hill 1940*d*, p. 162, pl. 3 figs 3a-b.
Hill *et al.* 1967, pl. D7, fig. 7.
Hill 1978, p. 26.

Spongophyllum murale Hill, 1950
= *Fasciphyllum murale* (Hill) Jell & Hill, 1970
Holotype UQF 10272.
From an uncertain locality, probably Martin Cameron's Quarry, Buchan (a bioherm in the lower Murrindal Beds), Victoria.
= Buchan Caves Limestone; Emsian Stage, Devonian.
Hill 1950*b*, p. 143, pl. 6 figs 13a-b.
Jell and Hill 1970*b*, p. 103.
Hill 1978, p. 27.

Spongophyllum serratum Hill, 1954
Holotype UQF 17100 A-E [D and E are slides].
From north of Bird Rock, Waratah Bay, Victoria.
= Waratah Limestone; Early Devonian.
Hill 1954*c*, p. 111, pl. 8 figs 15a-b.
Hill 1978, p. 30.

Streptelasma compactum Hill, 1953
= *Coelostylis compactum* (Hill) Neuman, 1967
Holotype portion* UQF 14205 [slide].
From the Sphaeronite Limestone, Gjovikodden, Toten, Norway.
Sphaeronite Limestone; Middle Ordovician.
* Ex Holotype 34793-5, Palaeontology Museum, Oslo.
Hill 1953, p. 149, pl. 1 fig. 4.
Neuman 1967, p. 459.

Striatopora? plumosa Jones, 1941
= *Thamnopora plumosa* (Jones) Jell & Hill, 1970
Holotype UQF 3987A-D [B-D are slides].
From Portion 73, Parish of Copperfield, Clermont, Queensland.
= Douglas Creek Limestone; Emsian Stage, Early Devonian.
Jones 1941, p. 51, pl. 2 fig. 5.
Jell and Hill 1970*b*, p. 107.
Hill 1978, p. 28.

Stringophyllum bipartitum Hill, 1942
Holotype UQF 4398 A-C [B is a slide].
From beds a-g, limestone in Fanning River, 2.4-3.2 km above Fanning River homestead, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 261, pl. 11 fig. 1.
Hill 1978, p. 17.
Zhen and Jell 1996, p. 65.

Stringophyllum irregulare Hill, 1942
= *Sociophyllum irregulare* (Hill) Zhen and Jell, 1996
Holotype UQF 4904 A-C [B is a slide].
From Burdekin Down station (fence running north from the east end of the night paddock), Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 261, pl. 11 fig. 4.
Hill 1978, p. 24.
Zhen and Jell 1996, p. 69.

Stringophyllum quasinormale Hill, 1942
Holotype UQF 4528 A-D [B and D are slides].
From the base of the Fanning River Limestone, 3.2 km upstream from Fanning River homestead, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 258, pl. 10 fig. 5.
Hill 1978, p. 29.
Zhen and Jell 1996, p. 62.

Stringophyllum quasinormale var. *ana* Hill, 1942
Holotype UQF 5011 A-C [B is a slide].
From branch of the Burdekin River, near Big Rocks, Burdekin Downs station, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 260, pl. 10 fig. 11.
Hill 1978, p. 16.

Symplectophyllum mutatum Hill, 1934
Holotype UQF 2943 A-K [E-K are slides].
Paratypes UQF 2497, 13187, 13192, 13193.
From Latza's farm, Portions 21 & 22 of Parish Malmoe, Yarrol, Queensland.
Riverleigh Limestone; Visean Stage, Carboniferous.
Hill 1934, p. 64, pl. 7 figs 1-6 (Holotype).
Pickett 1967, p. 26.
Jull 1969, p. 129, pl. 10, figs 8a-b.
Hill 1978, p. 27.
Webb 1990, p. 77.

Syringopora thomii Chapman, 1921
= *Roemeripora progenitor* (Chapman) *fide* Hill & Jell, 1970
Holotype portion* UQF 13864 A-G [E is a slide].

From grey limestone at Loyola near Mansfield, Victoria.
= Limestone lenses in the Norton Gully Sandstone, also commonly known as the "Loyola Limestone"; Early Devonian.
* Ex Holotype P13193NM
Chapman 1921, p. 222, pl. 10 fig. 4.
Hill and Jell 1970*b*, p. 179.
Hill 1978, p. 32.

Tetradium compactum Hill, 1955
Holotype portion* UQF 17722
From the Smelters Limestone in sample 31 (65.5 to 65.6 m) in core No. 2 Oceana, Zeehan, Tasmania.
= Gordon Limestone; Middle-Late Ordovician.
* Ex Holotype 23517 UT.
Hill 1955, p. 244, pl. 1 fig. 12.
Hill 1978, p. 19.

Tetradium conjugatum Hill, 1955
Holotype portion* UQF 18605 A-B.
From the Smelters Limestone, Queenstown Quarries, Tasmania.
= Gordon Limestone; Middle - Late Ordovician.
* Ex Holotype 2247 MU.
Hill 1955, p. 245, pl. 2 fig. 25.
Hill 1978, p. 19.

Tetradium dendroides Hill, 1955
Holotype portion* UQF 17781 [slide].
From the Smelters Limestone, Smelters Quarry, Zeehan, Tasmania.
= Gordon Limestone; Middle - Late Ordovician.
* Ex Holotype 2260 MU.
Hill 1955, p. 244, pl. 2 fig. 16.
Hill 1978, p. 20.

Tetradium petaliforme Hill, 1955
Holotype portion* UQF 17721.
From the Smelters Limestone, sample 50 at 136.8 m down Core No. 2, Oceana Mine, Zeehan, Tasmania.
= Gordon Limestone, Middle - Late Ordovician.
* Ex Holotype 23513 UT.
Hill 1955, p. 242, pl. 1 fig. 10.
Hill 1978, p. 28.

Thamnophyllum abrogatum Hill, 1940
= *Zelolasma abrogatum* (Hill) Pedder, 1970
Holotype UQF 4240 A-D [B-D are slides].
From the Bluff Limestone, Clear Hill, Murrumbidgee River, New South Wales.
= Cavan Limestone, Middle Devonian.
Hill 1940*c*, 260, pl. 10 fig. 4
Pedder 1963, p. 365.
Hill 1978, p. 15.

Thamnophyllum reclinatum Hill, 1939
= *T. mitchellense* (Etheridge) *fide* Talent, 1963
Holotype portion* UQF 4184 A-B [slides].
From Griffith's limestone quarries, southwest from Mansfield, Victoria.
= Limestone lenses in the Norton Gully Sandstone, also commonly known as the "Loyola Limestone"; Early Devonian.
* Ex Holotype R25186 BM (NH)
Etheridge 1899, p. 30, pl A figs 6-8, pl. B fig. 11.
Hill 1939*c*, p. 228, pl. 16 figs. 7-8.
Talent 1963, p. 39.
Hill 1978, p. 30.

Thamnopora randsi Jell & Hill, 1970
Holotype UQF 36332 A-F [C and D are slides].
From Portion 73, Parish of Copperfield, Clermont, Queensland.
= Douglas Creek Limestone; Emsian Stage, Early Devonian.
From the Douglas Creek Limestone (locality 1), Douglas Creek,
Jell and Hill 1970*b*, p. 107, pl. 8, fig. 5.
Hill 1978, p. 29.

Thamnopora reeftonensis Hill, 1956
Holotype portion* UQF 17518 A-C.
From limestone of Waitaki River, Reefton, New Zealand.
= Reefton Limestone, Lower Emsian Stage, Devonian.
* Ex Holotype CO 1256 NZGS.
Hill 1956, p. 13, pl. 2 figs. 12 a-b.

Thamnopora tumulosa Hill, 1950
Holotype portion* UQF 10321.
From the lower Murrindal beds, (field locality no. 183) Buchan district, Victoria.
= Murrindal Limestone Member, Tarravale Mudstone Formation; Emsian Stage, Devonian.
* Ex Holotype 48324 GSV.
Hill 1950*b*, p. 154, pl. 9 figs 31a-d.
Hill 1978, p. 33.

Thecostegitus ejuncidus Jell & Hill, 1970
Holotype portion* UQF 59428 A-B.
From Sanctuary Bay, Point Hibbs, Western Tasmania.
Point Hibbs Limestone; Early Devonian.
* Ex Holotype 51744 UT.
Jell and Hill 1970*a*, 104, p. 13, pl. 6 fig. 5.
Hill 1978, p. 21.

Tryplasma basaltiform Hill, 1953
Holotype Portion* UQF 14192 A,B
From Frierfjorden, Gjerpen-Langesund, Norway.
Encrinite Limestone; Middle Ordovician.
* Ex Holotype 8585 Paleontology Museum, Oslo.
Hill 1953, p. 152, pl. 1 fig. 8

Tryplasma brevikense Hill, 1953
Holotype portion* UQF 14193 A-C.
From quarry at Skjellbukta north of Brevik, Frierfjorden, Gjerpen-Langesund district, Norway.
Encrinite Limestone; Middle Ordovician.
* Ex Holotype 8528 Paleontology Museum, Oslo.
Hill 1953, p. 153, pl. 2 fig. 1.

Tryplasma ceriodes Hill, 1955
Holotype portion* UQF 17773 A-B.
From Ida Bay, Tasmania.
= Gordon Limestone; Middle - Late Ordovician.
* Ex Holotype 2123 MU.
Hill 1955, p. 240, pl. 3 fig. 36.
Hill 1978, p. 18.

Xystriphyllum insigne Hill, 1940
Holotype UQF 3425 A-E [D and E are slides].
From Limestone Siding, Silverwood, Queensland.
= Limestone lenses in the Silverwood Group; Early Devonian.
Hill 1940*d*, p. 164, pl. 3 figs 5a-b.
Hill 1978, p. 24.

Yabeia salmoni Hill, 1942
= *Aphyllum salmoni* (Hill), Zhen and Jell, 1996
Holotype UQF 5025 A-D [B is a slide].
From Burdekin Downs Station, on the anabranch of the Burdekin River, near Big Rocks, Queensland.
= Burdekin Limestone; Givetian Stage, Devonian.
Hill 1942*b*, p. 239, pl. 6 fig. 3.
Hill 1978, p. 30.
Zhen and Jell 1996, p. 32.

Zaphrenthis iocosa Hill, 1954
Paratype UQF 15063 A-B.
From the Bugle Gap Limestone, Fossil Downs homestead, west Kimberleys Western Australia.
Bugle Gap Limestone; Fammenian Stage, Devonian.
Hill 1954*b*, p. 13.

Zaphrentoides excavatus Hill, 1954
Paratype Portion* UQF 15088.
From the Mount Pierre Group, Bugle Gap, west Kimberleys, Western Australia
= ? Virgin Hills Formation, Late Devonian.
* Ex Paratype 557 CPC.
Hill 1954*b*, p. 12, pl. 3 fig. 19.

Zelolasma abrogatum (Hill)
See *Thamnophyllum abrogatum* Hill, 1940

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LOST & FOUND

Enquiries and information, please to Patrick Wyse Jackson (Department of Geology, Trinity College, Dublin 2, Ireland; e-mail: wysjcknp@tcd.ie). Include full personal and institutional names and addresses, full biographical details of publications mentioned, and credits for any illustrations submitted.

The index to 'Lost and Found' Volumes 1-4 was published in *The Geological Curator* 5(2), 79-85. The index for Volume 5 was published in *The Geological Curator* 6(4), 175-177.

Abbreviations:

CLEEVELY - Cleevely, R.J. 1983. *World palaeontological collections.* British Museum (Natural History) and Mansell Publishing Company, London.

GCG - *Newsletter of the Geological Curators' Group*, continued as *The Geological Curator.*

LF - 'Lost and Found' reference number in GCG.

252. Bibliographic information on Eocene plants.

Dr Robert Zorzin (Curator), Museo Civico di Storia Naturale di Verona, Palazzo Pompei, Lungadige Porta Vittoria, 9, 37129 Verona, Italy writes:

I am seeking bibliographic information about new methods to study fossil plants, their identification, and the diversity and distribution of plants in Europe during the Eocene.

Any help readers are able to give would be greatly appreciated.

253. Offspring Dear.

Peter Tandy, Department of Mineralogy, The Natural History Museum, Cromwell Road, London SW7 5BD, U.K. e-mail: P.tandy@nhm.ac.uk

Whilst doing some personal genealogical research, I came across a one line reference to someone called Offspring Dear (actually so!), who apparently is in the 1881 Census for the parish of Stotfold, Bedfordshire, as a 23 year old "fossil digger". Has anyone ever heard of him, or does anyone know of any specimens dug by him?

A CENTURY OF GRAPTOLITE RESEARCH IN CAMBRIDGE

by R.B. Rickards

Rickards, R.B. 1999. A Century of Graptolite Research in Cambridge. *The Geological Curator* 7(2): 71-76.

Graptolite research in Cambridge was dominated during the first half of the 20th Century by two people: Gertrude Elles and Oliver Bulman. They had quite different approaches to research, and to curation of collections. Elles' research was primarily field-based and her curatorial procedures a curator's headache; Bulman's work was primarily laboratory-based and palaeobiological. The present author overlapped with and succeeded Bulman, and his curatorial biases led to his succeeding A. G. Brighton as Curator of the Sedgwick Museum. The nature of these changes through the century and the contribution to graptolite research on a wider scale are analysed.

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Gertrude Lillian Elles (Figure 1) entered Newnham College, Cambridge as a scholar in 1891 and graduated with 1st Class Honours in Geology in 1895. After this she worked on graptolites with Lapworth in Birmingham and with Törnquist in Sweden, returning to Cambridge in 1897 to continue her work there until her death in 1959. She began a period of graptolite research in Cambridge that has remained unbroken until the present and which has resulted in well over 300 published papers, not counting those of research students. I never met Elles. She died in my last year as an undergraduate and I recall helping with the fund which Cambridge established, I think to assist younger geologists with field projects. My knowledge of Elles was largely gleaned from long conversations with O.M.B. Bulman and with A.G. Brighton the Curator, until 1969, of the Sedgwick Museum.

From the curatorial point of view Gertrude Elles was a bit of a problem to Brighton. She had a set of keys to the cabinets and simply helped herself to what she needed for research or teaching purposes. Brighton had to retrieve the specimens at intervals and return them to their proper place. She seemed to hold the view that that was the function of curators. She had a similar cavalier attitude to the cataloguing and curation of her research material. I have first hand knowledge of this because I curated the Elles collection in the period 1965-67 when I was a post-doctoral assistant to Bulman, and later on when I replaced Brighton as Curator of the Sedgwick. There were huge gaps in the type, figured and cited specimens and I was quite unable to find many of the specimens one would have reasonably expected to find.

The way she worked, whilst not unique, would make any conscientious curator shudder. She studied her specimens at one end of a long table. As each job was completed and her notes prepared, that batch of specimens was pushed to her right hand side, towards the other end of the table. Those specimens already at the far end of the table fell on the floor and accumulated in a heap. Brighton's attempts to rescue the material had to wait until Elles went off on fieldwork. In her later years with fieldwork ended, and when she was deaf, Brighton had to buck up courage and attempt rescues in her presence. Entry was gained not by knocking on the door, for she wouldn't hear it: he had to stamp on a loose plank outside the door, so that the other end of the plank jumped up and down. Brighton would then receive a bellowed instruction to come in.

In Bulman's (1960) obituary notice in Nature, there is a coded comment "....Elles' interest in fossils was pre-eminently that of the field geologist and stratigrapher..." Bulman arrived in Cambridge in 1926 and thus overlapped with Elles by more than a quarter of a century. She disapproved of his laboratory studies and heavy reliance on the binocular microscope, although she successfully supervised his Cambridge Ph.D. (He already had a Ph. D. from the University of London, jointly with Sir James Stubblefield.) Elles was by all accounts a fine field geologist working primarily on the Lower Palaeozoic in Wales and the Welsh Borderland but also, with Tilley, on metamorphism in the Scottish Highlands (1930). In her later years it was well known that she frowned upon younger members of staff who spent vacations in the laboratories rather than in the field, and she was known to stand near the foot of the stairs,

Figure 1. Gertrude Elles, taken from the Sedgwick Club photograph of 1908.

Figure 2. Ethel Wood (Dame Ethel Shakespeare), probably from a College photograph.

on occasion, giving forthright advice to any staff remaining in sight or hearing.

This preference for field studies is perhaps reflected in her published work, and she published fewer papers than her pupil Bulman. Some of the most notable were field based, such as the classic (1900) on the Wenlock of the Builth district. But her most important contribution to graptolite studies was the Elles and Wood (1901-18) monograph of British graptolites under Lapworth's guidance, which included ten major systematic texts, almost one a year between 1901 and 1914. What is interesting, and relevant to her research attitudes, is that the **text** of the systematics is less reliable than the illustrations. The illustrations, classics of their kind, were prepared by Ethel Wood (Figure 2), and they were meticulously accurate. Anyone who has compared the original specimens with the original drawings can testify to this. The details of the text are, however, often found wanting, in particular the rhabdosomal measurements so critical in graptolite studies. Quite often the measurements given do not equate readily with figured specimens. The drawings of the latter we can easily prove to be correct.

Some of the earliest work Elles carried out, as on the subgenera *Petalograptus* and *Cephalograptus* (1897) also contained some of her most-thorough systematic descriptions. Even so, it is interesting that many of the drawings illustrating the paper are diagrammatic, almost stylised in places, despite the rather obvious good preservation. Another of Elles' classic contributions (1922) was on the evolution of the graptolite faunas of the British Isles, but in this work the illustrations are rather crude outline drawings. The text is remarkably perceptive in many places, not least in her interpretation (1922, p.180) of the retiolitid list structures, and gives an extensive overview of graptoloid evolution. In her (1933) study of graptolite faunas from the Skiddaw Slates the text figures are to a much higher standard - but the acknowledgements show that they were prepared by Bulman. In a late paper Elles (1939) discussed the factors controlling graptolite successions and assemblages and was, as far as I am aware, the first person to suggest that some graptolites were free swimming. She also held the view at that time that some were epiplanktonic.

Elles was highly regarded in Cambridge, not least for her enthusiastic teaching. When women were able to take Cambridge University degrees she was the only one offered an Sc.D. (She already held a D.Sc. from Trinity College, Dublin, awarded when she was only 35). And she was the first female Reader of the University (1936). She was also the first woman to serve on the council of the Geological Society (1923-7).

Oliver Meredith Boone Bulman (Figure 3) returned to Cambridge in 1931 as a University Demonstrator (later Lecturer, Reader and Professor). His research

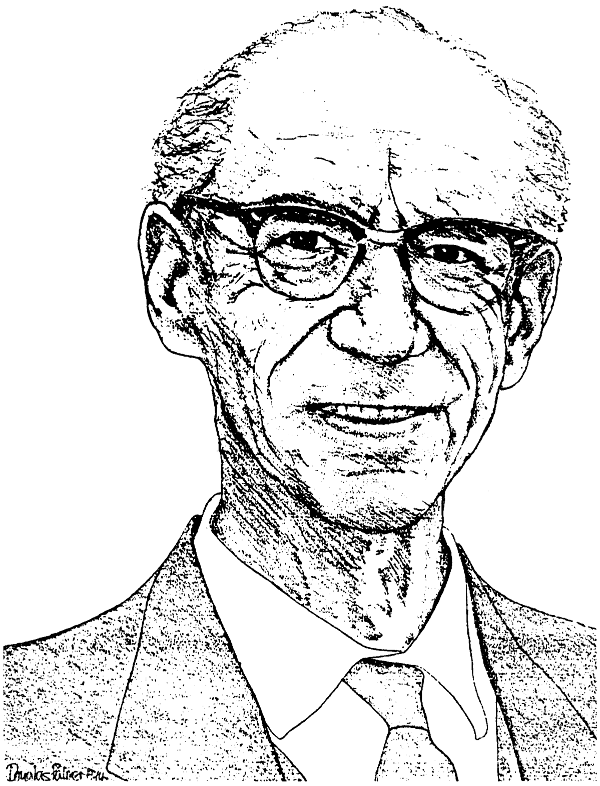

Figure 3. Oliver Bulman, reproduced with the permission of the Palaeontological Association from the original sketch by Douglas Palmer.

could not have been more different from Elles', nor his attitude to specimen care and curation. Brighton had no curatorial problems with Bulman, although he seemed to acquire Elles' keybunch (as I did) and helped himself to the collections as he needed to. But all specimens were returned to Brighton, and his research material was meticulously cleaned and prepared, and numbered and labelled ready for curation.

His laboratory studies far outreached those of Elles, and he involved himself in serial sections (both of isolated specimens and specimens in the rock), chemical isolation of material, wax models produced with photographic help, graptolite photography, and the most brilliant artwork illustration. Bulman's original wash drawings of his dendroid graptolites for the Monograph of British Dendroid Graptolites (1927-1967) are held by the British Geological Survey and are well worth inspecting as works of art. But after his early years he stopped doing field-based studies, relying instead on material provided by others or on material collected by himself and others on short, focused collecting trips. In this way too he formed a sharp contrast with Elles, becoming primarily a laboratory-based researcher. From what Bulman told me I know that this was an area of conflict between them. Brighton, on the other hand, was much happier with Bulman, and a steady stream of well-preserved, well-curated collections arrived, from all parts of the world, at the door of his curator's office. Bulman was also more productive in research than Elles: when Dennis Jackson and I (1974) and Sir James Stubblefield(1975) assembled a bibliography of his papers, they totalled 101, of which over 90 were on graptolites. They included major systematic monographs as well as evolutionary interpretations and mode of life studies. He was prepared to speculate occasionally, but only briefly.

I arrived myself in Cambridge in 1965 as a post-doc, after a few months as Curator and Librarian in the Department of Geology, University College London. I mention this only because of my trepidation at having to tell Professor Hollingworth that I wanted to leave after so short a stay: when I entered his office it was to find that he was already in full knowledge of the offer I had received from Bulman! It was typical of Bulman that he had prepared the way carefully and properly.

My post in Cambridge was as his assistant, a post I held for three years before going off to the Natural History Museum in London, and Trinity College, Dublin, finally returning in 1969 as Curator, under Harry Whittington the new Woodwardian Professor. Bulman was very generous with the amount of time he allowed me to spend on my own graptolite research, and he also encouraged me to help Brighton curate Elles' specimens and other material. I think it is fair to say that Bulman and I hit it off from the beginning despite our totally different backgrounds. We had splendid, and enjoyable arguments. Third person accounts of these I have heard from Richard Hey. Richard had the adjacent office to mine and used to listen to our louder debates with his ear glued to the breeze block wall separating the two rooms.

Bulman told me in his later years of his problems with Elles, although he did take her point about the values of fieldwork and always regretted letting this side of his own work decline. And for my part I recalled that when I began as his assistant he had told me to keep going both facets of my work and he emphasised that I should never neglect field work. There were limits though! I also remember that he was less than enthusiastic about my disappearing each September to attend field meetings of the Ludlow Research Group. He seemed then to have a low opinion of the organisation although he admitted, grudgingly, that as Holland and Walmsley were involved, it couldn't be all bad!

In 1965 he sent me off to Warsaw to see Roman Kozlowski, and at very short notice. "Do you good", he said "Miss Suttle (his secretary) will get you the tickets." In Warsaw I saw Adam Urbanek, and Lech Teller too, the latter having been detailed to look after me. Lech tried to get us a vehicle to go off to the Holy Cross Mountains to collect material. This was normally a routine matter. But problems proliferated and we never went: I had to make do with a few nodules that Lech had collected on previous visits. Years later I found on Bulman's correspondence files a copy of a letter to Roman Kozlowski. In which he wrote "...and this man enjoys fieldwork so much that I implore you to keep him in the laboratories for the duration of his stay." I did learn a great deal from all three of the Polish experts on graptolites and it was a most concentrated study period. But Bulman encouraged fieldwork only to a certain extent.

Everyone who knew Bulman well will tell you that he was a private and rather shy man. Indeed, there was at one time a rumour that he would be incapable of "popping the question." This proved quite unfounded, and he was happily married to Margot for his last 35 years; a staunch family man and devout Christian. As Woodwardian Professor he had to make decisions and he did so, sometimes seeming to be rather harsh. But he also brought to his leadership, and to his work, a rather dry sense of humour: privately his humour was much warmer. I remember one tricky incident when we were trying to isolate chemically a very rare and very delicate Ordovician graptolite. Every time one allowed the supporting medium (water, glycerine or alcohol) to drain away, the specimens collapsed under their own weight, breaking up as they did so. In order to see the internal structure we also needed to make them transparent with Schultz's Solution (a mixture of HNO_3 and $KClO_3$). This made them weaker still. The best supporting medium was glycerine, rather than water or alcohol. So Bulman suggested that I tried clearing the specimens using Schultz's Solution in the glycerine directly, without removing the specimens to a separate dish. I pointed out there was a serious risk of accidentally preparing trinitroglycerine as a biproduct. He looked at me for a moment and then said with a smile, "Why don't we ask Jana Hutt to try it?" Jana Hutt was our research assistant.

Bulman did not have large numbers of graptolite research students, perhaps the best known being Isles Strachan, Margaret Sudbury and David Skevington. It is often supposed that I was a student of Bulman's, but this is not the case: my Ph.D. on graptolites was done at Hull under John Neale. Strachan, Sudbury and Skevington published major works on graptolites and although all three are retired now, Margaret continues to work and to publish. In addition to research students there was a constant stream of graptolite research visitors to Cambridge, for example Gordon Packham as a post-doctorate researcher in the 1950s.

Although Bulman did not indulge in serious fieldwork he did make trips abroad to look at sections and collections. For example, he went to Australia and New Zealand as well as many countries in Europe.

There were other features about the successive overlaps of, firstly, Bulman with Elles and then myself with Bulman as well as the shifts from field-based to lab-based to the combined approach. Elles was curatorially unhelpful, Bulman the opposite, and I finished up as Curator. There has been a steadily increasing flow of good material into the museum and it continues to this day. Whereas Elles used a hand lens and Bulman a binocular microscope, I use both and electron microscopes too: this is as much a sign of the times as of personal approaches; as is, perhaps, the increased publication rate. But a more important change had a stratigraphical side to it. Elles worked both on Ordovician and Silurian graptolites, not superficially, but with the emphasis on utility. Bulman worked but little on the Silurian graptolites, and not at all on later ones. He told me he struggled with Silurian graptolites, which is why he asked me to help with the appendix in the Treatise (Bulman, 1970).

This statement about his difficulties with Silurian graptolites does not bear closer examination He was being unduly modest, in fact. In his last year he presented me with all his research notes, and in them are many of his characteristically meticulous drawings. I include some figures here (Figures 4-6) which show that even before Kühne (1955) and Urbanek (1966) published their splendid accounts of the structure of Ludlow graptolites, Bulman had reached the same conclusions. But he had no stratigraphic framework to help and I think his real struggle was understanding the evolution of Silurian forms, which is why he was so enthusiastic about the work of Sudbury (1958), Packham (1962) and Urbanek (1966). Had he been alive today he would have been excited by work taking place on Silurian graptolites.

I have already mentioned Elles' and Bulman's outstanding research students, and I have been fortunate in that regard too although, like Bulman, I have had relatively few. Some of them made definitive breakthroughs in graptolite research, notably Peter Crowther (ultrastructural studies, and his destruction of the extrathecal tissue concept favoured by Kozlowski, Bulman and myself, among others), Sue Rigby (graptolite modelling and mode of life studies) and Peter Durman (earliest evolution of hemichordates

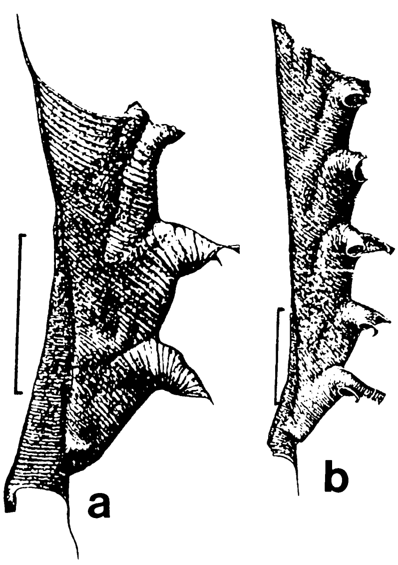

Figure 4. Retouched and prepared by G. Liljevall from Gerhard Holm's original photographs; a,b identified provisionally by Bulman as "*Monograptus flemingi* var. (nov?) or *riccartonensis*" and in his pencilled notes additionally as possibly "*uncinatus*"; from Gotland; he was, therefore, uncertain as to whether it was a Wenlock or a Ludlow species; c, left under open nomenclature by Bulman, from Gotland, this form is probably referable to the *Monograptus parultimus* group. Scale bars 1mm. All these forms are sketched in his notebooks. The provisional plates prepared by Liljevall for Holm's graptolites were never published in their entirely, but were cannibalised for other plates, and the forms illustrated here were omitted; specimen numbers respectively 2776, 2779, and not designated. Gerhard Holm was a famous Swedish palaeontologist who specialised in the study of chemically isolated material.

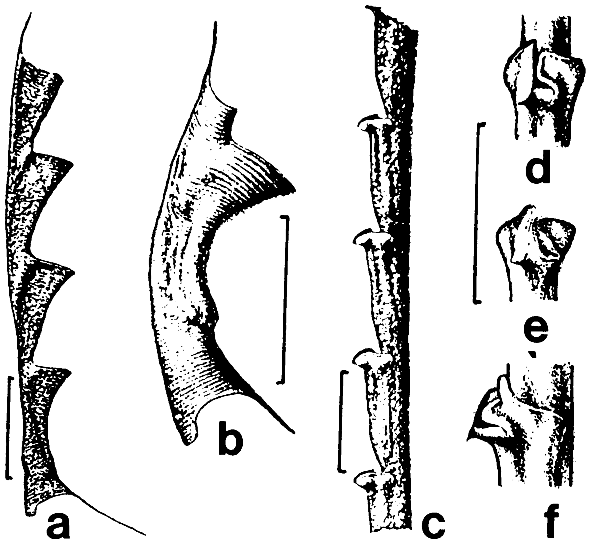

Figure 5. Details of preparation history as for Figure 4: a,b, labelled by Bulman as "aff. *bohemicus*"; they are probably referable to *Bohemograptus bohemicus*; possibly from Barsh; c-f, labelled by Bulman, probably correctly, as "*M. scanicus*", from Harbus, the first time such thecal structures had been recognised and related to forms previously known only in the rock. None of these figures were published although, once again, they are present in his notebooks. Scale bars are 1mm. Specimen numbers for a and b were not designated, the remainder are from 2679.

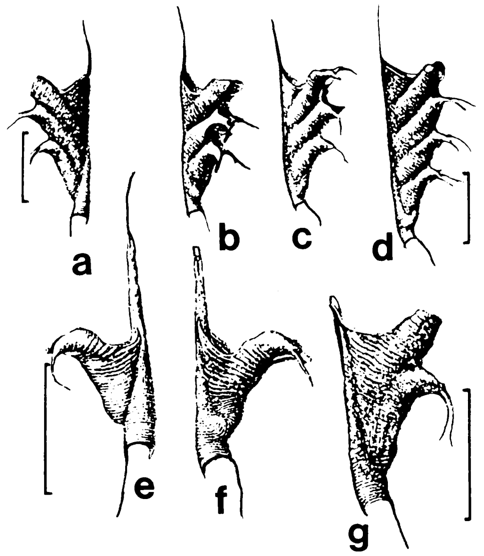

Figure 6. Details of preparation history as for Figure 4; a-g, labelled by Bulman as *Monograptus chimaera*, probably correctly; from Aarhus. Scale bars 1mm. Specimen numbers respectively 2668, 2667, 2665, 2674, 2677, and 2673.

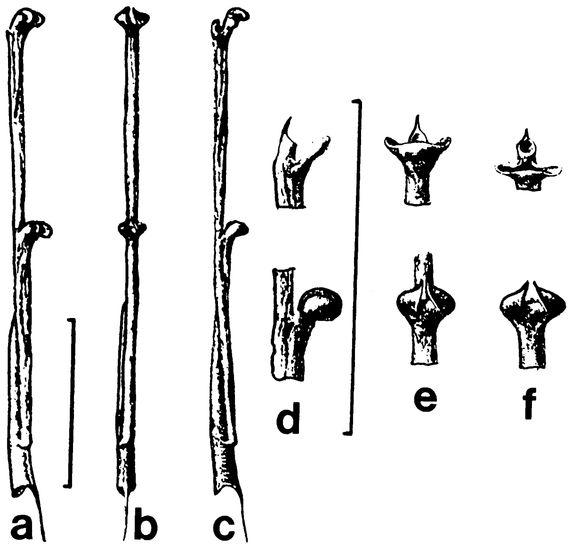

Figure 7. Details of preparation history as for Figure 4: a-f, labelled by Bulman as "*Monograptus scanicus*? Or *M. crinitus*?"; probably referable to *Cucullograptus pazdroi*; ?from Schulan. Scale bars 1mm. Specimen numbers not recorded.

and recognition of rhabdopleuran and cephalodiscan hemichordates in the Middle Cambrian). As well as research students both Bulman and I were blessed with a series of outstanding research assistants, all of whom published on graptolites, some extensively so. In order of appearance these were: Cynthia Cowie, Judith James, Jana Hutt, Jean Archer, Amanda Chapman and Lori Dumican. Judith James had been writing a very tricky paper on *Dicellograptus* at the time I took over from her as Bulman's assistant: my first job was to complete the paper for publication (James, 1965). Cynthia Cowie prepared those splendid graptolite models, usually on display in the Sedgwick Museum but which are at the moment being used in the Laser Doppler Anemometry work of Sue Rigby and myself. Jana Hutt did definite work on the rich Llandovery graptolite faunas of the Lake District, as well as startling both Bulman and Stubblefield by chemically extracting graptolites from the Shineton Shales where they had singularly failed to do so. Jean Archer did excellent work on Ordovician isolated graptolites. And Amanda Chapman is best known for her work on Australian Bendigonian faunas and for her research on Carboniferous dendroids.

In summary, it has been a richly productive and increasingly productive century of graptolite research at Cambridge. As I did not know Elles personally it is only speculation when I suggest that she would have approved of the on-going field-based studies. Bulman was still excited by what was happening, even in his final illness, and I know he would have been enthusiastic about recent developments. I remember him shaking his head in cheerful bemusement at the results of ultrastructural studies. Whether he would have fully approved of BIG G (British and Irish Graptolite Group) I'm not sure. Probably he would, despite his early reservations about the similarly-structured Ludlow Research Group. Should graptolite work end in Cambridge in the next decade or two, and I hope it does not, it has surely comprised a substantial contribution to palaeontology.

Acknowledgement

I should like to thank Margot Bulman for a great deal of help.

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TOTAL QUALITY MANAGEMENT IN MUSEUMS

by Alistair Bowden

Bowden, A. 1999. Total quality management in Museums. *The Geological Curator* 7(2): 77-80.

Written guidelines defining the individual procedures which make up a documentation system are an invaluable tool to good quality collection management - this paper explains the rational behind this statement and provides a format to written procedural documents.

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Introduction

> "We cannot avoid seeing how quality has developed into the most important competitive weapon, and many organisations have realized that total quality management is the new way of managing for the future." (Oakland 1989).

Total quality management relies on the introduction of written procedural documents. Though still uncommon in museums, these are an incredibly useful tool which ought to underpin many functions, particularly collection management (Bowden 1998). Fundamentally they act as a quality control. Their influence is both process and terminology related, and it is only through the maintenance of very high standards of both that the ultimate potential of a documentation system can be fulfilled. This two-fold quality control needs emphasis. Firstly, strict adherence to the individual tasks is fundamentally important to the accessibility of the collection. Secondly, the way in which data is expressed has a profound influence on the indexing and searching capacity of a system. Quite simply, quality manuals aim to eradicate this variance in technique and terminology. Besides this obvious role, quality manuals in museums are also very useful in a number of other circumstances: guidelines to part time and volunteer staff minimising the time needed to oversee work and negating inconsistencies; as a framework for co-operation between subject specialists and documentation staff; as a guide to accessing the collection; also as an essential tool to aid the change-over between curators.

The aim of this paper is to act as a guide to the structure of a quality manual and to offer suggestions from the development of the documentation system of the Museum of Lancashire Earth Science collections. For information on specific aspects of geological documentation, the reader is directed to the seminal work of Brunton, Besterman & Cooper (1985) and for information on data standards in geology, to the review by Cooper (1990).

Standing Operating Procedures

The British army relies heavily on Standing Operating Procedures (SOPs) as a means of structuring the individual tasks which make up the complex activities of modern warfare - indeed the first manual of military strategy, "The Art of War" written by Sun Tzu around 400-320 B.C. (Griffith 1963), was perhaps the first detailed procedural document ever written. Industry has adopted the concept and structure of military SOPs. These form the basis of the quality systems which have been produced to fulfil the requirements of various British and international quality standards.

Clear, concise written procedures are equally applicable to the museum environment, where many aspects of collection management involve complex processes and rely completely on the standard to which the data has been expressed. Table 1 lists the structure which has been adopted at The Museum of Lancashire which should act as a guide to the information which ought to be covered.

Initially, the SOPs that have been developed at The Museum of Lancashire cover all of the stages of documentation which are the responsibility of the Assistant Curator (Geology). The entire set of SOPs are kept together with an introduction and appendices in the quality manual (Table 2).

Number & Name: A clear title to the procedure and a number which helps to place this procedure in a framework.

Issue Number & Date: Each time a new amended version of the SOP is released, this section needs to be updated to allow easy reference to its currency.

1. Purpose: The objective of the SOP.

2. Scope: This defines the coverage of the SOP; what or who is governed by its contents.

3. Responsibility: This states the person who is responsible for ensuring that the SOP is followed.

4. Procedure: This section is the crux of each procedure. It will often be subdivided into smaller topics to focus attention on a structured, phased approach to the completion of the process.

5. Associated Documentation: This lists all the other relevant material which is not part of the main body of text.
-Forms (entry book, day book, accession register, computer catalogue)
-Attachments (further information directly attached to the SOP)
-Appendices (less relevant information kept at the rear of the quality manual)

Table 1. Format of a Standing Operating Procedure.

Finally, the dynamic, evolving nature of SOPs is an essential part of their success. Once the quality manual has been written, each SOP can be updated as a situation changes. The new issue number and date are noted on the new version and importantly, the old version is kept along with an explanation to the change and a note of the person responsible. It ought to be realised however, that altering an SOP can have serious repercussions in a museum environment i.e. hours spent in the stores making the actual collections conform to the new SOP.

Conclusion

Procedural guidelines are a simple tool which define the elements of a documentation system. They act as a quality control of all the process-related tasks, as a data standard for all the terminology and as a management tool for increasing efficiency (and decreasing inconsistencies).

Acknowledgements

I would like to thank Lt. Col. Kevin Hill MBE MC for fostering an interest in all things military and Sonia and my mother for their insight into the pros and cons of introducing quality management into modern industry. I would also like to take this opportunity to thank John Nudds, David Green and Simon Riley at The Manchester Museum for my introduction to all things museological and John Rayment and Mike Millward at The Museum of Lancashire for their advice, support and patience during my time at Clitheroe. Last but by no means least, I would like to thank those who have worked on the collections at Clitheroe: Derek Learoyd, Catherine Jopson, Geof Sullivan and in particular to "Stormin'" Norman Catlow.

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Table 2. Contents of the quality manual.

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Appendix: Example of a Standing Operating Procedure

THE MUSEUM OF LANCASHIRE [LANMS] EARTH SCIENCE COLLECTIONS
STANDING OPERATING PROCEDURES

SOP 3/6 **CATALOGUING & STORAGE - FOSSILS** Issue 3 (13/3/98)

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1. Purpose

To provide guidelines to staff on completing the computer "Earth Science Record" and storage of fossil specimens.

2. Scope

This procedure applies to all fossils.

3. Responsibility

The Assistant Curator (Geology), is responsible for ensuring that this procedure is being followed.

4. Procedure

4.1 Cataloguing

This procedure only deals with the completion of the computer record for fossils. For all other aspects of cataloguing, see SOP 3/1

It is necessary to follow this procedure so that all the records in the finished "Earth Science Catalogue" are in the same format. Without this uniformity, the searching and indexing capability of the system will be severely restricted.

- they contain a variety of fields which must be filled in with the greatest accuracy possible.

- all known factual data must be noted.

- all alterations, additional information, opinions or other notes made by the identifier or recorder must be clearly marked as such and include their name and the date.

4.1.1 Method of form completion.

(Attachment A - Example of completed form.)

Page 1

Accession number

- Made up of four parts

a. MDA code: LANMS (automatically inputted)

b. year of accession (1973-1999)

c. group number: (1-999)

d. sub-number: (1-9999) e.g. LANMS:1982.20.1234

Specific name

- ideally the genus and species ought to be noted, however if this is not possible, then the most specific designation that is possible.

e.g. *Homo sapiens* *Didymograptus murchisoni* *Lithostrotion* sp. Worm tracks Trilobite

<u>Fossil group</u> (see attachment B)

- from the options in the pop-up list

<u>Stratigraphy</u> (see attachment C)

- from the options in the pop-up list

<u>Locality</u> (see attachment D)

- it is imperative that consistency is maintained in this field or the searching and ordering capacity of the entire database will be seriously restricted

- written in a standard 'bottom-up' form

e.g. England, Cumbria, Derwent Water, Friar's Crag Mine

Permanent location

- the box number in which the specimen is stored
- e.g. Fos_box097

Temporary location

- if any material is removed from its normal place (see SOP 5) its new position should be noted here.

Recorder

- the name of the person who made the original recording, either on index card or in future directly on the computer

Date

- the date of the original recording

Remainder of record

The computer record is made up of four pages; pages 2, 3 & 4 are similar to page 1 above.

4.1.2 Changes to catalogue record

New information

The new/correct information is noted in the record as usual.

Old information

It is imperative that original/incorrect information is not lost (it may in fact be correct!). This should be written in the notes field along with the reason for the change and the name of the amender, with the date noted in brackets.

4.2 Storage

There are a number of different fossil collections in the stores and to locate the relevant collection, please refer to SOP 4/1.

Storage criteria

Criterion 1: Stratigraphy (see attachment C)

Criterion 2: Fossil group (see attachment B)

Criterion 3: British/Foreign

Criterion 4: Locality (see attachment D)

Criterion 5: Accession number (stored number)

The result is that intimately associated specimens of similar age, taxonomy and geographic location are actually stored together.

5. Associated Documentation

Forms:	Computer Catalogue	
Attachments:	A.	An example of a completed mineral computer catalogue entry.
	B.	Details of procedure for completing the "Fossil group" field
	C.	Details of procedure for completing the "Stratigraphy" field
	D.	Details of procedure for completing the "Locality" field
Appendices:	None	

The attachments have not been included here as they add little detail to the structure and content of procedural documents in a broad sense.

COMPARING GAP-FILLERS USED IN CONSERVING SUB-FOSSIL MATERIAL

by Nigel R. Larkin and Elena Makridou

Larkin, N.R. and Makridou, E. 1999. Comparing gap-fillers used in conserving sub-fossil material. *The Geological Curator* 7(2): 81-90.

Often when conserving mechanically weak sub-fossil bone material, an inert volumising filler for a chosen adhesive (e.g. Paraloid B72) is needed to create a gap-filling substance to strengthen some bones, so as to reduce the potential of damage to some of the more fragile specimens. Although a frequent method, little is in print on this subject. Testing determined the comparative suitability of five materials (calcium carbonate, glass beads, crushed glass, glass bubbles and phenolic microballons) as polymer fillers in terms of strength, shrinkage, reversability, ease of use, and adhesive properties at various filler to resin ratios. Glass beads (44 microns average diameter) at a ratio of 3:1 filler to resin by weight out-performed the other fillers in most of the categories.

Nigel R. Larkin and Elena Makridou, Conservation Department, Norfolk Museums Service, Castle Museum, Norwich, Norfolk, NR1 3JU, U.K. E-mail: nrlarkin@easynet.co.uk & elena.makridou.mus@norfolk.gov.uk. *Received 2nd February 1999; revised version received 21st September 1999.*

Introduction

Sub-fossil material includes bone, antler, ivory, teeth and artefacts made from any of these materials. Such material can cover a wide range of states of preservation, not least due to the amount of collagen loss or secondary mineralisation over time. There are several papers detailing problems to be experienced with sub-fossil bone material in collections (Andrews 1996, Doyle 1987) and their structure and decay is well documented (O'Connor 1987). Therefore here we concentrate on the application of gap-filling substances, using material from the West Runton Elephant excavation as an example.

The West Runton Elephant

The sub-fossil remains of the West Runton Elephant (*Mammuthus trogontherii*) and its associated fauna were excavated in 1995 (Ashwin and Stuart 1996, Stuart 1997, Turner-Walker 1998) from an early Middle Pleistocene site at West Runton, on the north Norfolk coast, which is the type-site for the Cromerian Temperate or Interglacial stage (West 1980, Stuart 1991). This *Mammuthus* skeleton is by far the most complete of this species known at present. It is the oldest elephant skeleton to have been discovered in this country, also it is one of the largest elephants ever to have lived and the list of associated fauna from the site is lengthy. The importance and diversity of the material and the large size of some of the specimens present many conservation and curatorial challenges. The material varies from bird bones a few millimetres in length to the elephant limb bones that are up to 144 cm long, 40 cm wide and 80 kilograms in weight. However, although all the bones have fine, well preserved surface detail, they often have little internal mechanical strength. This is due to the loss of reinforcing collagenous material from the original bone, combined with the lack of secondary mineralisation, although there is some infiltration of the bone micro-cavities by diagenetic iron sulphides (Makridou 1996, Turner-Walker 1998).

The repair of sub-fossil bone

To re-assemble the fragments of a specimen that was broken during burial processes would be to reduce the integrity of information available for study. Information inherent in their broken state is useful for taphonomic study, and the fragments are best left in their natural state and stored in association. However, where specimens have experienced damage during excavation or post-excavation work then some remedial conservation can be desirable, often entailing partial reconstruction of specimens, with appropriate consolidants and adhesives. However, since ancient biomolecule retrieval techniques are improving all the time, any sub-fossil material may contain potentially useful biochemical information that is not currently accessible, and therefore application of conservation materials should be minimal. The West Runton Elephant material has been dated to between 600,000 and 700,000 years old (Meijer and Preece 1996, Rink *et al.* 1996, Tony Stuart pers. com.) which is considered to be beyond the reach of current ancient biomolecule retrieval techniques. However, the current conservation program is treating the material with the necessary assumption that future techniques may successfully reach this far. Consolidants mostly contain organic molecules (particularly if dissolved in organic solvents) which will tend to distort the process of carbon dating and other investigatory techniques (Andrews 1996, Aldhouse-Green and Pettitt 1998: 759), and sub-fossil material, with its high original organic content, may react with conservation materials more readily than permineralised fossil bone (Shelton and Johnson 1995). For these reasons, if not because the long term stability of many materials is rarely known, conservators should be very cautious in applying remedial conservation techniques involving substances that adulterate the specimen and reduce its natural biomolecular integrity. Historically the application of gap fillers has often been a cosmetic exercise, to "fill-in" where the imagination should, even deliberately modelling the missing areas. This may be acceptable in some instances for display (Croucher 1986, Carpenter *et al.* 1994, Lindsay *et al.* 1996), but not for a working research collection where any gap filling should only be for structural reasons. It may often be much more appropriate to store the pieces of an individual bone separate from one another but kept in a single container, in their relative associated positions, and to provide adequate physical external support to individual bones or bone fragments rather than reinforcing the structure of the bones themselves. To join them could be to risk later collapse due to over-handling and ignorance of their fragile nature, and a filler may well obscure some interesting internal information. Replicas of the fragments can be made either by careful casting or by 3D scanning and stereolithography (Zollikofer *et al.* 1998) and these replicas can then be joined together to be studied and be handled at will.

However, if there are many bones of a single individual (as with the West Runton Elephant) much of the material may well not require invasive stabilisation processes and a large proportion of the material will remain unadulterated and available for biomolecular study. Therefore, to protect the most fragile and fragmented elements from further damage during handling and study, reversible or removable materials such as consolidants and gap fillers can be applied, with a cautious and minimalist approach. In the case of the West Runton Elephant and associated material a gap filler will only be applied to material where reducing its fragility in order to lower the risk of future damage outweighs the cost of reducing its biomolecular integrity.

Gap-filling materials

Consolidants and adhesives are not designed for filling gaps but when mixed with fillers various properties can be altered such as ease of application, viscosity strength and a reduction in shrinkage. Adding a filler increases the resistance to flow and viscosity of a polymer, which is essential for an adhesive which would otherwise drain out of a joint by gravity, or be sucked out of the glue line by capillary action (Horie 1987).

Although much useful information has been published regarding suitable inert fillers for resins in regard to gap-filling wooden objects (Grattan and Barclay 1988, Thornton 1991), ceramics (Walker and Shashoua 1996, Smith 1998, Walker 1998) and stone (Howard and Hibler-Vandenbulcke 1990), little has been published regarding fillers for sub-fossil bone. The few exceptions mostly pertain to either plaster of Paris (Anderson *et al.* 1994) which entails introducing high levels of moisture to areas of sub-fossil bone which can be inadvisable, or an "A.J.K. dough" (Rixon 1976, Howie 1979, 1995, Doyle 1987, Cornish *et al.* 1995, Lindsay 1992, Lindsay and Comerford 1996) which was a jute and kaolin mixture used specifically with Alvar 1570 (polyvinyl acetal), a substance no longer available in this country (Lindsay 1992, 1995). The A.J.K. dough was not considered completely satisfactory for some practices as it can have a high shrinkage rate upon drying, making it inappropriate for large fills (Smith 1998). Usefully, "micro-glass beads" are mentioned as an inert filler to prevent shrinkage of polymethyl-methacrylate used for filling gaps during acid preparation of specimens (Lindsay 1995, Croucher and Wooley 1982). However, often the filling of gaps in fossil material is mentioned without actually specifying the substance (Jaeschke and Jaeschke 1992), or as anecdotes regarding fillers found to have been used historically in fossil material (Cornish *et al.* 1995, Carpenter *et al.* 1994). This has included such fillers as plaster, horse hair, newspaper, wood, string, hemp, cotton, iron nails, sand, pebbles, sulphur, wood putty, paper-mâché, epoxy resin, car body filler and asbestos, most of which have clear disadvantages. Many palaeontological conservators have devised their own techniques, and faced with a substantial amount of sub-fossil material requiring immediate conservation and finding very little of current use in print on the gap-filling aspect of remedial palaeontological conservation, the authors decided to experiment with a few materials suggested by colleagues who had faced similar situations.

The increased viscosity of a polymer created by adding fillers is a very important factor in deciding its suitability as a gap-filler. An ideal result would be a malleable paste which hardly flows and stays where it is applied, even on a vertical plane. Also, one that is strong, sets hard though not too quickly or too slowly for the task, bonds well to other areas of polymer application where desired, whilst being as fully reversible as can be expected of the same polymer if the filler were not added. Although it is necessary for the gap filling material of a fragile museum object to adhere to itself and the object where desired, and not to give way when handled or stored for long periods of time, it is not desirable that when stressed the gap filler retains its integrity whilst the surrounding object gives way. Creating the exact strength required of a gap-filler depends not only on the properties of the filler powder, but also the viscosity of the resin and percentage content of the solvent. For this reason, different ratios of resin to solvent were experimented with.

Materials

The filler powders were mixed with the acryloid thermoplastic resin Paraloid B72 (an ethyl methacrylate co-polymer) in acetone, at various ratios by weight. Paraloid B72 was used as it is well known, tested and recommended (Down *et al.* 1996, Koob 1991, Jaeschke and Jaeschke 1992), considered versatile (Shelton and Chaney 1993) and is thought to be stable (Feller 1984). It has some advantages over polyvinyl acetate resins when used for sub-fossil bone as it is strong and hard without being brittle, and in particular will tolerate stress and strain on a joint better than the harder, more rigid and inflexible adhesives (Koob 1986). The solvents toluene and xylene were rejected on health and safety grounds. Acetone may evaporate comparatively quickly but, in the case of gap-filling, this can be a distinct advantage, preventing slumping. Previous work in conservation (Koob 1986, Elder *et al.* 1997) has proven that Paraloid solutions are reliable over time and very well established as consolidants and adhesives for sub-fossil material. Of paramount importance to conservators is the fact that resin is chemically reversible, if not completely removable. A gap filler that is only removable by mechanical means, such as plaster or epoxy putty, is clearly unacceptable for fragile sub-fossil material. Paraloid B72 was the only resin used on the West Runton Elephant material, either as an adhesive, consolidant or gap-filler, and only with the solvent acetone. Not only does the use of the same resin for every application ensure good bonding properties between the uses, but it facilitates any necessary future reversal of the materials. Where a combination of different synthetic materials are applied to a specimen this can "complicate the potential stress interactions between the different resins and the [specimen]" (Koob 1991).

After discussions with colleagues working in palaeontological and archaeological conservation, five different inert fillers were selected for testing (Table 1).

Method

Nine characteristics of each resin/filler mixture were examined and recorded whilst applying the mixture to the tin (or, later, to sub-fossil material), also after application until it set, and then when dissolved and removed. The mixtures were applied to identical tins with a spatula. A mixture was considered I) to be "too tacky" if it adhered to the spatula enough to make it difficult to apply it to the tin and difficult to move or model the mixture, II) to have too thin a viscosity if it could not be applied by a spatula but could only be poured, III) to exhibit non-adhesion if the mixture

FILLER	MATERIAL	PARTICLE SIZE	NOTES
Strand BLR2	Calcium carbonate (Urgonian limestone)	2 - 20 microns, mean 5 microns (rhombohedral)	Inert general purpose filler, mostly for extending polyesters: 99.8% $CaCO_3$
Airbrasive powder #10	Crushed glass fragments	75 Microns average (not spherical)	Used as airbrasive powder in fossil preparation: 99.9% aluminium oxide, 0.1% potassium, iron and silica.
Airbrasive powder #9	Glass beads	44 microns (spheres)	Used as airbraisive powder in fossil preparation: 96% silica, 4% corn starch.
Glass bubbles	Sodiumborosilicate microspheres	40-80 microns (spheres)	Size more variable than microballoons, and significantly harder.
Phenolic microballoons	Hollow phenolic resin spheres	50 microns (spheres)	For reducing weight & increasing workability of set polymer.

Table 1. Gap-filling materials compared in this study.

Figures 1-3 show gap-fillers applied to sub-fossil bone material, cross-sectioned. All fragments are from non-accessioned bovid femora, collected from the Early Devensian site of Shropham, Norfolk. Scale shows 0.5 cm intervals.

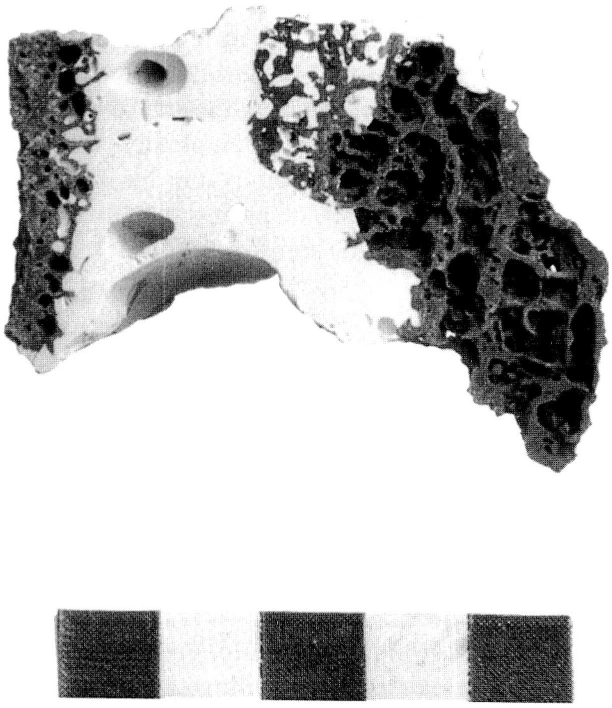

Figure 1. Calcium carbonate 2:1 filler to resin

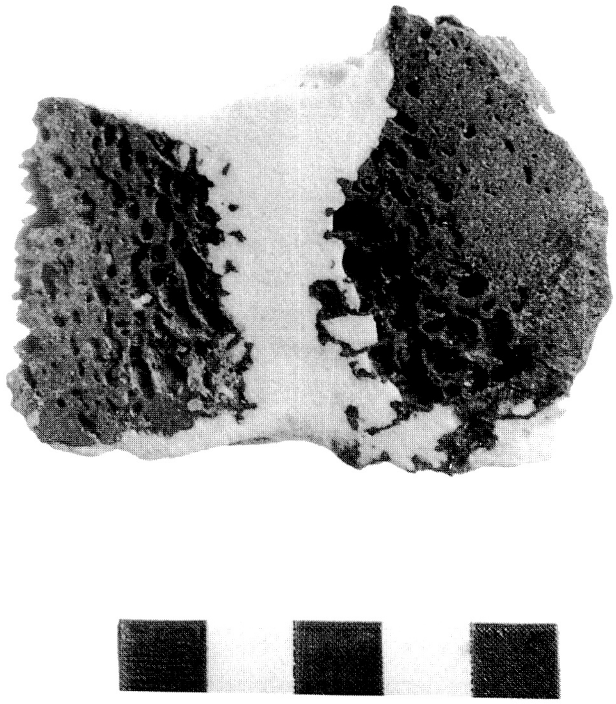

Figure 2. Glass beads 3:1 filler to resin

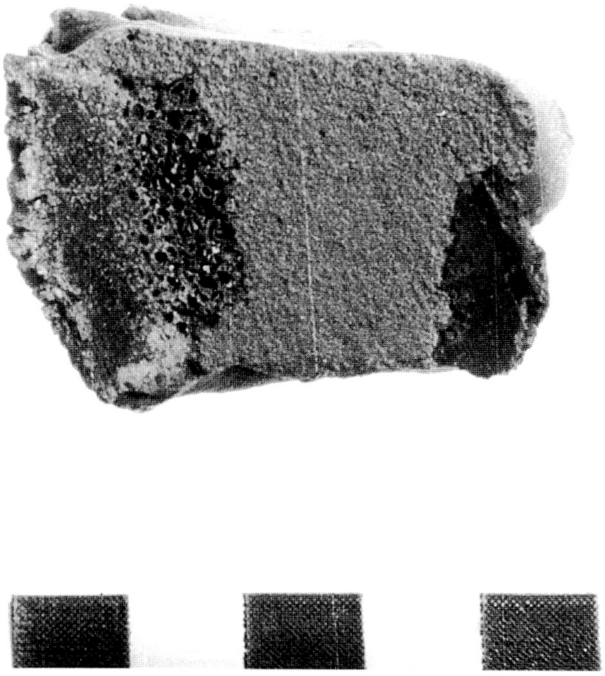

Figure 3. Phenolic microballoons 1:3 filler to resin

Figure 4. Capreolus mandible from the Mid-Pleistocene site of West Runton, reassembled from 16 pieces using Paraloid B72 and glass beads gap filler at 3:1 filler to resin ratio. Scale shows 0.5 cm intervals.

was not adhering to the tin (or, later, the subfossil material) or to itself, and IV) to exhibit shrinkage if, on setting, the mixture had pulled away from the sides of the tin. The mixtures were ranked in order of preference for V) their general ease of use during application (i.e. did the mixture stay where it was wanted, or did it slump easily?), VI) their hardness of set after ten days (tested by scratching with a metal tool), and VII) their ease of reversibility when, after fully set, acetone was applied in small quantities and the mixture was scraped away with a metal spatula. It was also noted VIII) how long it took for each mixture to set firmly (e.g. firm enough for another layer to be added without distorting the original application) as well as to set fully hard. Finally, a comparative score IX) was given for each mixture, taking into account all the above factors, and X) the weight in grams of a 20ml volume of each mixture is given so that their relative densities can be considered when looking at the results.

For each test, the resin and filler was weighed separately, and the filler added to the resin evenly whilst stirring thoroughly. The mixture was then applied to a tin 6.5cm in diameter with a spatula, and placed in a fume cupboard to set whilst under observation for 2 hours, and then checked periodically for ten days. All the tins were of identical sizes with the final mixtures weighing between 6 - 38g depending on the density of the filler. First, each filler material was tested at ratios 1:1, 2:1 and 3:1 (filler to resin). However, as the properties of the filler materials vary considerably (for instance the high volume-to-weight ratio of the microballoons), a wider range of tests were undertaken to find the optimum ratio for each material. The performances of these mixtures, at what appeared to be their optimum ratios, were then tested against one another.

After the best filler to resin ratio was determined for each product, each of these mixtures was tested comparatively in the tins and then applied to some scrap sub-fossil bone to compare their ease of application and adhesive performance on a realistic material. The bone material was treated beforehand with Paraloid B72 consolidant 10% (weight to volume (W/V)) in acetone to form a separating barrier and to help adhesion. After the fillers had set, a section was cut across the filled gap using a high speed geological circular saw so that the interior of the set gap-filling material could be studied (Figures 1-3).

Results

The authors decided that the glass beads outperformed all the other fillers tested, in particular because it was both relatively easy to apply (forming a firm paste) and easy to remove, and also because it set quite hard. The results of all the tests are summarised below and in Table 2.

Dilution of Paraloid B-72

Paraloid B72 at 15% (W/V) in acetone provided a medium that was too thin to be of practical use with any of the chosen fillers at any of the ratios, even at 5:1 filler to resin. None were viscous enough to make a reliable paste that would retain its shape. None had set hard even after ten days, and all exhibited little internal strength, almost certainly due to insufficient resin being present.

It was found that Paraloid B72 at 25% (W/V) in acetone worked well. It accelerated the setting time, created a more malleable, viscous paste and provided a much greater adhesive strength for all the fillers. The glass bubbles and microballoons in particular are very light and produce a thin mixture unless large quantities are used (e.g. a ratio of 1:3 filler to resin for

RATIOS (Filler to Resin)	**I** Too tacky?	**II** Too thin?	**III** Non-adhesion?	**IV** Shrinkage?	**V** Ease of use	**VI** Hardness >10 days	**VII** Reversibility	**VIII** Set firmly	**III** Overall use	**III** Weight in g.
Calcium carbonte (2:1)	N	N	N	N	3=	1=	5=	c	b	35g
Crushed glass (5:2)	N	N	N	N	6=	4	5=	c	c	30g
Glass beads (2:1)	N	N	N	N	3=	3	5=	c	b	38g
Glass beads (3:1)	N	N	N	N	1=	1=	5=	c	a	38g
Glass bubbles (1:4)	N	N	N	N	3=	5=	3=	c	d	8g
Glass bubbles (1:3)	N	N	N	N	6=	5=	3=	c	d	8g
Microballoons (1:2)	N	Y	Y	Y	8	6=*	1	c	d	6g
Microballoons (1:4)	N	N	N	Y	1=	6=*	2	c	d	8g

* Microballoons did not set hard, even after 10 days.

Table 2. Comparison of performance of mixtures at their optimum ratios. (This table concerns gap fillers applied in one thick layer, resin is always Paraloid B72 at 25% in acetone)

Key: **I**: is it too tacky? (Y/N). **II**: is the viscosity too thin? (Y/N). **III**: is there non-adhesion? (Y/N). **IV**: is there shrinkage? (Y/N). **V**: ease of use/malleability (In order of preference: 1=best; 8=worst). **VI**: hardness after 10 days (In order of preference: 1=best; 6=worst). **VII**: reversibility (In order of preference: 1=best, 5=worst). **VIII**: time taken to set firmly: a) 0-30 seconds, b) 30 seconds - 2 hours, c) over 2 hours. **IX**: overall use for filling gaps: a) very good, b) can be used, c) poor, d) no use. **X**: The weight in g of 20ml volume of the final, set, mixture.

the glass bubbles and microballoons, compared to 2:1 for the glass beads to get a similar viscous paste), and an increase in the resin viscosity rather than volume of the filler is more preferable for strength.

Ratio of filler to resin

Tests were carried out with Paraloid B72 at 25% (W/V) in acetone. Initially, the ratios 1:1, 2:1 and 3:1 (filler : resin, by weight) were tried but it rapidly became apparent that the filler materials required quite different ratios in each case to perform at their best.

At the ratio 1:1, the glass bubbles, crushed glass and microballoons each produced a very thin mixture that was rejected as impractical because it flowed too easily and would be difficult to control during application. At the ratio 1:1 The calcium carbonate and glass beads provided mixtures with a viscosity, surface tack, and adhesive property that were just about useable. However, they took more than two hours to become firm, about 48 hours to set hard, the set mixture remained brittle and there was a little shrinkage. The glass beads filler was the most easily reversed and removed by the application of acetone and scraping with a spatula, and the calcium carbonate least easily reversed. At this ratio, none of the fillers proved ideal.

At the ratio 2:1, the glass bubbles and microballoons again produced mixtures that were too thin so these two were rejected, and the crushed glass created a paste that was quite viscous. The calcium carbonate and the glass beads provided a workable paste and set harder and quicker than they did at 1:1, and again the glass beads were most easily reversed.

At the ratio 3:1, the only filler that was able to be mixed satisfactorily was the glass beads. This filler at this ratio provided a paste that appeared easy to apply to surfaces of different angles, and was reasonably easy to reverse and remove.

The glass bubbles, microballoons and crushed glass could not be mixed to a useable viscosity at the above ratios, therefore tests were carried out to find their optimum ratios. The performances of all these mixtures, at their optimum ratios, were then tested against one another. The results are summarised in Table 2.

Filler performance

The gap-fill mixtures above were applied to similar pieces of sub-fossil bone, and allowed to set for more than a week before a cross section was cut on a circular rock-cutting saw (Figures 1-3). These sections show how some of the different mixtures performed at the filler/bone interface, and the evenness and density of the fill. All the mixtures from Table 2 above were able to be applied, with varying levels of ease. All the mixtures were found to need more than two hours to be firmly set, and were removable by the application of acetone and a modelling tool. The results below pertain to the tests carried out in the tins as well as the tests on the sub-fossil material.

The calcium carbonate performed at its best at the ratio 2:1, providing a workable texture and viscosity that was easily applied. It set harder than any of the other mixtures with a fine, smooth and dense gap-fill that adhered well to the bone (Figure 1). Although some large and small air bubbles can be observed in the gap-fill the mixture is so strong that this is unlikely to affect its performance. It penetrated into the cancellous cavities of the bone, providing a firm join. However, it would be difficult to fully remove this material from the cavities and in the case of breakage under stress the bone rather than the filler may fail as the filler is so strong. The mixture did not fail even under extreme pressure when subjected to a hard twist between two hands. It was not the easiest filler to remove and it had a tendency to be stringy.

The crushed glass performed at its best at the ratio 5:2. The viscous paste this created was not considered completely unusable though it was a little difficult to apply, slumping too readily. The paste took a over 48 hours to set completely, and was not quite as hard as the calcium carbonate. There was a little shrinkage in the tins, but this was not observed when applied to the bone. The final gap fill in the bone adhered well, was very even with only one small bubble in the filler, and it penetrated the bone cavities only slightly. It remained a little more brittle than the glass beads and calcium carbonate but was easier to remove than the calcium carbonate. The mixture broke down its midline when subjected to a fair twist between two hands.

The glass beads mixture made a useable paste at the ratio 2:1 but this did not set hard very quickly. It was found they performed better at the ratio 3:1, providing a paste that could be applied to angled surfaces, set quite hard, and had a good texture. It was reasonably easy to reverse and remove. It adhered to the bone satisfactorily (Figure 2), and penetrated the cancellous cavities of the bone a little less than the calcium carbonate. The final gap-fill is hard and extremely even, with no cavities. The mixture broke down its midline when subjected to a hard twist between two hands.

The glass bubbles at ratio 1:3 was a very thick, light "fluffy" viscous mixture that was difficult to apply, but stayed where it was put due to its light weight.

When set, after 24 hours, it was a little crumbly and brittle, with no great strength. The glass bubbles at ratio 1:4 was less viscous and easier to apply, but still did not set very hard or strong and was also brittle. At 1:6 the mixture was too thin and runny to be of use, as it would not stay where it was applied. At all these ratios the final gap-fill in cross-section was smooth, even and contained no air bubbles except a few small ones at the ratio 1:6. At 1:4 the mixture penetrated the bone microcavities only a little but at 1:6 the depth of penetration was much greater. No shrinkage was observed but this filler seemed not to adhere to the bone quite so well as the others. It failed easily under pressure in the hand, probably because the filler material has a low strength to volume ratio, and there is a relatively small amount of resin present compared to the mixture volume.

The phenolic microballoons at the ratio 1:2 was very difficult to mix and did not adhere very well to the tin, or to itself. It remained soft with a rough surface finish, and was crumbly and brittle. However, at the ratio 1:4 it improved greatly, being less viscous, easier to mix, very easy to use, had an even, sugary, surface, setting firmly but not hard (scratches can be made with the fingernail). At 1:4 (Figure 3) the microballoons gave a very even fill, adhering to the bone surface well, with no air bubbles. It did not penetrate far into the cancellous microcavities of the bone. However, the mixture broke down its midline easily when subjected to a fair pressure in the hand. When fully set in the tin some shrinkage was experienced but this is not observed in the sectioned bone.

Discussion of results

The best results were achieved with Paraloid B72 at 25% (W/V) in acetone. The best filler overall was found to be the glass beads, at ratio 3:1 by weight (filler to resin). This was followed by glass beads at ratio 2:1, and then calcium carbonate at ratio 2:1. This was ascertained by general suitability as a filler regardless of material filled, judged in terms of malleability, viscosity, self-adhesion, strength and setting time.

In terms of ease of reversal and removal of the gap filler, the microballoons were able to be removed far more easily than the glass beads or calcium carbonate. However, the microballoons mixture was still soft, even after 10 days and the ease with which it can be removed is irrelevant. The calcium carbonate at ratio 2:1 and the glass bead mixture at ratio 3:1 did set fully hard, and were removed without any difficulty by applying small quantities of acetone at a time and removing with a small spatula.

Experience and common sense demonstrates that the best result is achieved by layering the gap filling material. By applying an amount at a time and allowing each layer to set before applying the next allows the solvent to evaporate more easily and evenly. Also, bubbles may get trapped in the lower levels if too much is applied at one time. Although significant shrinkage problems were not encountered in these experiments, if large gaps were filled in one go without layering, one might expect shrinkage to occur (Horie, 1987).

The size of filler particles determines the amount of filler that can be incorporated into a polymer. A filler material with a small average particle size, like the calcium carbonate powder, would give a high packing density of the particles. Sufficient polymer must be added to fill the voids between the particles if strength retention is required, or the mixture will be less sufficient at forming a strong homogenous bond (Horie 1987, Walker and Shashoua, 1996). This places a physical upper limit on the ratio of filler to polymer that can be usefully used. However, factors other than just particle size affect the strength of the set filler material, for example density or the inherent strength of the particle. The hollow phenolic microballoon spheres (with an average diameter of 50 microns) and the sodiumborosilicate glass bubbles (40-80 microns diameter) clearly provided the weakest fillers (suitable for re-modelling), whereas the crushed glass airbrasive powder (75 microns average particle size, but not spherical), and the glass beads airbrasive powder no. 9 (44 microns average diameter) were quite strong and the calcium carbonate (range 2 to 20 microns diameter, with a mean of 5 microns) was stronger still. The hollow phenolic spheres and the hollow glass bubbles, despite their size being comparable to that of the solid glass beads and far bigger than the particles of calcium carbonate, produced powders too light to make a suitable paste unless in a ratio of filler to resin of about 1:3 is used. They increase volume and reduce density of any filled resin, as they displace resin, rather than adsorb resin into their internal cavities. This can be seen in the table where the weights are given for identical volumes. The filler as a result then doubly relies on the strength of the resin as less strength is to be found (all other things being equal) in a hollow sphere than a solid one, which is why they are used for cosmetic re-modelling.

With small, solid particles sufficient polymer must be present to fill the voids between the particles if strength retention is required. This must have been achieved for the very fine calcium carbonate powder (average particle size only 5 microns) with the mixture of 2:1 filler to resin (using Paraloid B72 in acetone at

25% (W/V)) as it set quite hard and strong, bonding extremely well to itself and the bone material. As weight is used to measure the ratios, less volume is required of a powder containing small solid particles, in relation to the volume of resin.

A gap-filler gains a better purchase and makes a repaired break stronger when it is able to infiltrate slightly the microcavities of the bone material on either side and when it can adhere to the layer of consolidant applied beforehand. This spreads the strength of the join away from a single thin plain of weakness, to make a broader, stronger join, but it will be more difficult to fully remove the gap-filler if needed. The initial separating layer of consolidant could be seen as a barrier between the gap filler and the specimen, to preserve integrity of the specimen, but also as consolidating the surrounding material and creating a stronger surface for the filling material to adhere to. As in this case the consolidant and the resin of the filler are Paraloid B72, there is excellent bonding between the filler and the consolidated area of the bone. Whether or not the infiltration of the microcavities is desired depends upon the criteria the conservator wishes to fulfil. However, this does create a situation where the gap-filled and consolidated area of the bone may become stronger than the surrounding sub-fossil bone material. In the event of stress, the surrounding bone may fail rather than the original break. A filler should be chosen that allows some flexibility and is not greatly stronger than the surrounding material that it fills. For this reason the reasonably stress-tolerant polymer Paraloid B72 is recommended (Koob, 1986). All the gap fillers tested on bone material gave way under varying manual stress loads with the exception of the calcium carbonate.

In these tests, looking at specific chosen criteria applicable to sub-fossil bone and using only one adhesive resin at a given percentage in a given solvent, the authors have found a gap-filling substance that fulfils all the requirements laid out at the start of tests. However, there are many situations where others might choose differently depending on the situation. For instance, microballoons may be used where a weak filler is needed to enable further artistic remodelling (Smith 1998) but this is rarely important for the conservation needs of sub-fossil material. Glass micro-beads have been used as an inert filler in polymethyl methacrylates specifically to obviate shrinking (Lindsay 1987) and calcium carbonate is traditionally used for reducing the volume of a polymer (Horie 1987) to much the same effect. The British Museum found after testing glass microballoons with Paraloid resins B72 and B67 (Walker and Shashous 1996) that the glass microballoon pastes fulfilled their listed criteria as gap-fillers for friable ceramics in the following mixture: 30% (W/V) resin in 50:50 ratio by volume of acetone:industrial methylated spirits, with the filler/resin ratio 10:33 to 10:35. Their preferred filler to resin ratio by weight is equivalent to that used for the glass bubbles and phenolic microballooons in the tests above. Similar polymers, solvents, inert filler materials and ratios are being investigated for use on quite different museum specimens. The performance criteria, though overlapping, will depend on both the specimen and the task in hand and therefore the gap-filler of choice will vary.

Conclusions

In archaeological and palaeontological conservation there are increasing efforts to reduce the invasive use of materials such as consolidants, glues and gap-fillers to specimens wherever possible. This is partly in recognition of the advances of ancient biomolecule studies and therefore the need to prevent the adulteration of specimens, and partly due to an increasing concern regarding the stability, reversibility and removability of the materials introduced. Increased use of supportive packaging and the reduction of over-handling of specimens are more responsible methods of dealing with specimen fragility. However, with badly fragmented elements that need to be reconstructed to allow study, and where such techniques as stereolithography will not suffice or remain too costly, some use of resins may be necessary (Figure 4). Where this is the case, they are to be chosen very carefully for reversibility and stability, used minimally, and have detailed and accessible records kept of their application.

These tests show that for the sub-fossil material from West Runton an appropriate inert filler meeting our requirements, using Paraloid B72 at 25% (W/V) in acetone, is the glass beads at the ratio 3:1, (filler to resin by weight). However, other conservators and curators may be working with material with different criteria to be met and the authors wish to encourage the publication of any previous or future comparative studies on this subject.

Health and safety notes

All work using Paraloid B72 dissolved in organic solvents must be undertaken in well ventilated conditions, such as under a fume hood. For field use or where fume extracts are otherwise unavailable, fitted respirators with appropriate filter cartridges are recommended. When handling the filler powders, nuisance dust masks should always be worn to prevent inhalation of the very light particulates. Gloves, labcoats and eyeshields are important in cutting down the amount of direct contact with both the resin and the filler material. For all substances, it is necessary to have the manufacturer's official Materials Safety Data Sheet. Hazards associated with acetone solvent in particular are documented in Hazard Data Sheet Product No. 57053 1S, January 1990, available from BDH at the address below. Appropriate risk assessments under COSHH regulations are a required part of health and safety regulations.

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Appendix 1: Suppliers

Acetone: BDH Ltd, Broom Road, Poole, BH12 4NN, United Kingdom. Tel. 01202 669700. Suppliers of industrial chemicals.

Paraloid B72: Conservation Resources (UK) Ltd. Unit 1, Pony Road, Horspath Industrial estate, Cowley, Oxfordshire. OX42RD. Tel. 01865 747755 Fax. 01865 747035. Suppliers of conservation materials.

Glass bubbles and phenolic microballoons: Structural Polymer Systems Ltd, Love Lane, Cowes, Isle of Wight, PO 31 7EW. Tel. 01983 284000 Fax. 01983 298453. Marine products suppliers.

Airbrasive powder #9 and airbrasive powder #10: Reg Abrasonics, 599-613 Princes Road Dartford, Kent. DA2 6HH. Tel. 01032 2228227 Fax. 01032 228112. Supplier of airbrasive machines, powders and accessories.

Strand BLR2 (calcium carbonate): Scott Bader Ltd. Unit 7, Woodford Trading Estate, Southend Road, Wood Green, Essex. Tel. 0181 551 6221. Suppliers of moulding and casting materials.

BOOK REVIEWS

George, W.H. 1998. *John Gibson (1778-1840), manufacturing chemist and collector of Pleistocene fossils from Kirkdale Cave, Yorkshire and Ilford, Essex.* William H. George Publications, 20pp. Paperback. ISBN 0953409201. Price: £1-00 + 40p p&p.

This modest pamphlet has all the appearance of a journal off-print, which it is not – it is published by the author himself. This causes me a little concern because such things are likely to get lost or simply not found in the record of the history of geology. That would really be unfortunate as here we are given an insight into a name associated with one of the most significant geological events of the early nineteenth century. John Gibson was the discoverer of the bones at Kirkdale Cave, an event which through William Buckland sparked an international sensation. It put both Buckland and Yorkshire on the geological map. George gives a brief but useful up-to-date account of the discovery and its meaning. But this isn't the main value of the booklet. Here we are also given a plethora of dates, relationships and other small facts drawn from extensive primary research which makes this an essential publication for historians of Essex or Yorkshire geology. Here we have details of the family (including a family tree), relationships to his various partners in chemical manufacturing, particularly Luke Howard, 'The Father of British Meteorology'. In addition to Kirkdale, Gibson also investigated the Pleistocene at Ilford. His collected materials were widely distributed particularly in London. Modest but scholarly it will be a delightful find for anyone wishing to put a little more detail to a name or demonstrate that geologist actors in the history of science are not one dimensional characters.

Simon Knell, University of Leicester, Leicester, U.K. 12th July 1999.

Lucy, Gerald, 1999. *Essex Rock. A look beneath the Essex landscape.* Essex Rock and Mineral Society, Saffron Walden, 128pp. Paperback. ISBN 0 9534832 0 7. Price: £6.95.

For those of us brought up on the hard rocks of the Celtic fringe, Essex Rock seems to be a contradiction in terms. Even the author admits, in his preface, that the two words don't often go together. The county better known for its lads, girls, and clapped-out XR3is, does, however, preserve an important sequence of Paleogene, Neogene and Pleistocene sediments and their fossils. The earliest reference to Essex fossils, as the bones of giants, is found in Camden's *Britannia* in the 17th century, and since then some significant finds have been made, such as the Aveley elephants excavated in 1964 and now in the Natural History Museum. This book describes the rocks of Essex and the fossils they contain, highlighting the London Clay and Red Crag faunas, and explaining the complexities of the Pleistocene sequence of glacial, interglacial and Thames terrace deposits. The book also illustrates the role amateur geologists have played, and, indeed, still play, in recording and collecting the rocks and fossils of the county. It fills a gap in the literature, for, apart from the BGS Regional Guide to London and the Thames Valley (1996) which covers a much wider area, there is no other book describing the geology of Essex.

An introductory chapter provides a basic background to the subject for the non-geologist reader, before the book moves on to describe the structure and basement of Essex in a couple of short chapters. The Chalk, the oldest rock which crops out in Essex, gets a chapter of 7 pages, while the Paleogene and Neogene rocks which form most of the county are dealt with in the next three chapters. The largest part of the book (32 pages) is given over, rightly, to a description of the Pleistocene deposits and their faunas. A final chapter deals with economic geology in Essex. Four appendices include a geological fieldwork code; places of geological interest in Essex; a list of local museums and local and national geological societies; guidelines for collectors; and a bibliography.

The text throughout is clear, concise and well-written, and supported by illustrations which themselves occupy over 50 pages. So often, a book which does not originate from a major publishing house (and occasionally, some which do) is let down by the quality of its illustrations. No such criticism can be levelled at this publication. Its 84 figures include clear, well-executed line drawings and fossil sketches (though some are, arguably, a bit over-stippled) and good, well-chosen photographs, many taken by the author himself or sourced from archives.

If there is a criticism, I suppose it could be in the use of some old stratigraphic terminology and fossil names (such as *Carcharodon*, now *Carcharocles*), and the absence of a scale on many of the fossil illustrations, but this barely detracts from an excellent little book.

This is a well-produced, useful summary of the geology of a county which clearly has a lot to offer. Having read it, I now have a higher regard for that part of the British stratigraphic column I had previously dismissed as sludge! Gerald Lucy and the Essex Rock and Mineral Society are to be congratulated on this excellent publication.

Tom Sharpe, National Museums and Galleries of Wales, Cathays Park, Cardiff CF1 3NP, Wales, U.K. 19th October 1999.

THE GEOLOGICAL CURATOR

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