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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: View of a portion of the Joggins Fossil Cliffs UNESCO World Heritage Site at low tide (image: JFI). See paper by Melissa Grey and Deborah Skilliter inside.

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COLLECTIONS MANAGEMENT AT THE JOGGINS FOSSIL CLIFFS UNESCO WORLD HERITAGE SITE: A NEW MODEL?

by Melissa Grey and Deborah M. Skilliter

Grey, M. 2011. Collections management at the Joggins Fossils Cliffs UNESCO World Heritage Site: a new model? *The Geological Curator* 9 (5): 273 - 278.

This paper outlines what we believe to be a unique collections management model wherein two institutions, one, a non-profit charitable organization (Joggins Fossil Institute) and the other, a governmental institution (Nova Scotia Museum), collaborate within the limits and framework of provincial legislation to curate a collection of geological and palaeontological specimens. We provide details of the collection management model which includes the development a data management system (Mini-MIMS) and an on-line searchable database that has been made available to the public.

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Introduction

The Joggins Fossil Cliffs

The Joggins Fossil Cliffs (Nova Scotia, Canada; Figure 1A, B; Figure 2) site was inscribed on the UNESCO World Heritage List in 2008 for representing the finest example in the world of the Pennsylvanian (Late Carboniferous) period of geological history. It is one of only twelve sites on the World Heritage List representing a geological time period (Figure 3). The Cliffs are one of the thickest sedimentary successions of a Carboniferous coal basin in the world, measuring over 4,400 m (Boon and Calder 2007).

Along a 14.7 km stretch of rocky coastline, a diverse fossil record of more than 195 species of plants and animals are preserved *in situ*. The powerful Bay of Fundy tides cause the cliffs to continually erode and expose new fossils, enabling active research at the site (see Calder 2006; Falcon-Lang 2006; Rygel and Shipley 2005; Grey and Finkel in review, for reviews). The fossil record at Joggins provides evidence of life from aquatic and terrestrial tropical environments with representation from all levels of the food web. Standing fossil forests of lycopsid trees that once grew in wetland ecosystems are continually exposed in the cliff face. Traces of amphibians,

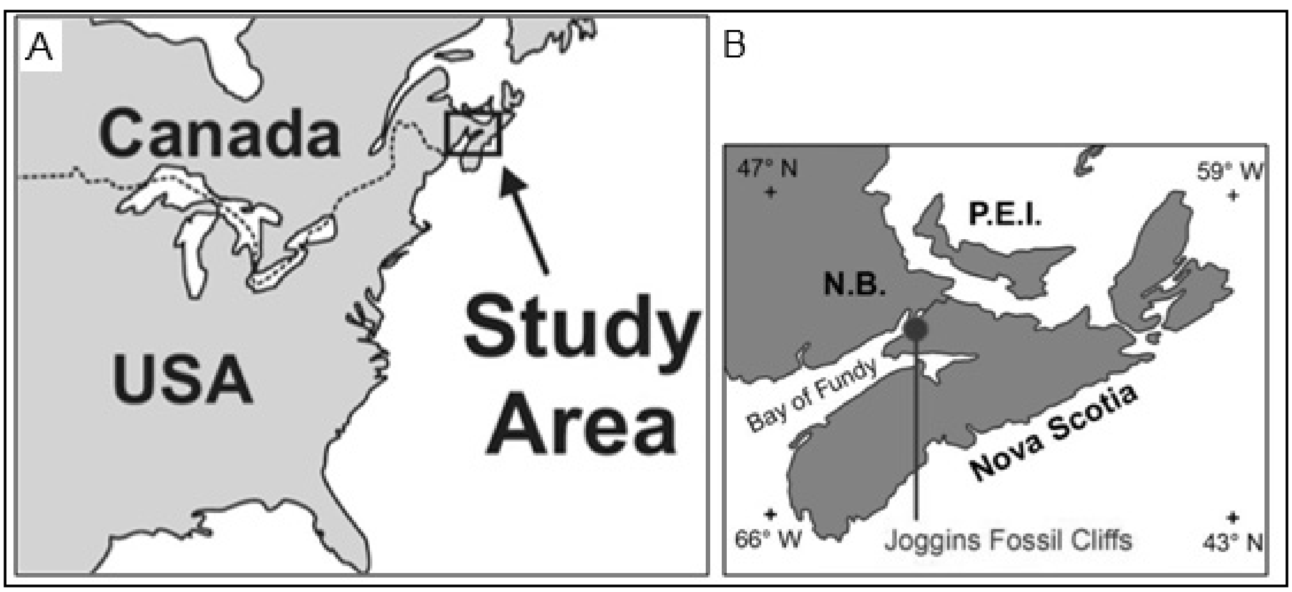

Figure 1. A) Location of the 14.7 km Joggins Fossil Cliffs World Heritage Site. A) Location in North America. B) Location along the Cumberland Basin (Bay of Fundy), Nova Scotia, Canada.

Figure 2. View of a portion of the Joggins Fossil Cliffs at low tide (image: JFI).

reptiles and giant invertebrates are preserved in silty shales which were once muddy river banks. Preserved in once hollow trees are the fossil remains of the world's oldest known reptile, *Hylonomus lyelli* (Carroll 1964). The early reptiles at Joggins represent the time when vertebrates fully transitioned from the aquatic environment to land with the evolutionary innovation of the amniote egg. The fossil record also includes plant species of seed-bearing ferns, lycopsid trees and giant horsetails; aquatic and terrestrial invertebrate species of shrimp, land snails, horseshoe crabs, bivalves, spiders, scorpions, giant millipedes and dragonflies; and vertebrate species of fish, amphibians and reptiles.

All fossils in Nova Scotia are protected under provincial legislation through the *Special Places Protection Act* (SPPA 1980; Chapter 438 of the Revised Statute, Province of Nova Scotia); the SPPA is administered by the Heritage Division of the Department of Communities, Culture, and Heritage, whose mandate is to protect important archaeological, historical, and palaeontological sites and remains, including those underwater. In order to collect fossils within the province a qualified person must obtain a Heritage Research Permit (HRP) from the provincial Coordinator of Special Places, with advice from the Curator of Geology. The SPPA precludes a more open collecting model, such as that adopted by the UNESCO-inscribed Dorset and East Devon Coast World Heritage Site in the UK where fossils that are common (i.e. not scientifically valuable) and found loose on the beach may be collected without a permit. The SPPA also effectively means that the Joggins Fossil Institute cannot legally own and develop a modern collection of fossils (i.e. any fossils collected after 1980) from the Joggins Fossil Cliffs because all fossils (from anywhere in the province) legally belong to the Province of Nova Scotia.

The Joggins Fossil Institute

The Joggins Fossil Institute (JFI) is a non-profit, non-governmental organisation that co-manages the Cliffs with Province of Nova Scotia and the province, as well as the local municipality, provides monetary support for operational costs. Management of the Cliffs is comparable to the Messel Pit UNESCO World Heritage Site wherein multiple parties, governmental and not-for profit institutions, partner to manage the site. By remaining independent of government, JFI has increased funding and fund raising opportunities, greater freedom to develop external partnerships, and the ability to maintain governance over the Joggins Fossil Centre, an interpretive gallery, visitor centre, cafe and gift shop, all housed in the same facility as the JFI.

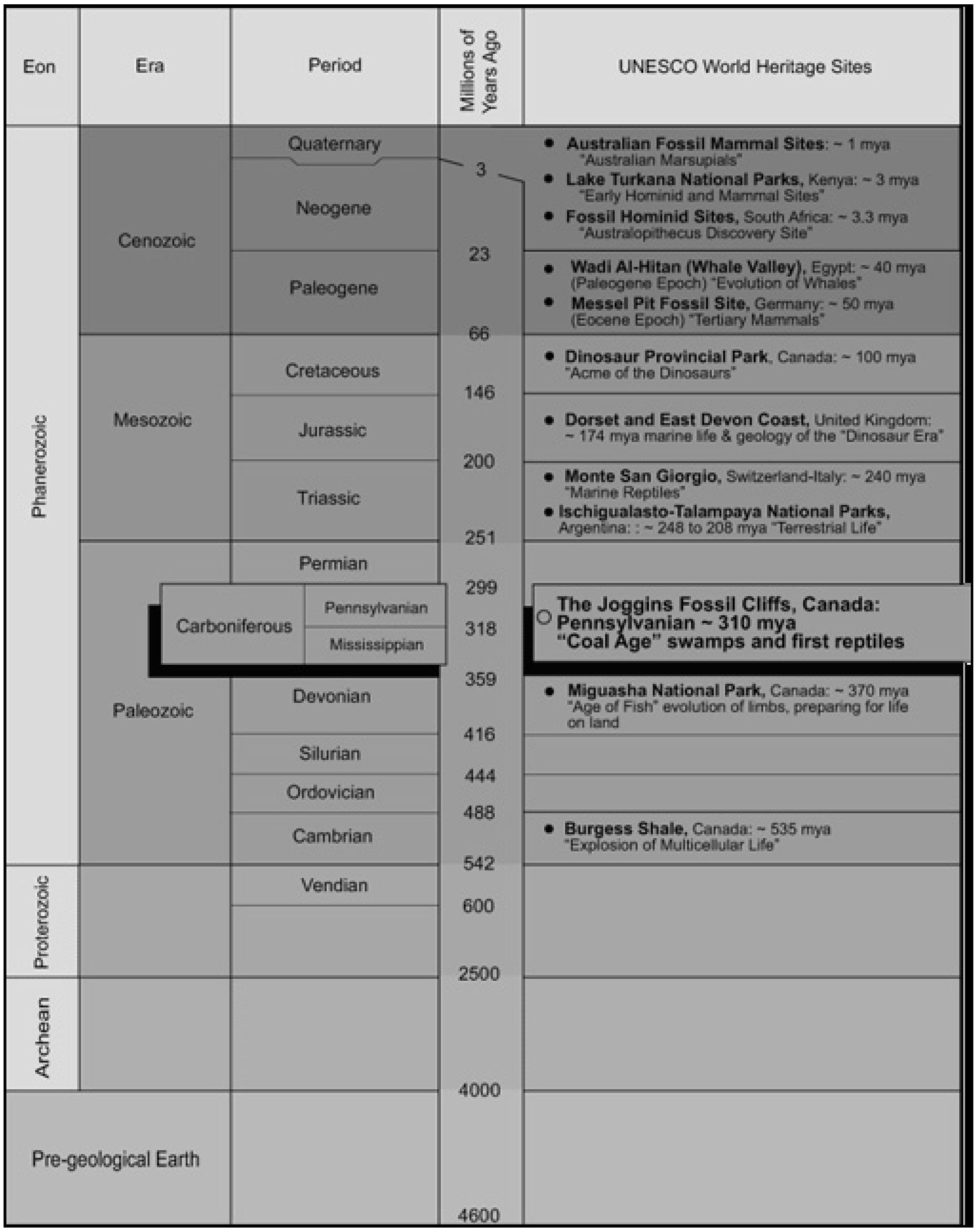

Figure 3. UNESCO World Heritage sites representing specific geological time periods (image: JFI).

JFI's vision is to hold a collection and a geographic site representative of the Carboniferous Period for the benefit and education of humanity. The Institute focuses on education and research, with the aim of being a world leader in communicating research to increase understanding of the natural diversity in the Carboniferous Period and to protect and conserve natural fossil heritage. With a presence on-site, the JFI can realize its, and the Province's, goals of education and outreach in terms of the geological and paleontological heritage of the region and communicating to the public the provincial legislation dealing with fossil collecting. In only its third year of operation, the JFI has seen visitors and researchers from around the world, and hosted geological/paleontological conference field trips and workshops. It has won numerous awards for its innovation, including those for community engagement, the architecture and environmental features of the Joggins Fossil Centre, and its environmental policies. The Joggins Fossil Centre (which houses an interpretive centre and the JFI staff) was created through collaboration with, and input from, federal, provincial, and municipal governments; JFI is governed by a Board of Directors that reflects these levels of government and also includes local residents and the scientific community.

Nova Scotia Museum

The Nova Scotia Museum (NSM) consists of 27 museums across the province, including over 200 historic buildings, living history sites, vessels, specialized museums and has approximately 1 million artifacts and specimens. These resources are managed either directly or through a unique system of co-operative agreements with societies and local boards. The NSM delivers its programs, exhibits, and products to serve both local residents and tourists in Nova Scotian communities. Over 620,000 people visited in 2009, making it a huge part of the province's tourism infrastructure. The NSM is the largest de-centralized museum in Canada, and is similar in structure to the National Museums system in Scotland.

The NSM was created by the *Nova Scotia Museum Act* (1989), a piece of provincial legislation. Through its museums, collections, research, exhibits, and programs, the NSM provides Nova Scotians and visitors to the province with an opportunity to experience and learn about our unique social and natural history. The NSM's history spans almost 140 years, making it one of the oldest provincial museums in Canada, established in 1868. Throughout its existence, the NSM has been a national leader in its commitment to decentralization, public education, community partnerships, and an innovator, making Nova Scotia's rich heritage accessible to Nova Scotians and worldwide audiences via the internet on the Nova Scotia Museum website.

Collaborative Curation of a Provincial Collection

The NSM and the JFI have entered into a collaborative model of curating a portion of the Nova Scotia Provincial Palaeontological Collection, specifically specimens from the Joggins Fossil Cliffs. The collaborative curation model was established within the framework of the *Special Places Protection Act, the Nova Scotia Museum Act,* and the NSM Collection Management Policy, available online at http://museum.gov.ns.ca/en/home/aboutnsm/policies/collectionmanagementpolicy.aspx.

The NSM provided advice on the construction of the JFI Collections storage facility during the building design process. The storage facility, which measures approximately 5 m^2, has three Spacesaver® mobile storage shelving units and four lockable Spacesaver® cabinets, used for the Type Collection. The floor is sealed concrete over which the Spacesaver® cabinets rest on plywood sealed with latex paint. Although the JFI Collections storage facility is not controlled for humidity, it was purposefully located in the centre of the building to minimize temperature and humidity fluctuations. For example, the average humidity in the storage facility was 38% (with a range of 31-45%) from November 1-5, 2010; the temperature was constant at 17ºC.

The Collections are divided broadly into Vertebrate, Invertebrate, Palaeobotanical, Trace, and Type specimens. Specimens are stored on the shelves or in the cabinets in boxes lined with ethofoam with accompanying catalogue cards on which appears relevant, succinct information. All materials are archival-quality. The catalogue records for the specimens are recorded in an NSM-designed and developed database known as Mini-MIMS (Mini-Museum Information Management System), which will be discussed in more detail below. Access to the locked Collections Storage facility is limited to the JFI Curator of Palaeontology and designates. The Collections Storage facility will also eventually house a collection of fossils that belong solely to the JFI, all of which were either collected prior to the implementation of the SPPA, or will be legally obtained from other localities. These specimens are curated under the JFI's Collection Management Policy, available online at http://jogginsfossilcliffs.net/research/documents/CollectionManagementPolicy.pdf.

All of the Joggins specimens currently housed at the JFI are on loan from the NSM. As the longest loan duration in the NSM Collection Management Policy is one year, the loans must be renewed annually, provided the JFI meets all loan conditions outlined in the NSM Collection Management Policy. Currently, the NSM still houses several specimens from the Joggins Fossil Cliffs, but the goal is to transfer the majority of the collection to the JFI storage facility. This will facilitate ease of access to Joggins specimens for researchers and display within the Joggins Fossil Centre.

The collections records are stored in a database called Mini-MIMS, designed and developed by the NSM, and based upon a more expansive, object-oriented database known simply as MIMS (Museum Information Management System). Mini-MIMS was developed specifically for the JFI and as a proto-type that may be further refined for use at other similar sites in the province. The database allows data to be entered in very specific fields and formats; database users are restricted to a few text fields to help describe the specimen and are limited to drop-down menu items for certain fields such as locality. Other fields of information, such as catalogue number, may only be entered in a specific format for the record to be accepted into the database. This specificity ensures that the data is 'clean', consistent, can easily be incorporated into the full version of the database (MIMS) with minimal editing, and provides for ease of data entry. Mini-MIMS was designed specifically for JFI and would need to be altered for use at other

Figure 4. Screen shots of the online searchable database of fossils held at the Joggins Fossil Institute. Fossils can be searched according to taxonomy (above) or through a gallery mode (below). URL: https://mims.ednet.ns.ca/Joggins/search.aspx.

sites. The JFI provides the NSM an updated version of their Mini-MIMS database once per month. The JFI has access to the full records of all NSM Joggins specimens, but does not have the capability to edit the full records. Editing of the full records on the MIMS database can only be completed by the NSM Curator of Geology to ensure consistency.

Any outgoing loans of specimens housed either at the JFI or the NSM are approved by the NSM Curator of Geology and the NSM Manager of Collections, in consultation with the JFI Curator of Palaeontology. The loan forms are completed by the Registrar at the NSM under the NSM Collections Management Policy. Shipping is arranged through whichever facility houses the specimen. Any fossil specimens exiting the country must be accompanied by a Cultural Export Permit from the Canadian Federal Government Department of Canadian Heritage, arranged through the NSM Curator of Geology.

The NSM Curator of Geology trained the JFI Curator of Palaeontology and staff in the care and curation of geological specimens according to the NSM Collections Management Policy. Training is held on an annual- or semi-annual basis as need arises. The NSM also provided training with respect to the Mini-MIMS database and JFI staff participated in refinement of Mini-MIMS. An inventory of the collection is provided annually to the NSM by the JFI and this ensures that all specimens formally on loan to the JFI from the NSM are accounted for.

The JFI and the NSM recently developed an online searchable database of fossils that are held in the collections at the JFI. The database can be searched according to taxonomy or through an image gallery (Figure 4). Information in the database is minimal and researchers are encouraged to contact the JFI or the NSM for further details, if necessary. For instance, sensitive data such as collector/donor information and precise stratigraphic locality have not been incorporated into the online database. The development of this online system serves as a model for future online databases of collections at the NSM.

As mentioned earlier, to collect fossils in the Province of Nova Scotia, a researcher must obtain a Heritage Research Permit on an annual basis. All permit applications for work on the Joggins Fossil Cliffs are approved through the Heritage Division of the Department of Communities, Culture and Heritage, with input from the JFI. This allows JFI staff to be aware of what research is being performed on the Cliffs, helps to establish contact between JFI staff and researchers, and prepares JFI staff for storage of possible new collections resulting from the research. The Joggins Fossil Institute plays a leading role in adding to the Provincial Paleontological Collection because it fosters research initiatives on site and it holds a Heritage Research Permit in order to add scientifically valuable and/or educationally useful specimens to the Collection.

Conclusion

We present what we believe to be a unique and successful collaborative museum collection management model within the framework of provincial legislation, which includes the *Nova Scotia Museum Act* (1989) and the *Special Places Protection Act* (1980). This collaborative approach is successful because those involved work towards the mutually agreeable goals of housing a growing collection of specimens from the Joggins Fossil Cliffs adjacent to the World Heritage Site, having the collection curated with the highest possible standards, and having the collection readily available for research and display. This collaborative curation model has allowed for the pooling of skills and resources, while easing the strain on the provincial collection space and staff resources.

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SPINELESS DISPLAYS OR WHY INACCURATE RESTORATIONS OF FOSSIL INVERTEBRATES DISCREDIT OUR MUSEUMS

by Stephen K. Donovan

Donovan, S.K. 2011. Spineless displays or why inaccurate restorations of fossil invertebrates discredit our museums. *The Geological Curator* 9 (5): 279 - 284.

Restorations of the morphology, ecology and function of fossil invertebrates may be inferior to those of groups more familiar to the public and artist, such as tetrapods. This is illustrated by an extreme example, a drawing of the Lower Jurassic pseudo-planktonic crinoid *Pentacrinites* Blumenbach on display in the Manchester Museum. It is shown, accurately, attached to the underside of a floating log. However, it is incorrectly illustrated attached by a cemented holdfast rather than by cirri. Indeed, the reconstruction lacks any cirri despite *Pentacrinites* having a densely cirriferous stem; the column is too short, has an incorrect cross-section and an erroneous pattern of columnal insertion; the cup and proximal brachial plates are too big; the pattern of arm branching is wrong; and pinnulation is inaccurate. Yet *Pentacrinites* is known from multiple well-preserved specimens from the Jurassic of the British Isles and was originally described more than 200 years ago. Museum restorations of fossil tetrapods have to be accurate because they are a group that we know well, yet many invertebrate groups are alien to the public and, if they are 'educated' by such grossly inaccurate restorations, so they shall remain.

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Introduction

In the early 21st Century, the most important contribution that museums can provide for the public is access to real objects in an educational context. The television and personal computer allow a near-infinite procession of images to be invited directly into the home, but a trip to a museum can provide a different experience based on authentic objects. Nonetheless, explanation and interpretation of real objects, supported by accurate restorations, still has an important role to play in any museum display. In palaeontology, for example, as knowledge and ideas concerning some fossil groups has changed, so their restoration and reconstruction in drawings and models has been revised. This comment is particularly applicable to those vertebrate groups of special interest to museum visitors of all ages, such as dinosaurs, Pleistocene mammals and fossil man. To give one well known example, interpretations of the Wealden dinosaur *Iguanodon* has changed over time from being reconstructed as a lizard in the 1830s (Rudwick 1992, figs 34, 35; Dean 1999, fig. 6.3) to a more rhinoceros-like armoured tetrapod in the 1850s (Rudwick 1992, figs 60-65, 72, 93; Doyle 2010, fig. 66b) to bipedal and sluggish in the 1890s (Hutchinson 1893, pl. 7), and tetrapedal or bipedal and active at the present day (Czerkas and Olson 1987, pp. 2-3, 105-107). Other, less popular groups, however, have not only been largely ignored despite our understanding of them having improved, but even what has been known for many years may be poorly, even incorrectly illustrated or restored.

Donovan (2011) recently demonstrated how fossil crinoids have been and continue to be incorrectly illustrated in books, museums and other public displays. There are two ways in which these illustrations are erroneous: either the gross morphology of the crinoids is incorrect; or crinoid palaeoecology and function is poorly interpreted. The former is unforgivable, as crinoid morphology has been well understood and defined since the 1850s and earlier. The morphology of the crinoid endoskeleton is well illustrated in any and all modern, and not so modern, textbooks of invertebrate palaeontology. A failure to draw upon these readily available resources may result in an incorrect, even bizarre restoration (Donovan 2011, figs 3, 5). Direct observations of the ecology of extant stalked crinoids, which typically live in water depths of 100 m or more, is a rather more recent field of study. These date from the first direct observations by research submersibles (Macurda and Meyer 1974) and have shown that the majority of living stalked crinoids are rheophiles, not rheophobes as had been presumed for the previous 150 years. That is, the crown, bearing the arms, pinnules and tube feet (=feeding organs), are directed down-current (=sub-perpendicular to the sea floor) as a feeding net (rheophile) rather than upwards (=sub-parallel to the sea floor or as a funnel) to capture falling organic detritus (rheophobe). Unfortunately, rheophobic crinoids are still prevalent in many restorations in books and museums (Donovan 2011) more than a third of a century after Macurda and Meyer's seminal observations.

But applying our knowledge of extant stalked crinoids to the morphologically rather more varied taxa that are known from the fossil record may be problematic. Particularly, crinoids with extremes of morphology or environmental preferences not known at the present day present difficulties. For example, certain groups of Palaeozoic and Mesozoic crinoid were pelagic (Hess 2010), either evolving flotation devices or attaching to floating objects (=pseudoplankton; Wignall and Simms 1990). Museums are to be congratulated for interpreting such unusual ecological preferences for the public, but they have to do it right. Herein, I discuss a restoration of a Jurassic pseudoplanktonic crinoid, *Pentacrinites* Blumenbach, 1804, that bears little morphological resemblance to that genus, which is well known from multiple specimens in many collections and widely documented in the scientific literature (see, for example, Simms 1986, 1989, 1999; Hess 1999, 2010).

A poorly restored pseudoplanktonic crinoid

The restoration in question is a drawing displayed in a tall showcase devoted to Jurassic palaeontology in the Rocks and Minerals Gallery on the ground floor of the Manchester Museum. This is towards the south end of the gallery, on the side away from the Oxford Road and adjacent to the Museum's skeleton (cast) of *Tyrannosaurus rex*. Terminology of the crinoid endoskeleton follows Moore *et al.* (1978) and Ubaghs (1978).

The label associated with the reconstruction states: "*Pentacrinites*, a crinoid which hung down from floating logs." There are four crinoids attached to the underside of a floating log (Figure 1); they are hanging straight downwards. All are attached to the log by a distal, cemented discoidal or crustose holdfast *sensu* Brett (1981, table 1). The stem is completely

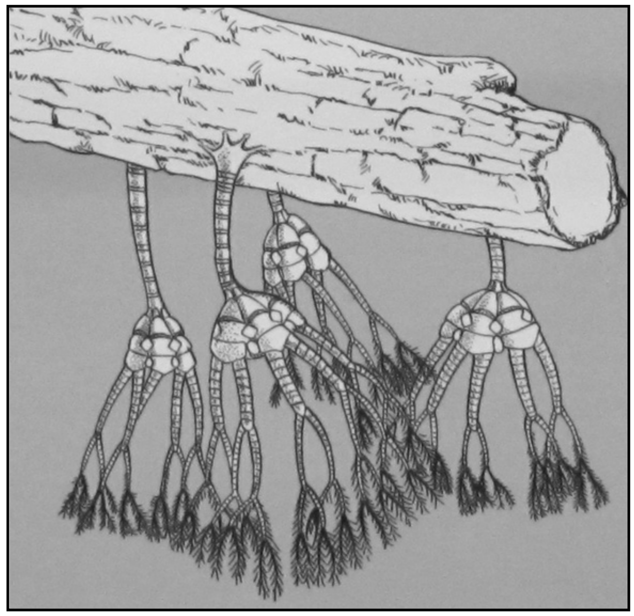

Figure 1.* "Pentacrinites*, a crinoid which hung down from floating logs" (specimen label). Compare the morphology of this crinoid with those illustrated by Simms (1986, 1989), Seilacher and Hauff (2004) and Hess (1999, 2010).

lacking in radices or cirri (Donovan 1993). The columns of all four individuals is short, perhaps about 20 columnals, circular in section and heteromorphic, N1 (*sensu* Webster 1974; explained below). Cups are relatively large, and the two lowest arm ossicles, primibrachials IBr_1 and IBr_2, are large and separated by interbrachial plates (Figure 1). Arms are short (a little longer than the stem) and branch isotomously four times; pinnules are only apparent on arms after the tertaxillary (=third point of branching).

Discussion

"I am only, of course, giving you the leading results now of my examination ... There were twenty-three other deductions which would be of more interest to experts than to you" (Sherlock Holmes in 'The Reigate Squires'; Conan Doyle 1894 [1967 reprint], p. 134).

The inaccuracy of this restoration can best be judged by comparison with illustrations and morphological information that can easily be gleaned from the scientific literature. One accurate restoration is provided which supports many of the ideas discussed herein (Figure 2); other relevant images are referred to below. The principal morphological characteristics derived from my description are numbered 1-10 in Table 1, and compared with descriptions and interpretations from the scientific literature. These same points are discussed in more detail below.

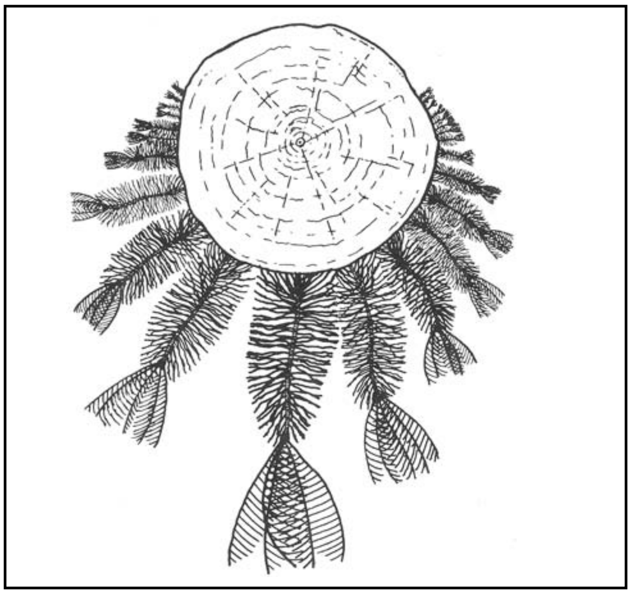

Figure 2. A diagrammatic restoration of short-stemmed* Pentacrinites fossilis *Blumenbach attached to floating driftwood (after Simms 1986, text-fig. 2a). Larger specimens concentrated at the bottom reflect early larval attachment; lack of space caused later larvae to attach higher on the sides of the log.

1. Orientation

The good agreement between the restoration (Figure 1) and the literature (Figure 2) is probably coincidental, the Manchester Museum crinoids being drawn as inverted rheophobes (see above). Seilacher and Hauff (2004, pp. 9-10, fig. 9) speculated that *Pentacrinites* was an active filter feeder, with the abundant cirri actively generating feeding currents down towards the base of the crown. Hence, the stem, short in comparison with the closely related *Seirocrinus* (Seilacher *et al.* 1968), did not need to be directed in the current to feed (Seilacher and Hauff 2004, fig. 1).

2. Attachment

Larval attachments of *Pentacrinites* are small cemented discs less than 1 mm across (Simms 1986, pp. 481, 483, text-fig. 2c; 1999, p. 180). Yet post-larval individuals were not cemented, but rather attached by the very numerous cirri which contained contractile tissues (Donovan 1993).

	Manchester Museum	Literature
1.	Hanging straight down from log	Hanging straight down
2.	Distal, cemented holdfast	Cirriferous attachment
3.	Stem lacking in radices or cirri	Stem densely cirriferous
4.	Column short, perhaps about 20 columnals	100 mm - 1 m
5.	Column circular in section	Columnals pentalobate proximally, pentagonal to sub-circular distally
6.	Column heteromorphic, N1	Column heteromorphic, at least N434243414342434
7.	Cups large	Cups relatively small
8.	Primibrachials IBr_1 and IBr_2 larger than radials	IBr_1 and IBr_2 smaller than radials
9.	Arms branch isotomously four times	Arms branch isotomously twice, then endotomously a number of times
10.	Pinnules are only apparent on distal arms	Arms pinnulate from $IIBr_2$

Table 1. Comparison of features of restoration of pseudoplanktonic crinoid in Manchester Museum (Figure 1) and the morphology of such crinoids as determined from the palaeontological literature (cited in text), but mainly from the description of* Pentacrinites fossilis *Blumenbach in Simms (1989, pp. 16-19).

It is also relevant to point out that crinoids are sparse on this reconstruction (contrast Figures 1 and 2). The common close association of *Pentacrinites* individuals is explained by Simms (1999, p. 180): "Where these crinoids do occur on a piece of driftwood, they occur in great abundance and with a range of sizes, whereas other pieces are devoid of crinoids. This suggests that a major barrier, in the form of vast stretches of open ocean, prevented all but a handful of crinoid larvae from ever reaching new, uncolonized pieces of driftwood." Thus, success for many larvae was to attach progressively higher on the driftwood which supported their parents (Figure 2), a funeral barge which eventually became waterlogged, overloaded or both, and sank.

3. Presence or absence of cirri

This is the single most glaring and grotesque error in the restoration in the Manchester Museum. So-called *Pentacrinites* in Figure 1 completely lacks cirri, yet *Pentacrinites sensu stricto* has the most dense and numerous development of these attachment structures of any genus in the entire fossil record of the stalked Crinoidea. For comparison, see Simms (1999, fig. 191) and Hess (1999, figs 201, 202).

4. Length of column

Although no scale is given (Figure 1), the column appears short. Simms (1989, p. 17) noted that the stem of *P. fossilis* varies between 100 mm and 1 m in length; crinoids in Figure 1 have stems shorter than 100 mm by comparison with other features (cups, arms). For further comparison, *Pentacrinites doreckae* Simms had a stem 500+ mm long and, in *Pentacrinites dichotomus* (M‘Coy), it was 200 mm, with a corresponding arm length of c. 150 mm (Simms 1989).

5. Column section

There is nothing to suggest any angularity in the figured columns (Figure 1) and their section thus appears to be circular. In contrast, the generic diagnosis of *Pentacrinites* states "Stem pentalobate to pentagonal, with sharp interradii" (Simms 1989, p. 15). At most, they assume only "a subcircular outline in very large columnals with inflated radii" in *P. fossilis* (Simms 1989, p. 17).

6. Insertion of columnals

Nodal columnals grow at the base of the cup; internodals are intercalated between nodals and, therefore, away from the base of the cup (see, for example, Donovan 1984, text-fig. 5). Broadly, a crinoid that secretes numerous internodals will grow a longer column than an otherwise identical species that does not. The restoration in Figure 1 shows only an alternation of tall (nodals = N) and shorter columnals (priminternodals = 1), giving a repeat distance of only N1 (*sensu* Webster 1974). Contrast this with the extremely different morphology of *P. fossilis* which has 15 internodals of four orders between each nodal (Simms 1989, pl. 2, figs 4, 8), regularly intercalated N434243414342434.

7. Size of cup

The stalked articulate crinoids commonly have cups that are small compared to the rest of the animal. In Figure 1, radials and basals are plainly apparent, but the cup appears unusually large when compared with illustrations of crowns of *Pentacrinites* (for example, Simms 1989, pl. 2, figs 5, 7). The crinoid in Figure 1 has a cup more typical of a Palaeozoic species (see below).

8. Primibrachials and interprimibrachials

In *P. fossilis*, the first two plates of the arms, the primibrachials IBr_1 (supported by the radials) and IBr_2 (the primaxillary, where the first branch of the arms occurs), are moderately large, but are smaller than the radials and do not abut. In Figure 1 these same plates are the largest in the crown and form continuous circlets, being separated by interbrachial plates. There are no interbrachial plates in *Pentacrinites*, although certain patterns of preservation might suggest their presence due to more or less displacement of ossicles of the tegmen or, less likely, cirri. Nevertheless, the cups in Figure 1 have the appearance of monobathrid camerate crinoids from the Palaeozoic rather than any Mesozoic crinoid.

9. Arm branching

Each of the arms of the crinoids in Figure 1 branches equally (= isotomously) four times. The arms of true *Pentacrinites* branch isotomously only twice. Thereafter, this pattern changes to one in which numerous slender, long branches are developed at regular intervals on the inner sides only of each pair of branches (= endotomously). This was particularly well illustrated by Simms (1999, fig. 189; reproduced by Hess 2010, fig. 10).

10. Pinnulation

The crinoid arms in Figure 1 bear pinnules only after they have branched three times. Simms (1989, p. 18) noted pinnules being developed externally on the second secundibrachial ($IIBr_2$), that is, from the second ossicle above the most proximal branch. The pinnules of *Pentacrinites* are both densely developed and moderately long (again, see Simms 1999, fig. 189). In truth, the pinnules in Figure 1 are more like bristles on a bottle-washer's brush.

This 'restoration' thus conveys very incorrect morphological information to the public. My detailed description and interpretation of this illustration, comparing it to true *Pentacrinites*, has been presented to emphasise the many ways in which it fails to provide a true representation of the named genus. Only at the coarsest level - a pseudoplanktonic crinoid hanging down from a log - does the restoration (Figure 1) convey the correct information. But the morphology of these crinoids is so very different from true *Pentacrinites* as to be worthless. It is so wrong that its first close encounter with a crinoid expert has engendered this contribution. In truth, the Manchester Museum must be considered, at best, reckless to display something so grossly inaccurate.

I could be accused of being a crinoid expert merely fussing over the fine details of an inconsequential reconstruction. I would argue that if a restoration or reconstruction of any fossil isn't right, then what purpose does it serve apart from misinformation? It is presumably easier to reconstruct a pseudoplanktonic crinoid wrongly than correctly, but does erroneous illustration serve a useful purpose? In comparison, why lavish resources to, for example, piece together a complicated skeleton like that of *T. rex* correctly? Why not swap the limbs around or stick the tail on the end of the nose? Because people would know it was wrong, whereas few members of the public could correctly identify a poorly illustrated crinoid. Tetrapods, with which we are most familiar, commonly receive superior treatment in museums, books and all restorations than do invertebrates.

But it is not only crinoids that have suffered in the Manchester Museum. They are merely an illustration of a wider malaise. Immediately next to *Pentacrinites* is a restoration of a nest of the Jurassic oyster *Gryphaea* (Figure 2). Such a well known Jurassic fossil can surely be reconstructed correctly? This common bivalve has an umbonal region that is thickened and heavy, and presumably sank into the sediment (other reconstructions suggest it would also have been stable rolled over 'on its side'). Either would have had the effect of elevating the commissure above the sediment surface, thus favouring cleaner respiratory and feeding currents entering the shell (Hallam 1968, fig. 23; Fürsich 1980; LaBarbera 1981). Yet the Manchester Museum restoration is the

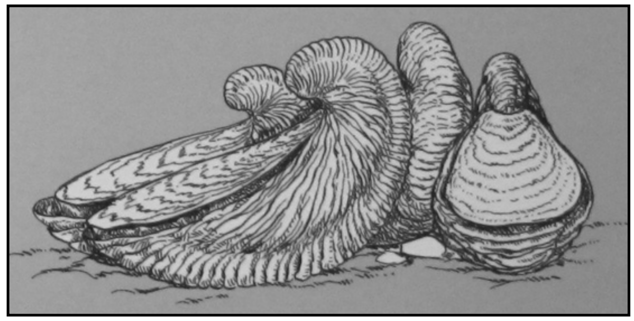

Figure 3. "*Gryphaea*, a Lower Jurassic 'oyster' with a thick shell. The smaller species is sometimes called the 'devil's toe-nail'" (specimen label). A superior restoration of this life group would have had the commissures elevated and the umbos depressed.

exact opposite, with the commissure tilted upwards. Interpretation of another invertebrate, displayed in the shadow of *T. rex*, again comes off second best.

Conclusion

I would suggest that the different approaches used to illustrate vertebrates and invertebrates in some museum displays has much in common with which the ways such organisms may be animated for the cinema. The excellence of animation of dinosaurs in the movie *Jurassic Park* had much to do with its success, just as skeletons restored in dynamic poses, like *Tyrannosaurus rex* in the Manchester Museum, make them stars of the display. In contrast, exhibits and restorations of invertebrates may or may not be accurate and rarely enjoy the care lavished on a dinosaur skeleton. They bring to mind another animated character of questionable accuracy; Sponge Bob Square Pants.

Acknowledgements

Hannah and Pelham Donovan are thanked for humouring their father's insatiable desire for visiting museums. Drs Mike Simms (Ulster Museum) and Svend Stouge (Editor-in-chief, *Palaeontology*) kindly gave permission to reproduce Figure 2. Drs Hans Hess (Naturhistorisches Museum Basel) and Mike Simms are thanked for their positive reviews.

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AUSTRALIA'S FIRST DISCOVERED FOSSIL FISH IS STILL MISSING!

by Susan Turner

Turner, S. 2011. Australia's first discovered fossil fish is still missing! *The Geological Curator* 9 (5): 285 - 290.

Seeking Australian specimens collected in the 19th century always needs detective work. Fossils collected by one colourful collector, the Polish 'Count' Paul Strzelecki, from early travels in the colony of New South Wales are being sought. A 30-year search has still not brought to light in Australia or Britain the first fossil fish found from the Lower Carboniferous of New South Wales.

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Introduction

160 years ago a man with the unpronounceable (unless you cope well with Polish) and usually mis-spelt name and a shady past, "Count" Pawel ('Paul') Edmund Strzelecki (various dates, 20 June or July 1796 or 1797-October 6 1873: Wiki) left Europe to sail to the British colony of New South Wales where in 1839 he made a living financing himself by selling geological specimens (e.g., Rawson 1957, Heney 1961). And, despite his claims, he was not strictly a Polish aristocrat. Instead, he was a mere "szlachcic" (even very poor people, but of noble origin, could belong to the "szlachta" from a landowning or former landowning family even if they lost their property). Also included in this class (some 10% of the Polish population) were people whose merits had been acknowledged by the king. His later service to the British Government during the Irish Potato famine in the late 1840s did earn him both respect and a title (e.g., Rawson 1957).

Born in Gluszyna near Poznan in Poland as the third child of a struggling landowner of nobility, Strzelecki was educated in Warsaw. and then went to live in Kraków. After the national uprising against tsarist Russia in 1830, he was forced to emigrate to London and then he took the major step of visiting the other side of the world.

His biographers (Heney 1961, Paszkowski 1997) do not give details of Strzelecki's student days or education but Paszkowski judged him an honest if 'old-fashioned' exponent of the scientific method. How did Strzelecki get interested in the early 1800s in what became known as geology? He did study at the Agricultural Institute in Moclich in the former East Germany, then Prussia, and was keen on mineralogy and rocks. It is clear from his work in the Oceanian region that he was also well ahead of his times in his understanding of the relationship of the indigenous people with their landscape and geology. Primarily a Wernerian (did he go to Freiberg Mining Academy?), he was aware of Hutton's influence (Andrews in Paszkowski 1997).

During his short sojourn in Australia (he arrived in Sydney on 25 April 1839-22 April 1843, e.g. Heney 1961), Strzelecki covered a lot of ground in the

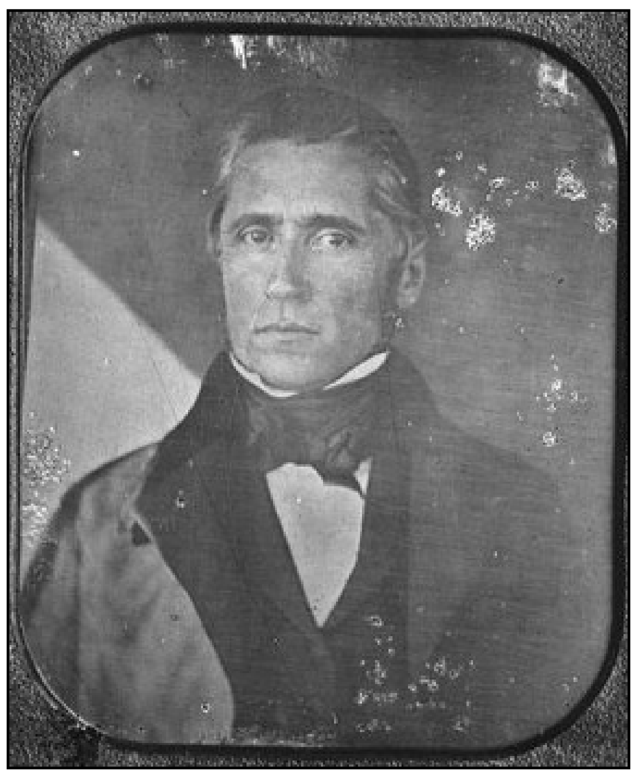

Figure 1. Photograph of P.E. Strzelecki (modified from Wikipedia, accessed February 2010).

colonies of Victoria, New South Wales and Tasmania; he named the highest mountain that he climbed in 1840 after one of his compatriots (General Tadeusz Kozciuszko) and made the first decent geological map of the known part of Australia (Strzelecki 1845, Branagan 1986). And he travelled on foot!; some 11,000 km (7,000 miles). During one of his traverses, around 1843, he picked up the first fossil fish specimen in Australia. It is this specimen that I am seeking.

Strzelecki's Fossils

During literature searches in the early 1980s looking for evidence of Devonian and Carboniferous shark remains in Australia, after I had discovered a most unusual tooth in what was thought to be Upper Devonian or Lower Carboniferous limestone in north Queensland (e.g. Turner 1982), I discovered a reference in Benson's (1921: p. 25; 1922) papers to what I realised was a fossil fish spine and possibly shark in the Early Carboniferous of New South Wales (which in the 1840s was the easternmost colony of mainland Australia). Not only that but the locality from which the spine came was named "The Ichthyodorulite Range" (County Gloucester: Karuah River); this word 'ichthyodorulite' actually means "fossil fish

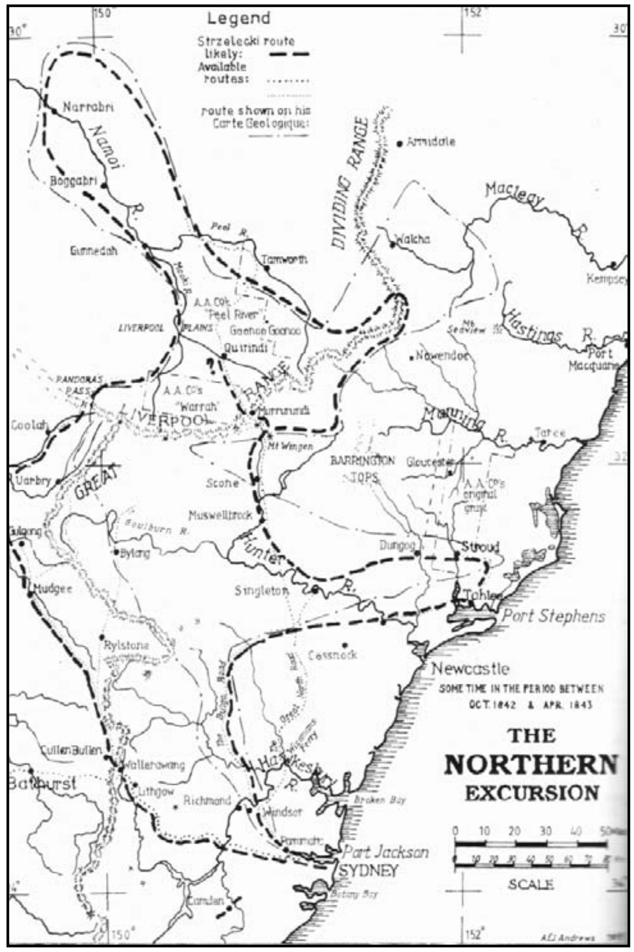

Figure 3. Part of Strzelecki's 1845 map.

spine" and the unusual designation was my clue. I knew I was on to something as this label implied to me that there was in that part of Australia in that time range the presence particularly of a shark(?) or even a gyracanth acanthodian fin spine (see e.g. Turner *et al.* 2005).

I had only just begun to 'get into' the ichthyodorulites myself with the help of an old friend - Eastman's edition of Zittel (1902). Thus, I began to investigate where the first-ever fossil fish from Australia was found in the range of hills at Booral near Newcastle, NSW [the latter city named incidentally by Captain Cook with help from his Lieutenant, Kent whose relation was a member of the Newcastle-upon-Tyne Literary and Philosophical Society to which I used to belong myself when I lived and worked at the Hancock Museum, Newcastle and first began to curate 'ichthyodorulites' in the fine Thomas Atthey collection; Turner in Cleeveley 1983; Newman *et al.* 1996]. The name of the range of hills was apparently given to the geographic feature after Strzelecki's find in the early 1840s for it occurs in De Koninck (1878, 1898) and later maps (e.g. Benson 1922), although there is no mention in the current NSW Gazetteer (J. Pickett, GSNSW Sydney, *pers. comm.* c. 1981).


Figure 2. Statue of the P.E. Strzelecki erected by the Polish community at Jindabine, New South Wales (photo © Dr S. Turner)

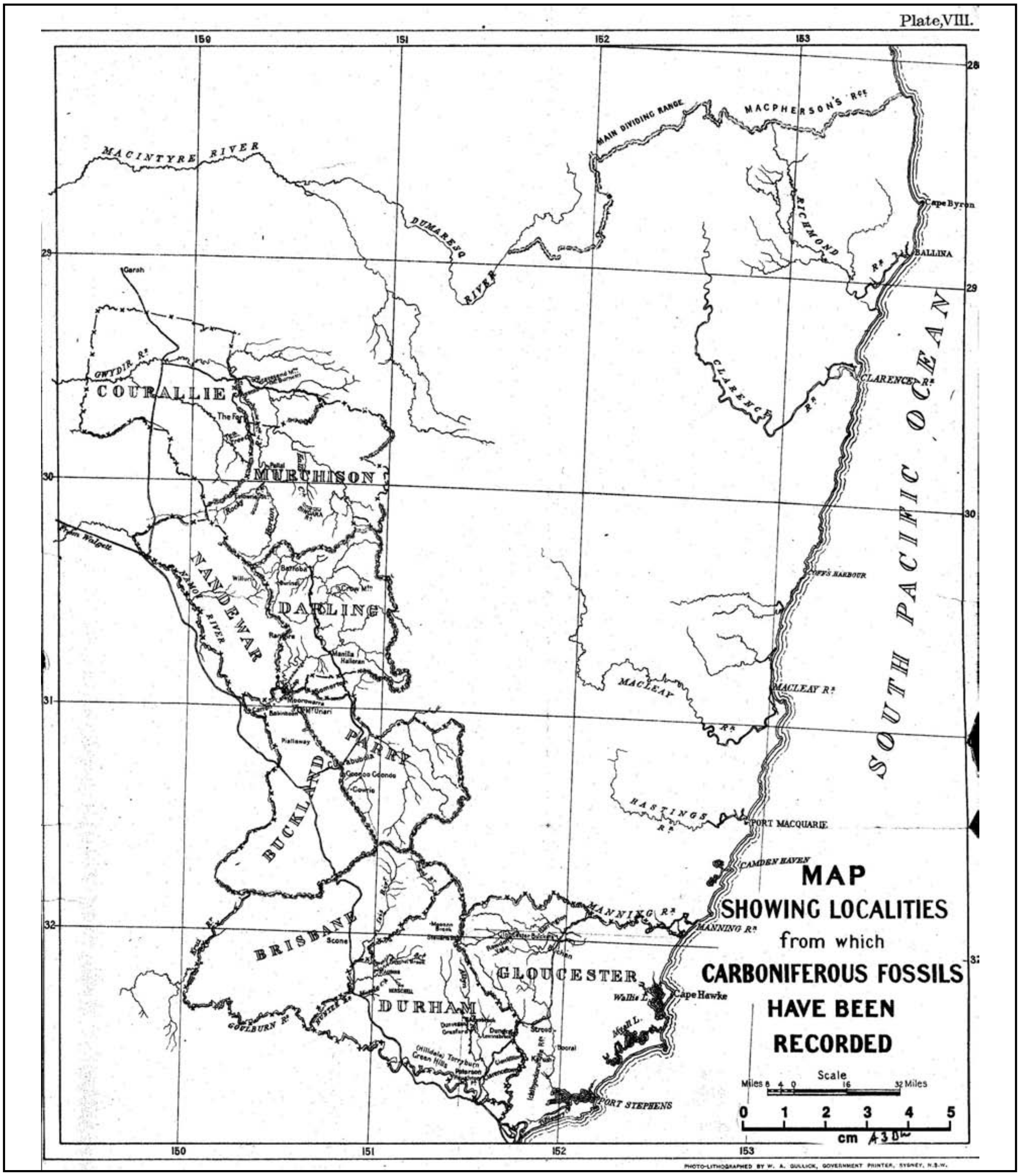

Figure 4. Map showing the Ichthyodorulite Range from Benson 1921.

It became clear to me that the reference to a fossil fish and thus Strzelecki's place in the history of finds in this continent had been neglected. The best review at the time by Sherbon Hills (1958) credited J.D. Dana with describing the first fossil fish from Australia. Dana visited during the American Exploring Expedition of 1838-1842 and met the Revd C. P. N. Wilton, as noted by Leichhardt (in Clarke 1867); his fish is a Permian "palaeonisciform or chondrostean" named *Urosthenes australis* Dana, 1848 later re-examined by BMNH doyen Arthur Smith Woodward in 1931 (Long 1991). However, Strzelecki seems to have picked up his fish earlier than Dana in the late 1830s, as described in his 1845 book, and he also has priority of publishing by three years (Turner to Jones in Young and Laurie 1996, Jones *et al.* 2000).

On his trek Strzelecki left Sydney in 1842, after meeting briefly with the Revd William Branwhite Clarke (1798-1878), who would later be styled 'Father of Australian Geology' (see e.g. Grainger

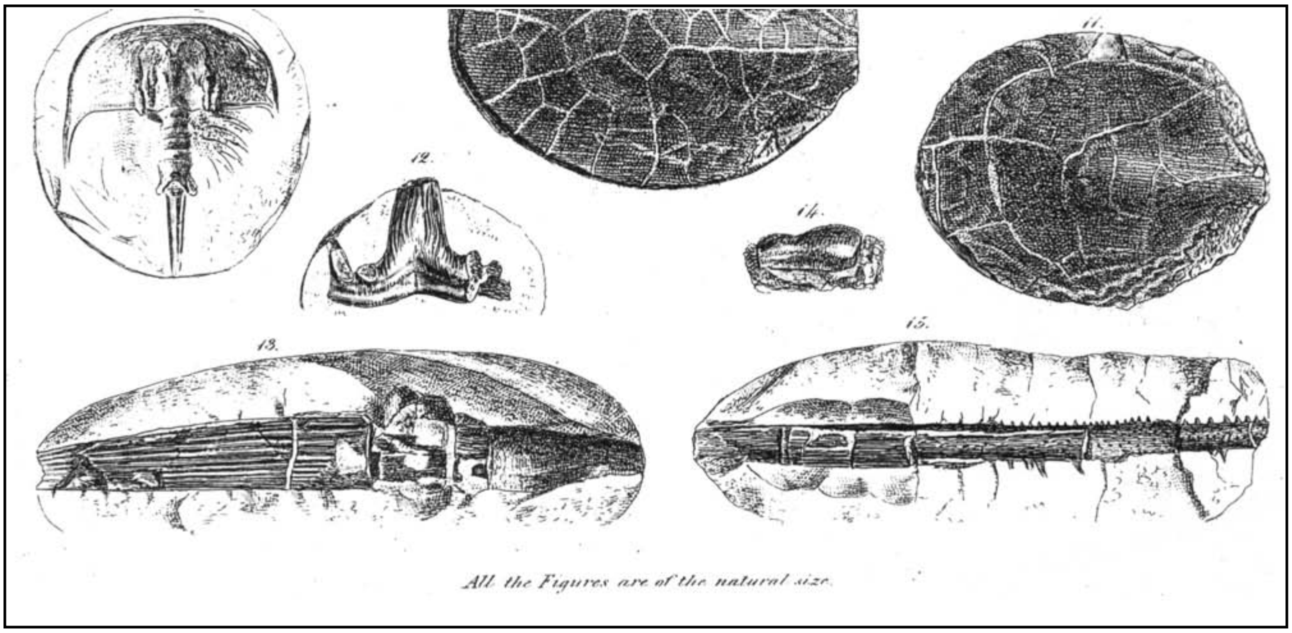

Figure 5. Prestwich's Carboniferous Coal Measures shark remains from Coalbrookdale, Shropshire, figured in 1840: note especially the spines - xenacanth or ctenacanth/hybodont.

1982). Clarke had himself just arrived in the colony and would go on to cover much the same ground as Strzelecki publishing widely (e.g. Clarke 1878) but, as far as we know because his collections were mostly destroyed in a disastrous fire in Sydney, without finding further fossil fish.

After his journey Strzelecki (as advised by Clarke) sent his specimens to London and they went to John Morris at the British Geological Survey (then in London). Carboniferous fish were thus among the first fossils found in Australia (Jones *in* Young and Laurie 1996). The "ichthyodorulite" described by Morris (in Strzelecki 1842, 1845) from a "dark Limestone" in the Lower Carboniferous Booral Formation was compared by him with one described by Joseph Prestwich (1840) from the Coal Measures of England. Ostracodes from the same deposits were identified by Morris (in Strzelecki 1845) as *Bairdia affinis* (see Jones 1989). Based on Morris's assessment with the hint about Prestwich's illustrations (Figure 3), the Australian spine might belong either to a ctenacanth, a xenacanth or a hybodont shark, all of which could be expected in Australia in the Early Carboniferous and have subsequently been found (e.g. Turner, 1990, 1993; Long 1996; Turner and Burrow 2011). However, Strzelecki's specimen was then promptly 'lost'; whether it was sold, or returned to its owner by then in Britain, or sent by ship to Australia, or hidden in a drawer at the survey, we do not know. Despite enquiries at GSUK and NHM over the years, I have never managed to locate it. So, where are all Strzelecki's missing specimens? When she did her Ph.D. at Cambridge (Turner 2007), Dorothy Hill (1937) did find some of his corals and some of his Permian bryozoans from Tasmania are in the Natural History Museum in London (Wyse Jackson *et al.* 21011). I note also that Professor David Branagan (a fellow member of INHIGEO), who attended the GSL bicentenary meeting, has also been attempting to find Australian material; but no word yet that he has traced the missing fish for me. And sadly I have still not been able to retrace Strzelecki steps to Booral; maybe this year.

Acknowledgements

Thanks for help at museums from the late Colin Patterson (NHM, London), John Pickett (GSNSW, Sydney), and Peter Jones (now ANU, Canberra). For comments on Polish history and culture, I thank Dr Michal Ginter (Warsaw). Wikipedia was also useful.

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DIGITIZING COLLECTIONS: EXPERIENCES FROM THE UNIVERSITY OF IOWA PALEONTOLOGY REPOSITORY DIGITIZATION PROJECT

by Tiffany S. Adrain, Ann F. Budd and Jonathan M. Adrain

Adrain, T.S., Budd, A.F. and Adrain, J.M. 2011. Digitizing collections: experiences from the University of Iowa Paleontology Repository Digitization Project The Geological Curator 9 (5): 291 - 299.

The University of Iowa Paleontology Repository is the fifth largest university fossil collection in the U.S., holding over 1 million specimens from all geologic ages, worldwide. A digitization project, funded by the National Science Foundation (DBI-0544235; $284,724), has made previously inaccessible collections available to researchers, including the Amoco Conodont Collection, the Paleozoic Coral Collection, the Neogene Coral Collection, the Trilobite Collection, the Amoco South Florida Collection, and the Micromammal Collection. Specimen data are captured using a Specify Biodiversity Collections Database and shared with the Paleontology Portal (www.paleoportal.org). Inventories of new, as yet uncatalogued, collections are available on the Paleontology Repository website (http://geoscience.clas.uiowa.edu/paleo/index.html), including the Crossman Crinoid Collection and the Pope Collection. Ancillary materials have been digitized and made available, including 1,316 Amoco conodont locality folders and 7,000 field photographs (funded in part by a University of Iowa Innovations in Instructional Computing award). Along with specimen samples, cores, and maps, these photographs form the basis for the Tropical America Virtual Field School, an on-line teaching resource drawing on collections made during 30 years of fieldwork in South Florida and the Caribbean. A database of specimen images is being developed, particularly useful for fragile specimens that cannot be loaned. Information for researchers is complemented with information for the public, using different methods of data access and presentation. The Fossils in My Back Yard website provides a user-friendly option for looking at the same specimen data without overwhelming the non-scientist.

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Introduction

Following the introduction of computers into museum collection management in the 1960s (Misunas and Urban 2007), a major goal has been to document or catalogue collections electronically and make that information available to the public and researchers. The importance of digitizing collections is illustrated by the U. S. National Science Foundation's (NSF) October 2010 announcement of a new program, Advancing Digitization of Biological Collections (ADBC), "to create a national resource of digital data documenting existing biological collections and to advance scientific knowledge by improving access to digitized information (including images) residing in vouchered scientific collections across the United States" (NSF 2010). The program was developed in response to community initiatives including the Interagency Working Group on Scientific Collections (National Science Technology Council 2009), The NSF Scientific Collections Survey (Flattau *et al.* 2008) and a 10-year strategic plan produced by the Network Integrated Biocollections Alliance (NIBA) (NIBA 2010). The University of Iowa (UI) Paleontology Repository has recently completed a digitization project funded by the National Science Foundation's Improvements to Biological Research Collections program and now provides over 50,000 electronic records on-line via the Paleontology Portal and various in-house website resources (see the UI Paleontology Repository website at http://geoscience.clas.uiowa.edu/paleo/index.html). This effort can be used to illustrate the type of digitization projects that can be undertaken for a sizeable research collection with a small staff and budget.

The UI Paleontology Repository

The UI Paleontology Repository began as the State University of Iowa Cabinet of Natural History, created by an 1855 Act of Iowa General Assembly to house natural history specimens collected by the early State Surveys of Iowa. Zoology and botany collections formerly in the Cabinet are now under the responsibility of the UI Museum of Natural History and the Iowa State University Ada Hayden Herbarium respectively. The UI Paleontology Repository houses over one-million specimens and is the fifth largest university fossil collection in the U.S (Allmon and White 2000, table 2). The collection focuses on Paleozoic marine invertebrates, microfossils, Quaternary mammals, and Neogene corals, and includes over 25,000 type and referred specimens.

The UI Paleontology Repository is administered and supported by the UI Department of Geoscience in the College of Liberal Arts and Sciences which funds one full-time, permanent, collections manager and provides space, facilities, funds for incidental expenses, and office support. Curatorial supplies, student stipends, outreach materials and professional travel are funded through a quasi-endowment that distributes approximately $2,500 a year. Undergraduate student interns from the Museum Studies Certificate Program support semester-long collection-based projects. Longer-term assistance with larger projects requires additional funding from UI initiatives or external sources. In 2006, the UI Paleontology Repository was awarded a National Science Foundation Grant to digitize priority collections (DBI-0544235 3 yrs., $284,724); "Computerization of the University of Iowa Paleontology Repository" (PI = A. F. Budd, Co-PIs = J. M. Adrain, T. S. Adrain, C. A. Brochu). The goals of this project were to:

- Prioritize collections at risk from losing associated data
- Make collections data accessible on the Internet
- Increase research access to collections
- Make digital images available on-line for researchers and fossil enthusiasts
- Digitally preserve associated printed documentation
- Develop web-based education tools
- Provide training opportunities for undergraduate, graduate and Museum Studies students

Supplementary funding was awarded to create a public-friendly website: "Fossils in My Back Yard" (Research Experiences for Undergraduates Supplement to National Science Foundation Grant DBI-0544235 (1 yr., $13,303)); and to digitize 7,000 field photographs for the development of an interactive educational resource: "Tropical America Virtual Field School" (University of Iowa Innovations in Instructional Computing Award (1 yr., $17,200)).

Digitization: what, why, and how?

A simple definition of digitization is the transcription of information into a digital form so that it can be directly processed by a computer. In a paleontology collection, the data in question include the specimen itself, any recorded or inferred information relating to a specimen (locality, stratigraphy, identification, citations, associated people (collector/donor) etc.), and ancillary materials of archival and or research use, e.g., labels, field notebooks, locality files, photographs, original digital databases or spreadsheets, research data-sets, measurements and analyses.

Like many long-standing collections, the UI Paleontology Repository has a backlog of specimens to catalogue. Of the one-million-plus specimens, 125,996 specimens/lots have been assigned catalogue numbers and either catalogued in a card index system (late 1800s to late 1900s) or in a computer database (since the 1980s). This backlog is due to the large size of the collection and the minimal and intermittent availability of staff associated with collection cataloguing throughout its history. The importance of digitizing paleontology collections is illustrated by the benefits:

- Preservation of associated data at the specimen or lot level
- Documentation of collection knowledge residing with individual staff, reducing its loss on staff turnover
- Development of a collection inventory, allowing staff to become more familiar with the material
- Improved efficiency in searching the collection to answer research and public enquiries
- Increased access to the collection both physically and on-line, which increases research and educational use and development of the collection, and helps justify institutional support and the cost of maintenance

Digitization can take two forms: preservation digitization and digital representation or access. Preservation digitization adheres to recognized standards and procedures for archival quality digitization. For example, preservation digitization of a printed photograph would require the original to be scanned in 8-bit grayscale or 24-bit color, 3,000 to 5,000 pixels across the long dimension, at 100% size, and saved as a TIFF. An access copy can be 8-bit grayscale or 24-bit color, 150 dpi and 600 pixels across the long dimension, and saved as a JPEG (Western States Digital Standards Group 2003). A general rule is to produce archival-quality digital resources where possible, with lower resolution access formats if necessary. The standard of digitization employed depends on the intended use and available resources. Digitization methods used in the UI Paleontology Repository are outlined below.

1) Recording specimen data in a relational, searchable database including transcribing data from written records such as labels and field notebooks, and editing and reformatting copies of original databases to integrate with the specimen catalogue.

The UI Paleontology Repository currently uses Specify Biodiversity Collections Software (v. 5.2.3) to record specimen data (Figure 1). It is designed by the Specify Software Laboratory at the Biodiversity Research Center, University of Kansas and is distributed free of charge to collaborating non-profit institutions. Specify has free software upgrades and support, and is widely used in natural history collections (274 collections in 16 countries - see http://specifysoftware.org). Specify is adaptable to diverse natural history collections and can be configured for multiple data portals for world-wide access for the scientific community. Specimen data are transcribed from written records such as specimen labels, field notebooks and publications, or, if held in a pre-existing database, edited and reformatted for integration with the Specify collections database. In many cases abbreviated data have to be interpreted, or old stratigraphic terms updated. The digital record is the interpretation of the available data, and this is a major reason for preserving the original documentation in case of error.

2) Making digital images of specimens.

Specimens are photographed using a compact digital Nikon Coolpix 5400. Each taxon is photographed according to standard views in research publications, often from multiple angles to produce a single collage image. Image resolution and format depend on the camera's optical and pixel resolution, but in general the initial image should be an uncompressed, lossless format like TIFF rather than a lossy (compressed) format like JPEG, with a minimum 12M (megapixel) size, e.g. 4000 x 3000 pixels. A digital Single Lens Reflex camera with specific lenses for different image requirements will provide a higher

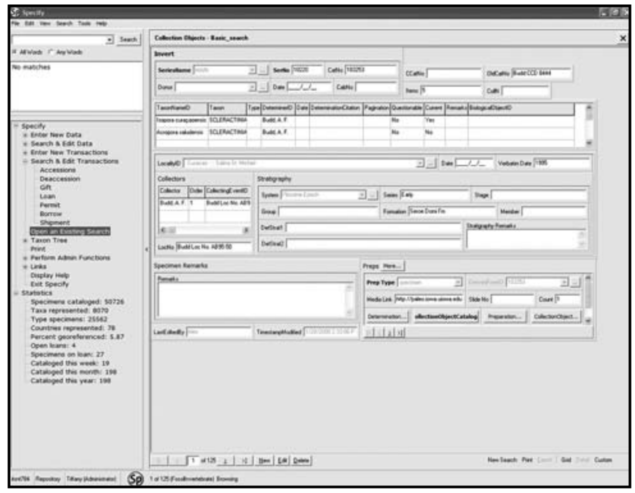

Figure 1. A typical UI Paleontology Repository Specify collections database data entry form.

quality image, but is more expensive than a compact camera. The purpose of the project and available budget will dictate what type of camera is required. In our case the images are intended as digital representations of the specimens to better inform researchers about the collections and their research potential. They are not intended to replace the specimen itself or to substitute for publication quality images.

Digital images are edited in Adobe Photoshop to a consistent format with uniform black background, scale bar and label (Figure 2), and saved as JPEG images of different sizes (150 dpi and 600 pixels

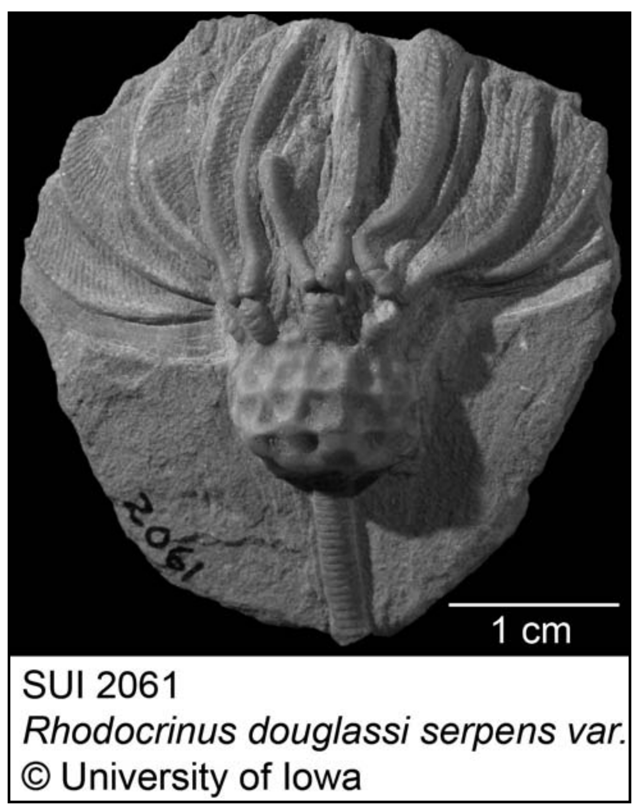

Figure 2. A typical digitized specimen image, (shown in colour on-line).

along the long axis for larger image, and 72 dpi and 150 pixels along the long axis for a thumbnail image). All JPEG images are stored on a server so they can be accessed via the Internet. The original digital image (high resolution, unedited TIFF) is archived on CD-ROM and on external hard drives. Image metadata (specimen catalogue number, taxon, identification, type status, image resolution, camera setting, specimen view, specimen storage location, copyright or use restrictions, date photographed, photographer's name) are recorded for each edited image. The image file name records the specimen catalogue number for easy reconciling and sorting e.g. 009183_tb.jpg. The URL of the image on the server is entered in the associated specimen database record for each image. Researchers who borrow or deposit cited material are encouraged to provide digital images of the specimens.

3) Digitizing photographic prints and written records such as labels and field notebooks.

In general, photographs, handwritten specimen labels and field notebooks are scanned with an Epson Perfection V700 Photo flat bed scanner to preservation standards (Western States Digital Standards Group 2003, FADGI 2010). Some documents, such as the Amoco Conodont Collection locality files (see below) are scanned using a Fujitsu ScanSnap color image sheet feeder scanner for digital representation with the purpose of making them web-accessible. These scanned documents are saved as PDF files, placed on the server, and the URL entered in the relevant specimen records in the Specify collections database. Original photos and documents are cross-referenced with associated specimens and archived, i.e., placed in archival storage media and recorded in an archive finding aid (a simple list of archive box contents) available on-line.

Selecting collections to digitize

With a large uncatalogued backlog, it is more practical to identify discrete sub-collections that can be assessed and prioritized for manageable digitization projects, than to try to tackle the entire collection in one project. At the UI Paleontology Repository, selecting sub-collections begins with a collection survey to determine curation level (Adrain *et al.* 2006) and the amount of work and time needed to prepare for digitization at specimen or lot level. The criteria used to prioritize sub-collections vary and may be numerous according to the digitization project goals. Criteria used to select sub-collections for digitization in the UI Paleontology Repository include:

- Uncatalogued specimens with good quality data available, especially where data are separated from the collection, not easily located, and in danger of becoming disassociated
- Specimens and data unknown to the research community but with potential research value, either new bulk acquisitions or old collections fallen out of research memory
- Specimen data in danger of deterioration, including data in old format databases on obsolete media and historic labels deteriorating physically (for example, due to abrasion from specimens), or chemically (for example, acidic paper becoming brittle)
- Bulk acquisitions including large bequests and field collections that pose a curation challenge beyond normal operating capacity and that are creating a backlog because of their size
- University faculty collections deposited at retirement requiring immediate documentation before the researcher leaves permanently
- Collections with associated data such as digital images or analytical data that would enhance research resources beyond digitizing specimen-based information
- The need to provide access to specimens too fragile to loan, for example silicified trilobites, by making research quality photographs available

Collections selected for digitization

The collections prioritized for digitization can be divided into three categories:

- Bulk donations of large research collections, with continuing research access demand, accompanied by a wealth of data in multiple formats, e.g. Amoco Conodont Collection, Amoco South Florida Collection
- Bulk donations of large private collections of high potential research value, unknown to the scientific community, e.g. Pope Collection of Iowa Pennsylvanian marine invertebrates, Crossman Collection of US Midwest echinoderms
- Previously curated collections that can be enhanced easily for digitization and on-line access, e.g., trilobite, coral, micromammal and type collections

The Amoco Conodont Collection of about 25,000 cavity slides was donated by BP Amoco in 1998, along with a Microsoft Access database, and over one thousand printed files of locality data (Figure 3). Other collections including foraminifera, modern pollen and macrofossils were distributed to various institutions (Groves and Miller 2000), allowing for potential future collaboration. The database was in danger of corruption and/or loss, and the unique

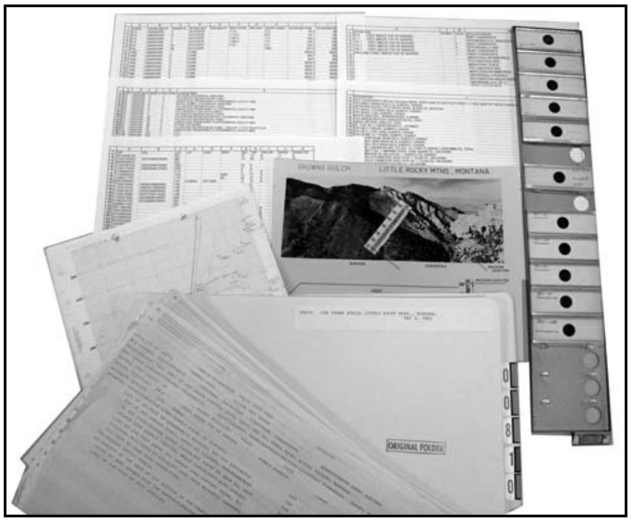

Figure 3. The Amoco Conodont Collection: specimens and ancillary materials.

Figure 4. The Amoco South Florida Collection: specimen samples and ancillary materials.

printed locality files, which pertain also to the other Amoco collections, were routinely sent on loan and stored away from the conodont collection in an "off-site" facility, putting them at risk of loss or disassociation. The collection was made a priority for research and collaboration potential and data capture needs. The locality folders were scanned for web-access rather than archival preservation because of the amount of time and digital space preservation scanning would require. Material was scanned with the sheet feeder scanner on a "normal" quality setting and the contents of each locality folder saved in PDF format and made available on-line. Oversized material (e.g. well log and continuous-sheet computer printouts) was partially scanned with a flatbed scanner and marked with a footnote requesting the researcher to contact the UI Paleontology Repository for more information. Each specimen cavity slide containing one or more specimens was reconciled against the accompanying database which was then edited in preparation for transfer to the Specify collections database.

The Amoco South Florida Collection of Holocene marine invertebrates was collected during 30 years of fieldwork by UI faculty and colleagues as part of the Amoco South Florida Carbonate Seminar. The collection consists of meticulously sorted samples, cores, printed locality and species files, and a wealth of teaching materials, including maps, identification boards, laboratory manuals and 7,000 field photographs including aerial and underwater views (Figure 4). This collection was prioritized for digitization for its potential as a teaching resource and because its multiple components stored in various places could be disassociated over time. Again, accompanying data were in an old format Microsoft Access database on dated media. As well as digitizing specimen lot data in the Specify collections database, research datasets were enhanced with data from lab manuals and transferred to an Oracle database for development of interactive web resources, and the 35 mm slide field photographs were cleaned and scanned commercially to archival quality.

Two large private donations were included in the digitization project so that inventories might be made available before the collections are fully curated. The Pope Collection contains 900 lots of Pennsylvanian marine invertebrates from Iowa localities that are now inaccessible. The Crossman collection consists of 10 tons of US Midwest crinoid material bequeathed by local fossil enthusiast Glenn Crossman in 2002. Much of the material is unidentified making full curation difficult without specialist knowledge. However, it is still important to digitize such collections so that the research community is aware of their existence, either by publishing collection metadata (age, formations, taxa, collector, and localities) or a more detailed, if incomplete, specimen or lot inventory on-line.

Type specimens, although the most well-known and best researched of the UI Paleontology Repository collections, provide excellent material for image digitizing because of good preservation and preparation and existing on-line data access. Holotype specimens were photographed according to staff technical abilities. Two UI researchers (Adrain and Budd) are amassing large trilobite and Neogene coral research collections respectively, accompanied by high quality digital research images. These images are formatted and edited according to UI Paleontology Repository standards outlined above, cross referenced with the specimen's Specify collections database record and made available on-line. Many coral specimens are figured and cited on the Neogene Marine Biota of Tropical America (NMITA) website (http://nmita.iowa.uiowa.edu/), providing an opportunity to add existing on-line resources to the specimen record. The trilobite specimens are microscopic silicified specimens that cannot be mailed on loan and can only be loaned to researchers experienced in handling silicified material. Making high quality images of these specimens available will enable research access without risk to the specimens. The micromammal collection was also selected for digitization because it was already well curated and described in unpublished site reports, but was not digitally captured or available on-line. The Paleozoic coral collection is an underutilized resource that has been reorganized, assessed by a visiting specialist, and improved under a previous NSF-supported project (DBI-0096768 "Reorganization of the University of Iowa Paleontology Repository," Budd, J. Adrain, J. Golden). Historic labels had been cleaned, scanned and preserved under polyethylene sheets. This was a logical collection to continue curating to the next stage (specimen cataloguing) allowing it to be made accessible on-line. Based on a practice of colleagues at the UI Museum of Natural History, the next goal is to photograph entire drawers of specimens rather than individuals and cross-reference these digital images with specimen records on-line.

Providing access to the digital collections

In addition to capturing data, one of the goals of digitizing these collections was to make them available on the Internet. The variety of digitized material and types of data available enabled several different means of access and use.

The Specify collections database allows users to share data with web-based data portals such as the Paleontology Portal (www.paleoportal.org) and the Global Biodiversity Information Facility (www.gbif.org), where researchers can search collection databases of multiple institutions at the same time, thus increasing exposure of collections data. Specify's web query component also allows the creation of collection/institution-specific on-line queries that can provide images, links to specimen-related documents such as the Amoco locality PDF files, and links to other websites that have relevant specimen information, such as the NMITA website. This type of data access is aimed more towards researchers than members of the public. The UI Museum Studies Program's Collection Care and Management class looks at on-line museum databases as a class assignment and in the last three years has consistently determined natural history collections more difficult to access on-line compared to art museums and social history museums. Usually specific criteria, such as species name, are required to search a natural history collections database, and the result is usually a spreadsheet of data with or without images. Non-specialist members of the public may gain more enjoyment from alternative methods of data presentation.

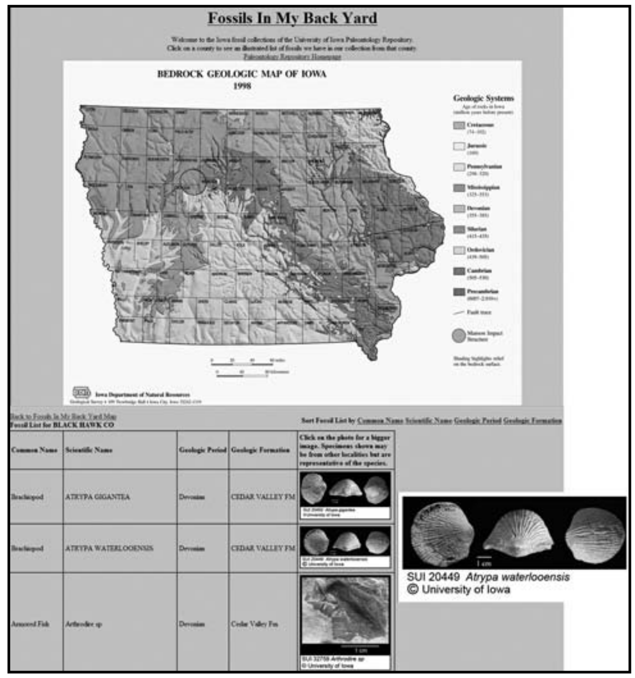

Figure 5. The "Fossils in My Back Yard" website provides public-friendly access to collection data.

A broader impact goal of the UI Paleontology Repository's digitization project was to widen public access to the on-line collections. A website called "Fossils in My Back Yard" was developed to allow visitors to more easily browse fossils from Iowa in the collections. A digital version of the Iowa bedrock map produced by the Iowa Geological and Water Survey invites visitors to click on a county to see an illustrated list of fossil species from that county (Figure 5). Each county is an html hotspot link that runs an XML query based on the county name. A data subset from the Specify collections database was loaded into a very simple Oracle database that can be updated easily using Microsoft Access. Representative species images, usually of the holotype, are used instead of individual specimen images. The query results are an illustrated list of species from individual Iowa counties rather than a list of specimens to avoid repetition and overwhelming the user. Members of the public are using the website to identify their own fossil finds. A future goal will be to expand the website to include more fossils and modern plants and animals found in each county in

Figure 6. Ancillary materials, in this case field photographs of a reef dive, are used to create a teaching resource.

collaboration with other natural history collections in Iowa.

Materials and data from the Amoco South Florida Collection are being used to develop a new educational resource, the Tropical America Virtual Field School, initially for UI undergraduate classes, but accessible on-line in the future. Some of the 7,000 scanned images are being used to create interactive slideshows or "virtual tours" of a reef dive (Figure 6) and an aerial tour of South Florida where students can navigate through the slideshow and click on various features for information, with a short quiz at the end to evaluate teaching effectiveness. A digitized map of mollusk biofacies and a related query form provide access to specimen sample data using XML protocols. Specimens from the reference collection are being used to illustrate an identification key and exercise.

Key considerations for planning a digitization project

1) State of the existing data

One digitization goal was to reformat existing databases by parsing the data into relevant fields and bulk-migrating the data into the Specify collections database. Unfortunately, both the Amoco South Florida Collection and Amoco Condont Collection databases showed major discrepancies when compared with the physical collections. The Amoco Conodont Collection database contained minimal stratigraphic information requiring essential data to be extracted from the printed locality folders with the possible introduction of human error in interpretation. The dataset contained over 5,000 entries for slides not present in the UI Paleontology Repository collection, which in turn contained over 5,000 slides that were not in the database. Data are now being entered into the Specify collections database manually rather than bulk-migrated and are meticulously checked against each slide and locality folder.

2) People and training

Extensive digitization projects require IT support with experience in writing dynamic queries, installing and maintaining database systems, joining data portals, and creating web interactivity. If necessary, funding should be included for IT support and a dedicated student IT assistant for the project duration. A large digitization project requires a team of assistants competent at entering and interpreting data. Although the UI Paleontology Repository's digitization project funded only one graduate student to assist with data entry, many more undergraduate students were employed - eighteen students in total over four years, in addition to students working on other projects. Student training and supervision became the most time-consuming tasks for collections staff compared to development of collection tasks. Staff management training is recommended for those unfamiliar with working with a large number of students or volunteers. Collaboration with colleagues in other departments or institutions is recommended. The UI Libraries staff provided invaluable advice and assistance with digitizing and preserving archive material. A UI Libraries initiative, the Iowa Digital Library, will provide additional web access to images.

3) Equipment

A team of assistants requires extra computer hardware and software for data entry and image formatting, as well as additional office furniture and workspace. The increased volume of digital material required two servers to be purchased for the Specify database, the images and scanned document files and the UI Paleontology Repository website. Photographic equipment was not high-tech or expensive because of the anticipated wear and tear on the equipment due to the number of users, but it is worth investing in equipment that can provide archival quality digitization if necessary.

4) Physical access to the collections

Physically accessing backlog collections is sometimes an issue. The Pope Collection was still in original containers (Figure 7), and the Crossman Collection had to be relocated to a different building and reorganized. Basic curation issues should be addressed either before the digitization project begins or as part of the project.

Figure 7. The Pope Collection in original storage. Physical access should be addressed before digitization begins.

5) Task analysis and time management metrics

You should be realistic about the time required to complete the digitization project. Research the average data entry time per record and the number of records anticipated, or the time required for scanning or photographing and image processing at different resolutions. Be aware that data entry also involves data gathering and may require more involved research.

Pros and cons of digitizing

There are pros and cons to every digitization project. Digitization is time-consuming, but data-cleaning of existing databases is well-worth the cost in time to make sure that data are in the correct format and are accurate before they are finally entered. With a large team with twice-yearly turnover, data entry consistency can be a problem. Make sure that data entry instructions are clear and readily available. Specify Biodiversity Collections Software provides custom field notes to display data dictionary and terminology control information. Specimen records must be checked for consistency in data entry. Frequently check that procedures for photography and scanning are being followed and metadata recorded as specified. Sometimes accidental changes become permanent. Be aware that the more you interact with a collection, the more your tasks will expand. Determine whether project time management will allow you to tackle collection problems or needs as they arise, or, if they must wait until the end of the project, how you will track tasks that need to be done.

From a collection manager's view, a digitization project is extraordinarily helpful in getting to know the collection and increasing the ability to aid collection users. In addition to providing a collection inventory, a digitization project can include ancillary materials and protect the link between materials often stored apart as well as the link between specimens and associated data. A digitization project can result in the physical preservation of ancillary data as well as the digital preservation, as the value of ancillary materials is revealed. A digitization project should increase collection research use. Currently 6% of UI Paleontology Repository website visitors come via the Paleontology Portal (Google Analytics data). Collection statistics including loan requests and specimen citations will be monitored to gauge project success and the need for further announcements or information dissemination to the scientific community. As well as straightforward specimen data access, digitizing collections can provide a base for multiple spin-off projects like the Tropical America Virtual Field School and Fossils in My Back Yard websites. Finally, digitization can increase public access and encourage interaction and communication.

Acknowledgements

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CONSERVATION OF THE BUCKLAND FOSSIL TABLE HOUSED AT LYME REGIS MUSEUM

by Beth Werrett

Werrett, B. 2011. Conservation of the Buckland Fossil Table housed at Lyme Regis Museum. The Geological Curator 9 (5): 301 - 304.

In 2010 Lyme Regis Museum was awarded an AIM (Association of Independent Museums) grant to conserve the Buckland Fossil Table, an object of historical significance. This article aims to briefly outline the issues affecting the object and the course of conservation treatment chosen to preserve this iconic piece.

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Introduction

In 2010 Lyme Regis Museum successfully attained a grant from AIM (Association of Independent Museums) to conserve the Buckland Fossil Table. The table had been owned by William Buckland, one of the leading geologists of the 19th Century. Buckland was a highly regarded character who, whilst Professor of Geology at Oxford University, carried out pioneering work not only in the study of dinosaurs, but also the analysis of coprolites or fossilised faeces.

In 1938 Frank Gordon, William Buckland's grandson, donated the table to Lyme Regis Museum. Buckland had strong ties with Lyme Regis having been born in nearby Axminster and frequented the cliffs of the area with other geology and fossil enthusiasts including Mary Anning. The table is highly unusual and an extremely popular exhibit at Lyme Regis Museum.

The large inlay panel of the Buckland Fossil Table is set with coprolites which have been cut in half and polished to a high sheen (see Figure 1). The 64 coprolites in the inlay panel are thought to be fossilised fish excrement. The central section of each nodule is the coprolite which is surrounded by a fine grained grey material thought to be clay- ironstone. The small veins radiating from the central coprolite are thought to be cracks filled with a deposited white opaque mineral, possibly calcite or baryte. The exact composition of the minerals has not been determined, as it would require destructive testing which is not deemed appropriate due to the historical significance of the object.

Condition of the table

The table was stable, but fragile when it arrived at the Wiltshire Council Conservation Service. The table top was original, but the base of the table was replaced with a simple oak frame in the 1990s. The veneer over much of the table top had lifted from the table surface, probably due to the age of the adhesive and fluctuations in the humidity of its display envi-

Figure one: Table top before conservation

ronment. In many areas the veneer had been lost completely. It was thought that a protective cover may once have covered the table top as there was a pronounced line of accumulated polish indicating where the cover may have been situated. In addition the table top is once thought to have been displayed mounted on a wall, another possible explanation for the screw holes present in the wooden surround.

It is thought that as the piece was on open display and the public were able to touch the surface of the inlay panel this may have weakened the matrix surrounding the coprolites, leading to loss of material (Figure 2). This was so great that in some areas the fossils were flexing risking further damage in the future. In addition a substantial amount of cracking had occurred to the underside of the inlay panel. Repairs had been made in the past with substances resembling plaster and animal glue, however many of these repairs were unsightly and failing themselves (Figure 3). During cleaning it also became apparent that a large section of the underside of the inlay panel had been lost, this area had been filled with an excess of plaster.

Figure 2. Detail of damage to inlay surface.

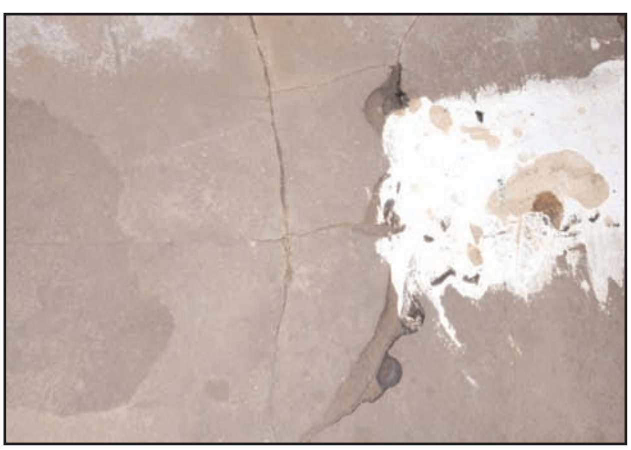

Figure 3. Detail of damage to underside of inlay panel.

Conservation Treatment

Due to the significance of the table and the unusual nature of the inlay a number of specialist Natural History conservators were consulted. The aim was to determine that the materials and treatments chosen would not have a detrimental affect upon the object. A lot of useful information and advice was gathered and a suitable treatment plan formulated.

Analysis of the original fill materials and the matrix to determine their composition was considered. However, the project had a fixed budget and timescale, which restricted what could be undertaken. Analysis was felt to be a lower priority than other aspects of the treatment of the table; therefore unfortunately we were unable to carry out analysis as part of this project.

It was decided to seal the exposed edges of the matrix and the coprolites prior to filling to ensure that the materials used did not permeate the original material of the table. It is also hoped that this will facilitate easy removal of the fills in the future if it is required.

It was advised that the introduction of moisture to the coprolites be avoided, as they could be sensitive to fluctuations in humidity. Therefore the areas of loss and cracks to both the upper and lower surfaces of the inlay panel were filled with a mix of acrylic adhesive, glass micro-balloons and artists pigments. These materials would form a fill that was strong, but light placing no stress on the surrounding original material. Only the new fills were tinted to blend with the original matrix. It was felt that the earlier repairs which were often white or yellowy in colour were part of the history of the object and should be retained in their current condition. The previous repair to the underside was trimmed back mechanically and areas of weakness reinforced with the same acrylic adhesive mix. It was felt that as the treatment carried out had made the fill more apparent, by removing the aged surface layer, it would be appropriate to tone in the fill. A block colour was used to provide a more cohesive appearance, but still allow the area to be easily discernible from the original material (Figures 4 and 5).

It was decided to undertake simple repairs to the lifting veneer surfaces to ensure that no additional damage occurred. Consultation with a specialist furniture conservator resulted in two options for re-adhering the lifting veneer. From appearance and solubility tests the original adhesive is thought to be an animal glue. Attempts to reactivate this adhesive with a com-

Figure 4. Conservator at work.

Figure 5. Detail of underside after conservation.

bination of heat and water proved unsuccessful. It was decided to apply a small quantity of rabbit skin glue to the surfaces which had lifted, as this was sympathetic to the original methods of manufacture. The rabbit skin glue should react to changes in the environment in a similar way to the wood avoiding stress building in the joins and causing damage.

The general accumulation of dirt was removed with smoke sponge (vulcanised natural rubber). Paint spots on the surface of the table were carefully removed with a bamboo skewer. The polish line was carefully pared down with a scalpel. The whole table was then given a light polish with microcrystalline wax to provide a protective layer and improve the general appearance of the piece (Figure 6).

Following conservation of the table the Conservation Service liaised with a specialist mount maker to ensure that a protective covering was constructed to provide protection from handling by the public. It was advised that this cover should sit within the copper alloy border which surrounds the inlay panel, allowing it to protect the fossil inlay, but remain visually unobtrusive. In addition a support board was constructed to support the inlay panel from underneath. It is hoped that this will prevent damage occurring in the future.

Conclusion

The project was felt to be successful as an acceptable compromise was found between preserving an extremely significant museum piece and maintaining the public's interaction with the piece. The stabilisation of the failing matrix and filling of areas of loss has maintained the cohesive appearance of the inlay panel, whilst ensuring that no additional loss or damage occurs. It was extremely important to the curator of Lyme Regis Museum that the Buckland Fossil Table be returned to open display, as the discussion

Figure 6. Table top after conservation.

of the 'poo table' was a popular part of the museum tours for adults and children alike. The use of protective and supportive coverings should ensure that the table can be protected whilst allowing a similar level of public access to the piece as was enjoyed prior to conservation.

Acknowledgements

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INVESTIGATIVE CONSERVATION OF THE ROYAL CORNWALL MUSEUM MINERALS

by Laura Ratcliffe and Amanda Valentine-Baars

Ratcliffe, L. and Valentine-Baars, A. 2011. Investigative conservation of the Royal Cornwall Museum minerals The Geological Curator 9 (5): 305 - 314.

A programme of conservation work was initiated at the Royal Cornwall Museum (RCM) to stabilise some decaying groups of minerals identified by a condition survey. The main problems identified were pyrite decay and accelerated, often localised corrosion on the native coppers. Decay products from the unstable specimens were sampled and analysed using X-ray Diffraction (XRD) to identify them and therefore try and determine which contaminants in the storage environment were significant in their formation. Conservation of the decaying material was undertaken in order to prevent further damage. Low humidity microclimates were created to store the minerals. Approximately 260 specimens, about 2% of the overall mineral collection, were stabilised in this way during 2007.

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Introduction

The mineral collection at the Royal Cornwall Museum (RCM) comprises over 13000 specimens, the majority of which were collected in the 19th and early 20th century and stored in a series of historic cabinets (both storage and display) and drawers, or on open shelf storage before their current acid free boxed state. A condition survey of the mineral collection, undertaken in 2005 indicated that parts of the collection were showing signs of deterioration.

It was recognised that specimens containing iron pyrite and native copper collected in Cornwall were particularly likely to be suffering from decay.

The oxidation rate of pyrite is known from studies to become most serious at relative humidities above 60%, with microcrystalline framboidal pyrite being the most reactive. It was suggested that long term exposure to the high humidity typical of a maritime climate paired with long term housing in an historic building, known to be previously environmentally unstable, was likely to correlate with the deterioration of the specimens. The decay products from some of the affected minerals were analysed to determine the key factors in the decay.

Storage history of the collection

Prior to deposition at the Royal Cornwall Museum, the majority of the pyrite and copper specimens were parts of collections held in country houses within Cornwall (for example the Rashleigh and Barstow collections assembled in the 19th Century). Some of these would have been on open display and some stored in wooden cabinets, the ones we have remaining show a good seal and tightly fitting doors. The environment in these houses would not have been stable and the minerals were not isolated from one another.

These various collections all entered the RCM within the last 100 years and were stored in a variety of rooms within the main museum building before being installed in their current location some 10 years ago. Central heating would probably not have been a factor until 50 odd years ago. The storage conditions during this period are unlikely to have been stable but were not recorded. The same can probably be said for conditions within the original collector's houses.

Between ten and twelve years ago, periods of environmental fluctuation have been monitored within this store with rises and falls of up to 15% either side of 55% RH on occasion over the course of a year. Approximately ten years ago modifications were made to the store. Metal roller racking was installed and the specimens are now housed on shelving in single layers of shallow acid free specimen trays within lidded brown cardboard boxes, these are stacked three deep (Figure 1). The humidity in the store was controlled with a wall mounted air-conditioning unit keeping the humidity at around about 50% RH and a relatively steady 18°C. There are other organic natural history materials within the store so a reasonable compromise has been made with a target level of 50%RH.

Figure 1. The current storage racking for the geology collection.

Deterioration of the collection

A collection wide condition report in 2007 revealed that some minerals were degrading more than the others, most notably those containing iron pyrites and some native copper specimens. No correlation between original donor and rates of decay on specimens was noted. No link between location within the store or previous storage areas within the museum (that are known about by current staff) Although more particulates were found on specimens previously stored on open shelving, this had not appeared to make any difference to which specimens corroded or to the corrosion rates on the deteriorating specimens. Some of the decay appears to be collection site specific; in particular pyrite decay on specimens where the support matrix contained finely disseminated iron pyrites or chalcopyrite, an example being the calcite specimens from Wheal Wray mine. It is probable that site specific crystal formations and growth patterns will have an effect on the stability of particular location specimens but that is not going to be discussed at this time.

It would be fair to say that wherever the original collection site and subsequent series of storage/display locations have been, a consistently stable environment has not been a common factor and has undoubtedly contributed to some specimens becoming chemically unstable over time

Specimen deterioration

Chemical instability noted in the collection is most prevalent in the native moss coppers (a particular growth formation of native copper typical to some Cornish sites), and metal sulphides, typically iron pyrite, marcasite and chalcopyrite bearing specimens. Some of the galena and sphalerite specimens also showed signs of unidentified surface efflorescence. Comparable deterioration is seen in some of the copper based objects in the Archaeological Collection, which have been subject to similar storage conditions. The archaeological copper found within the county tends to corrode with unusual aggression if it is not kept in low humidity microclimates.

Pyrite Decay - a brief background of its causes

Pyrite (FeS_2) is a commonly found mineral within many geological collections. It is brassy yellow and mainly present as cubic or octahedral crystals either as easily identifiable individual growth formations or micro crystalline in form. Finely disseminated pyrite is often found in geological specimens. The decay of pyritic material is a significant problem within geological museum collections. The effects can range from slight damage, if treated early, to the complete destruction of the specimen if left unattended.

Pyrite decay occurs when iron pyrite reacts with atmospheric water and converts to iron sulphate and sulphuric acid. According to Waller (1987), in the presence of moisture the oxidation process of pyrite can be summarized as:

$$2FeS_2 + 7O_2 + n + m + 2H_2O \longrightarrow 2FeSO_4 \text{ x } nH_2O + 2H_2SO_4 \text{ x } mH_2O$$

Both oxidation products are hydrated. Sulphuric acid in solution with water is created as a by product. The ferrous sulphate is present both as the efflorescence product (crystalline hydrate) and in solution, the relative proportions of which depend on the level of RH.

Pyrite decay is easily recognizable, there is a distinctive sulphurous smell, efflorescence products appear and in severe cases, cracks appear within the specimen. The sulphuric acid created by the solution of the sulphur trioxide vapours can lead to damage or even complete destruction of storage materials and specimen labels (Stooshnov and Buttler 2001).

Microcrystalline pyrite is highly susceptible to oxidation. Large crystalline varieties of pyrite are regarded as stable but these can also tarnish or develop efflorescence blooms in extremes of environmental conditions (Howie 1992; Valentine and Cotterell 2008).

A range of factors affect the rate of decay: relative humidity, temperature, surface area, pH, oxygen concentration, and trace elements within the specimen/mineral. Past experiments have shown that some factors are relatively more important than others, particularly relative humidity (RH) and temperature (Morth and Smith 1966; Smith and Shumate, 1970; Waller 1987). A study of secondary mineral changes on specimens within museum collections by Blount (1993), shows that natural, seasonal RH changes will influence the environment within the museum building and that the decay mechanism between material within the museums and those in their natural environments were similar.

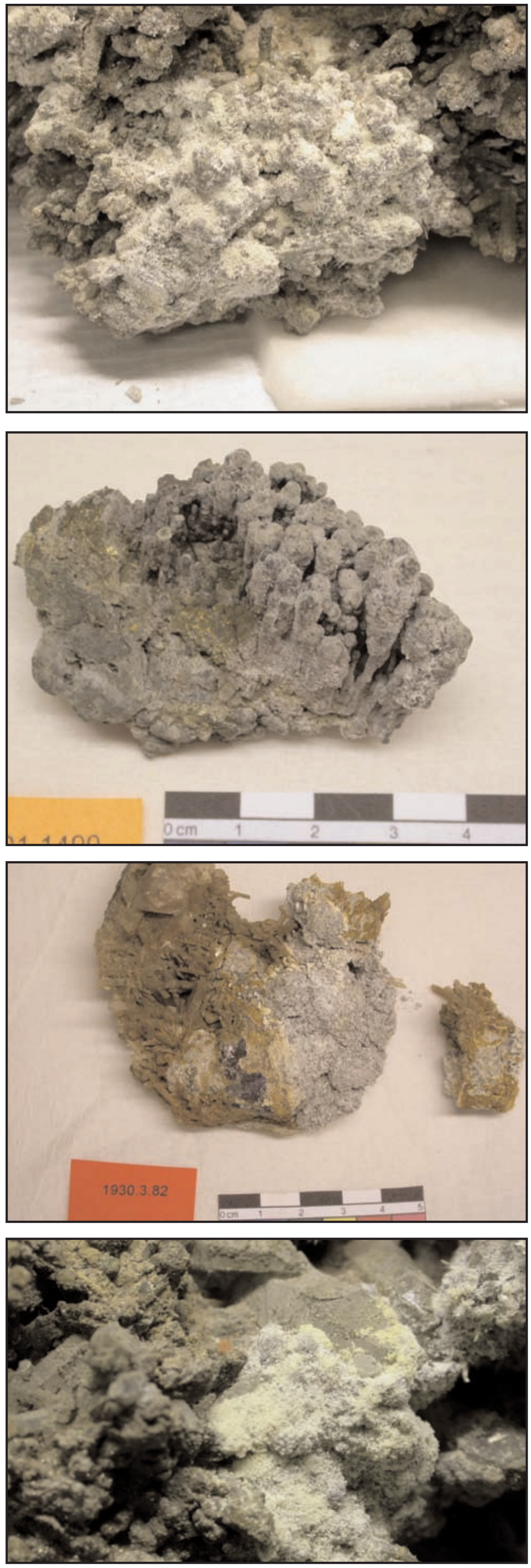
Howie (1992) recommended that specimens should be stored in a RH of less than 30%. However, a long term study discussed by Newman (1998) suggests that if the environment is kept at 40% RH the collection may remain stable. Fellows and Hagan (2003) agreed and suggested that this is a more realistic and achievable target for specimens being stored without a microclimate. Increased temperatures cause the oxidation rate of the pyrite to increase and therefore it is important to keep temperatures as low as is practically possible (Newman 1998).

Pyrite decay in the RCM collection

The majority of the specimens identified as chemically unstable were affected by pyrite decay. The specimens were exhibiting the following symptoms of pyrite decay:

- packaging damaged by sulphuric acid, visible as scorch marks.
- various hydrated sulphates forming efflorescence's in the form of crystal blooms and powder ranging in appearance from white, through pale green to pale yellow.
- Expansion, identified by the cracking of specimens, sometimes with the loss of material.

Only about one quarter of the deteriorating specimens were affected to the point of material loss or breakage. Most decay had occurred on the reverse of the specimens where they had been in close contact with typical packing material such as paper, card and tissue. It is likely that a lack of air circulation to these areas created microclimates favourable to decay allowing acidic vapours to build up and catalyse deterioration on the underside of specimens.



Figures 2-5. Typical examples of pyrite decay on the RCM collection.

Decay products identified

Efflorescence samples from specimens showing evidence of pyrite decay were analysed using X-ray Diffraction (XRD) and can be seen in Table 1.

Specimen type	Colour of efflorescence	Results of analysis	Location of origin	Specimen and sample number
Bitumen with pyrite FeS_2	Yellow white	Melanterite $FeSO_4 7H_2O$ Pyrite FeS_2 Rozenite (Poss?.)$Pb_5Sb_8S_{17}$	Unrecorded location	x-2032 433/21
Chalcopyrite $CuFeS_2$	Yellow white	Bianchite $(Zn,Fe)SO_4.6H_2O$ Goslarite$ZnSO_4.7h_2O$	Unrecorded location	x-2033 801-795
Sphalerite chalcopyrite and siderite ZnS, $CuFeS_2$, $FeCO_3$	White green	Bianchite $(Zn,Fe)SO_4.6H_2O$ Gunningite $ZnSO_4.H_2O$ Clinochlore (Poss?.) $(Mg,Fe^{2+})_5Al(AlSi_3O_{10})(OH)_8$	St Agnes - Cornwall	x-2034 801.890
Galena with bitumen and pyrite inclusions PbS, FeS_2	White	Melanterite $FeSO_4 7H_2O$ Marcasite FeS_2 Gypsum $CaSO_4.2H_2O$ (+ unidentified mineral)	Ashover, Derbyshire	x-2035 801.1204
Galena with fluorite, pyrite and mineral pitch globules PbS, CaF_2, FeS_2	Yellow	Anglesite $PbSO_4$ Melanterite $FeSO_4 7H_2O$ Galena PbS	Ashover, Derbyshire	x-2036 801.1205
Galena with pyrite and bitumen PbS, FeS_2	White green	Marcasite FeS_2 Melanterite $FeSO_4 7H_2O$ Gypsum $CaSO_4.2H_2O$	Ashover, Derbyshire	x-2037 801.1207
Galena with sphalerite, fluorite and pyrite PbS, ZnS, CaF_2, FeS_2	White green	Marcasite FeS_2 Fibroferrite $Fe^{3+}(SO_4)(OH).5H_2O$ (+ unidentified mineral)	Ashover, Derbyshire	x-2038 801.1210
Stibnite on quartz Sb_2S_3, SiO_2	Pale yellow	Melanterite $FeSO_4 7H_2O$ Halotrichite/Pickeringite (*) $MgAl_2(SO_4)_4.22H_2O$ (+ unidentified mineral)	Unrecorded location	x-2041 801.1389
Tetrahedrite on quartz with pyrite $(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$, SiO_2, FeS_2	Pale green white	Melanterite $FeSO_4 7H_2O$ Szomolnokite (Poss?) $FeSO_4.H_2O$	Fahlerz Kingston mine, Stokeclimsland, Cornwall	x-2042 801.1812
Pyrargyrite on quartz Ag_3SbS_3 , SiO_2	Yellow white	Melanterite $FeSO_4 7H_2O$	Unrecorded location	x-2043 801.1831
Polybasite on argentite $[(Ag,Cu)_6(Sb,As)_2S_7][Ag_9CuS_4]$, Ag_2S	White yellow	Copiapite group Aluminocopiapite / $Fe^{2+}Fe_4^{2+}(SO_4)_6(OH)_2.20H_2O$ Magnesiocopiapite (Poss?).	Czechoslovakia	x-2044 801.1838
Malachite and chalcocite $Cu_2(CO_3)(OH)_2$, CuS_2	White	Quartz SiO_2 Muscovite $KAl_2(AlSi_3O_{10})(OH)_2$ Wroewolfeite $Cu_4(SO_4)(OH)_6.2H_2O$	Unrecorded location	x-2045 801.10279
Siderite $FeCO_3$	Yellow orange	Melanterite $FeSO_4 7H_2O$ Pyrite FeS_2	Lanlikery, Cornwall, previously Maudlin mine	x-2046 801.4636
Chalcopyrite "partly coated with mundic…and hexagonal Xtals of grey copper" $CuFeS_2$	Yellow to white	Bianchite $(Zn,Fe)SO_4.6H_2O$ Goslarite $ZnSo_4.7H_2O$ Gunningite $ZnSO_4.H_2O$	Illogan, Cornwall Cooks kitchen.	x-2052 1903.1.248
Chalcopyrite and quartz $CuFeS_2$, SiO_2	Pale grey white	Bianchite $(Zn,Fe)SO_4.6H_2O$ Goslarite $ZnSo_4.7H_2O$ Chlorite / Clinochlore (poss ?)	St Agnes, previously Cuanown mine, merged into Wheal Friendly	x-2053 1903.1.280
Nickeline with bismuth and quartz $NiAs$, Bi, SiO_2	White	Scorodite $FeAsO_4.2H_2O$ Melanterite $FeSO_4 7H_2O$ Gypsum $CaSO_4.2H_2O$	Schneeberg	x-2054 1903.1.767
Tetrahedrite $(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$	White green	Quartz SiO_2 Bianchite $(Zn,Fe)SO_4.6H_2O$ Goslarite $ZnSO_4.7H_2O$	St Austell, Crinnis Consols	x-2055 1093.1.962
Pyrargyrite and proustite on fluorite and pyrite Ag_3SbS_3, CaF_2, FeS_2	Yellow to white	Rozenite $Pb_5Sb_8S_{17}$ Melanterite $FeSO_4 7H_2O$ Gypsum $CaSO_4.2H_2O$	Himmelsfurst	x-2056 1903.1.969
Cassiterite SnO_2	Grey white	Melanterite $FeSO_4 7H_2O$ Cassiterite SnO_2	Cornwall	x-2057 1903.1.1309
Pyromorphite $Pb_5(PO_4)_3Cl$	Yellow	Anglesite $PbSO_4$ Melanterite $FeSO_4 7H_2O$ (+ unknown mineral)	Brittany, France	x-2058 1903.1.1309

It is possible that some of the XRD results may not tally with the original specimen identification due to partial or misidentification in the past. As far as is known the identifications for the specimens present here are correct but it is worth noting that discrepancies have been found in the collection and may be relevant to the results (Table 1).

Copper corrosion: A basic outline of copper corrosion in the presence of moisture

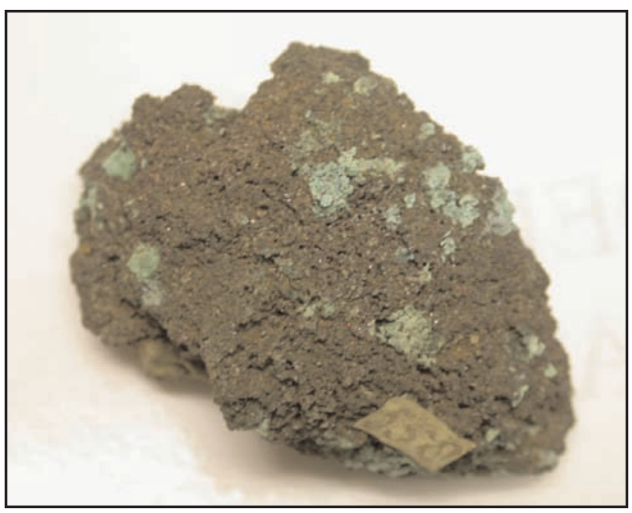
Copper and its various alloys corrode in the presence of air and moisture. This generates a series of corrosion layers on the metal surface which can become quite complex. Initially on deterioration of the metal surface, copper ions are produced (Cu_2+ or $Cu+$) and react with oxygen to form a crust of compact primary cuprite (Cu_2O) directly in contact with the metal surface (Cronyn 1990). These oxide layers can become a stable barrier layer, protecting the metal from further deterioration or part of an ongoing decay process depending on the environment.

Corrosion can then continue as further copper ions migrate outwards from the decaying metal surface to either continue reacting with oxygen to deposit a cuprite layer on the metal surface itself, effectively replacing it or they migrate through the oxide layer to deposit on its surface as a secondary crust. At this stage, interaction of the metal ions with components in the atmosphere or soil around the copper (carbonates, sulphides, chlorides, oxides etc) occurs and will affect the composition of these secondary layers.

Most typical of these are reactions with sulphides and chloride ions which form various copper based compounds on the metal surface. There is great scope for complex combinations of these minerals forming and the extent to which decay progresses depending on the environment it is occurring in. More aggressive decay mechanisms can be seen as areas of bright green on copper objects, typical in appearance to that in Figure 8. They are usually caused by localised chemical instability such as a drop of water or a weak area in the patination layer allowing further or more aggressive deterioration of the metal to occur. More information on this can be seen in the articles by North and McCloud (1987) and Jones (1992).

Copper decay at the RCM

Specimens of native copper and cuprite (Cu_2O) showed similar signs of deterioration. Powdery decay products, in various shades of green were observed in localised areas on an otherwise metallic or stable oxide coated surface. These areas were identical in appearance to pit corrosion on archaeological material, and indicate corrosion in a chloride rich environment rather than more typical atmospheric tarnishing. Storage facilities for both geological and archaeological collections had been similar, exposing the collections to the same potential decay mechanisms. In some specimens it was obvious that a drop of liquid had fallen on the surface and become an active site for corrosion leaving a watermark or drop shape of corrosion on an otherwise clean specimen. In other cases, a green voluminous powdery corrosion layer covered the specimen, often on the underside with little air circulation and therefore a localised microclimate.



Figures 6-7. Examples of copper decay on copper based archaeological and mineralogical material from the collections.

Facing page: Table 1. Minerals present in the areas of Pyrite decay on specimens:
Poss? indicates that the mineral named is possibly identified as indicated but due to similarities of results for some crystals sharing the same chemical signature in the -XRD it is hard to determine exactly which one of these is present until further research is carried out.

Figure 8. Examples of copper decay on copper based mineralogical material from the collections.

The specimen shown in figure 6 whilst very shiny has not been treated in any way, it is just a smooth patina of age.

Decay products identified

For comparison with typically known decay products on archaeological metals, XRD analysis was carried out on a selection of the decay products found on the native copper specimens (Table 2)

Analysis of results: Pyrite decay

XRD of the decay products shows a predominance of hydrated sulphides, in particular melanterite, and some un-decayed pyrite. Also present are oxidation products of the other minerals represented within the specimens, decay mechanisms for which may themselves have been catalysed by the decay products from the oxidation of the pyrite. The high values of the water of crystallisation in the decay products suggest a high RH during formation which is consistent with an unstable environment. It is likely that once decay began, probably a long time ago, the tightly sealed wooden storage drawers and cabinets will have helped create microclimates within which the specimens and their decay products could interact. Waller *et al.* (2000) provides a very useful study of gaseous pollutants within stored mineral collections. The presence of hydrated iron sulphate compounds on specimens not previously identified as containing pyrite suggests the presence of microcrystalline pyrite previously unidentified. Cross contamination from other specimens is not likely. More research would be needed into site specific mineral formation and contaminants to verify this though.

Copper Corrosion

The corrosion products are mostly copper sulphates, indicating the presence of sulphide gasses during the post collection lifespan of the specimens. This is likely to have been the result of off-gassing from decaying pyrite nearby during previous storage/display locations (presently the copper specimens are not stored with pyrite containing material, decaying or otherwise), or possibly from other environmental contaminants such as combustion by-products. Previously used historic specimen drawers and cabinets were wooden and would have had little air circulating though them allowing harmful gasses to build up. Moisture would have also been a con-

Specimen type	**Colour of efflorescence**	**Results**	**Location of origin**	**Sample and Specimen N°.**
Native copper Cu on quartz SiO_2 with malachite $Cu_2(CO_3)(OH)_2$	Green powdery	Antlerite $Cu_3(So_4)(OH)_4$ Brochantite $Cu_4(So)_4(OH)_6$	Sparnon mine, Redruth, Cornwall	x-1725 1903.1.46
Red copper ore Cu_2O	Green powdery	Brochantite $Cu_4(So)_4(OH)_6$ Cuprite Cu_2O Wroewolfeite	Tincroft mine, Illogan, Cornwall	x-1728 1903.1.14
Native moss copper Cu	Green powdery	Cuprite Cu_2O Akaganite â-$Fe^{3+}O(OH,Cl)$	Cornwall	x-1729 1903.1.13
Moss copper Cu	Green powdery	Brochantite $Cu_4(So)_4(OH)_6$ Clinochlore $(Mg,Fe^{2+})_5Al(AlSi_3O_{10})(OH)_8$ Muscovite $KAl_2(AlSi_3O_{10})(OH)_2$ Djurleite $Cu_{31}S_{16}$	Poldory mine, St Day, Cornwall	x-1733 801.259
Native copper Cu	Green powdery	Brochantite $Cu_4(So)_4(OH)_6$ Antlerite $Cu_3(So_4)(OH)_4$	Poldory Mine, St Day, Cornwall	x-1734 1903.1.18
Native copper and Cuprite Cu, Cu_2O	Green powdery	Antlerite $Cu_3(So_4)(OH)_4$ Brochantite $Cu_4(So)_4(OH)_6$	Trevarno, Helston, Cornwall	x-1735 1903.1.30

Table 2. Native Copper specimens XRD results of the corrosion products.

tributing factor as a lot of the decay products show elevated hydration states, suggesting RH of 70 or 80% at some point, something not uncommon in older buildings with little or no heating. Both the moisture and the sulphides would have contributed to make an aggressive environment, allowing corrosion of the copper to take place.

Treatment of the collection

To protect the unstable pyrite and copper specimens from further deterioration the causes of deterioration needed to be eliminated. Mechanical removal of the decay products, particularly on the pyrite specimens will eliminate the aggressive by-products of the decay process.

Oxygen could be removed using oxygen absorbers in conjunction with barrier film and microclimates, however anoxic environments were not used due to the number of specimens requiring treatment and the cost of materials required. Another minor concern was the decreased volume of the pouch after the oxygen has been removed and the risk of pressure damage to fragile minerals. However, a protective former or specimen tray with a lid could be used to prevent this but simplicity and a need to prevent increase to the volume of the stored collections proved dissuasive.

Chemical treatments such as ammonia vapor (Waller 1987) are used to stabilize pyrite decay but were not undertaken as any remaining decayed material is discolored by this treatment. Whilst the decay products were mechanically cleaned off the specimens as much as possible, a lot of the specimens are composite ones and were very heavily textured or very fragile on the surface and the risk of any remaining corrosion products discoloring other components on the specimen was deemed a very real risk and preferably avoided. Also many of the specimens concerned included minerals that may be adversely affected by ammonia and again, whilst removal of the decayed material should minimize this, the risk was again preferably avoided by not using this treatment. Worth noting as another deciding factor in this was the use of volunteers for some of the work and the museum's health and safety policy prohibiting volunteers from carrying out certain tasks using chemicals.

Since moisture is a known catalyst for both pyrite and copper decay an anhydrous solution was decided on, removing the moisture from around the specimens by storing them in low humidity microclimates. It was not possible to expand the storage area of the collection at the RCM, so any re-packaging undertaken could not increase the footprint. The specimens are stored in HEY mineral index group order (Clark 1993) so movement of specimens from their designated boxes and positions within these was also undesirable.

Stewart boxes (polypropylene boxes with an air-tight lid) or Escal™ barrier film pouches (a multi-layered laminate, which includes a gas and water vapor barrier film and a heat sealable layer) were used for the micro-climates, both are made of inert material and specimens were cushioned in individual specimen trays using Plastazote™ (see appendix 1 for supplier and more information) For the stabilization of a number of specimens in the same cardboard packing box, Stewart boxes were used (Fig.9). Individual specimens were placed in Escal™ barrier film pouches with small packets of silica gel inside (Fig.10). This made best use of space and prevented the need for expansion.

Within the microclimates, moisture was removed using silica gel. A mix of 90% colorless silica gel and 10% orange self indicating silica gel was used. The indicating gel would show any compromise in the integrity of the enclosure or indicate the silica gel was fully saturated through air exchange or seepage and in need of replacement. The amount of silica gel used was roughly equal to the weight of the mineral specimens to be treated. In some of the larger enclosures and in the Stewart boxes humidity indicator strips were also used. It was not practical to include them in of the smaller pouches (figure 9).

The use of Ageless tablets as oxygen scavengers was considered but decided against in order to keep costs down so was not fully explored at this time. Making oxygen free as well as a moisture free environment however would be another level of protection for incredibly unstable pieces. Retrospectively, it would have perhaps been the optimal solution to eliminate further pyrite decay entirely. As this project had quite

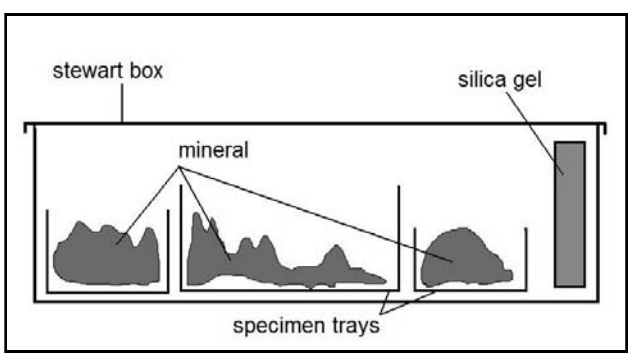


Figure 9. Stewart box microclimate

severe budget restrictions the addition of ageless sachets, whilst not terribly expensive individually, in quantity did add to the price of what was a smaller part within the wider re-packaging work being done on the collection.

The Escal™ barrier film is supplied in sheets or as open ended tubes. A heat sealer is used to seal closed the open edges of the sheet or pouch as outlined by Day (2005). A small perforated polythene pouch of silica gel was placed in the Escal™ pouch and caught up in the inner seal (although care is needed to prevent breaching the seal) to stop it moving about within the pouch and damaging the specimen (Figure 10). This method was employed by Day (2005), and in the assessments done by Carrió and Stevenson (2002) Escal™ was an excellent barrier to maintain RH levels suitable for pyrite decay treated specimens.

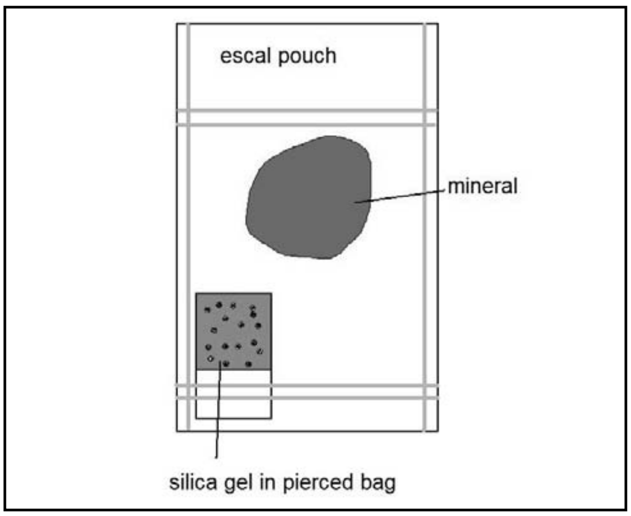


Figure 10. Barrier film pouch microclimate

Readings from the humidity strips within the microclimates fall well within boundaries of stability for both copper and pyrite materials, showing a consistent 15-25%RH. After one year no damage to specimens or recurrence of decay has occurred and the readings remain the same.

It is important to be aware that sudden re-introduction of these specimens into ambient RH for any reason could put mechanical stress on the material. Partially breaching the microclimate and allowing the humidity of the interior to slowly equalize with that of the outside room appears to allow specimens to be removed safely for study.

Time and cost of the project

The project involved six months work and took a year to complete by one person alongside other work. The bulk of the time was spent systematically working through the specimens looking for active decay. Materials costs were approximately £1200 - for Stewart boxes, Escal, polythene bags, indicator strips, PlastazoteTM (foam packaging) and silica gel. The main cost was labour. In similar projects the work could be done by trained volunteers to reduce costs.

Stabilising mineral collections on a museum wide scale need not become too costly as long as a good plan of work is drawn up and a systematic approach used. The work carried out should reflect the requirements of the collection and can be carried out in stages, tackling the most urgent needs first to spread any costs.

Conclusion

Deterioration of some of the copper and pyrite mineral specimens at the RCM was investigated through XRD analysis of their decay products. It was found that the decay products were the result of a reaction of the primary material with varying levels of moisture and oxygen. This can be accounted for by poor storage environments in the past and on-going lack of removal of decay products that auto-catalyse the decay reaction. The decay process has likely been going on for a long time, in some cases possibly since collection of specimens up to 200 years ago and most likely aggravated by lack of ventilation during storage. Stabilisation of the affected specimens using anhydrous microclimates after mechanical removal of the decay products has so far proved to have been effective. Three years on, no further decay has been detected in the treated specimens. The combination of Escal™ pouches and Stewart boxes within the existing storage restrictions has allowed us to stabilise the collection whilst maintaining its current stored volume. The use of an oxygen scavenger such as Ageless in the microclimates, whilst not used in this instance, would also work to help keep the unstable specimens from deteriorating.

Future research

The decay products identified in this study suggest previous exposure to high humidity of the collection, potentially 70-80%RH at times. It has been suggested that a study of any metastable minerals within the collection would help to confirm the RH levels. At this time such work was not possible but would be a relevant addition to the work already done should time and resources allow. A deeper look into the stability of specimens from particular sites would also be of interest, particularly with regards the Cornish pyrite bearing specimens.

Acknowledgements

With thanks to Caroline Buttler for her advice and support and Tom Cotterell for his help with the analytical work. Also many thanks to the referee for their valuable suggestions during the writing of this paper, and to the volunteers at the Royal Cornwall Museum for their continuing work on the mineral collections to help stabilise it over the years.

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Appendix 1 Suppliers and product information

Escal:
ESCAL™ is a ceramic deposited gas and moisture barrier polymer film developed especially for the protection of cultural properties. It is supplied in rolls and can be cut to size and sealed with a heat sealer or ESCAL™ CLIP to make pouches for microclimates.

Conservation By Design, Timecare Works, 5 Singer Way, Woburn Road Industrial Estate, Kempston, Bedford, MK42 7AW.
Telephone: (01234) 846300
www.conservation-by-design.co.uk

Plastazote
(rcm use grade LD24):
Polyformes Limited, Cherrycourt Way, Leighton Buzzard, Beds, LU7 4UH.
Tel: 01525 852444
Email: info@polyformes.co.uk

THE PALAEONTOLOGICAL COLLECTION AT FACULTAD DE CIENCIAS, UNIVERSIDAD DE LA REPÚBLICA (MONTEVIDEO, URUGUAY): PAST, PRESENT AND FUTURE

by Alejandra Rojas

Rojas, A. 2011. The palaeontological collection at Facultad de Ciencias, Universidad de la República (Montevideo, Uruguay): past, present and future. The Geological Curator 9 (5): 315 - 324.

The Palaeontological Collection at Facultad de Ciencias (Montevideo, Uruguay) is the most diverse palaeontological collection in Uruguay, both in terms of taxonomic and chronostratigraphic scope. It dates back to about 1953 and supports research, teaching and outreach at the institution. During most of its existence, the care of the Palaeontological Collection was inadequate. Fortunately, the importance of the preservation of fossil specimens for the long term and the need to implement internationally agreed best practices in collection management has been recently recognized. With up-to-date training and the commitment of voluntary students, the Collection has undergone a general condition assessment, reordering of the specimens, enhancement of their storage and a regular environmental monitoring. Although many improvements have been made, other important goals are to be pursued for the near future. Among the most important is the design of a management policy to govern the care and use of the Collection and to achieve the digitization of the related data. The management of the Palaeontological Collection has become a formative activity for young palaeontology students and its results in terms of the improvement of the collection care, helps to commit the institutional authorities to their stewardship responsibility for the scientific and cultural heritage of Uruguay.

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Introduction

The Palaeontological Collection housed in the Facultad de Ciencias, Universidad de la República in the city of Montevideo is the most diverse fossil collection in Uruguay both in terms of its taxonomic and chronostratigraphic scope. The collection comprises mainly Uruguayan fossils represented by microfossils, ichnofossils, fossil invertebrates and vertebrates and few palaeobotanical specimens. It is the most representative collection of the Uruguayan stratigraphic record which includes from Precambrian to Quaternary fossil taxa.

The Palaeontological Collection dates back to about 1953 and started by the research of the invertebrate palaeontologist Rodolfo Méndez Alzola in Devonian marine assemblages. At the beginnings, the collection housed fossil, mineralogical and rock specimens together. That arrangement continued until about 1978 when the Bachelor in Geological Sciences degree was created at the Facultad de Ciencias. At that point, the palaeontological and geological specimens were split apart.

Since its origins the Palaeontological Collection has grown almost exclusively through the research activities of the successive members of the palaeontology staff of the institution. As such, the collection was initially composed mainly of Devonian marine invertebrates as brachiopods, trilobites and bivalves. In 1960 the first fossil vertebrates were accessioned and ichnofossils started to be studied and actively collected around 1995. The Collection currently houses about 9,300 specimens including 50 type specimens serving as an important resource for anyone wishing to study the Uruguayan fossil record. Well represented are Devonian marine invertebrates, Carboniferous-Permian freshwater arthropods, Paleocene freshwater and terrestrial gastropods, Miocene, Pleistocene and Holocene marine taxa, especially molluscs. Fossil vertebrates are well represented by Permian amphibians, reptiles and basal synapsids, Jurassic-Cretaceous freshwater fishes, Oligocene mammals, Miocene marine fishes and terrestrial vertebrates and Pleistocene terrestrial mammals. Ichnofossils of Paleocene terrestrial invertebrates and Miocene marine invertebrates are the most diverse and abundant trace fossils in the collection. All the specimens are catalogued and accessible for use and support the teaching, research and outreach activities of the Facultad de Ciencias.

The Palaeontological Collection had to be moved twice as the result of the Faculty being assigned new facilities. The first move in the early 1970s had very negative consequences as many specimens and labels were lost or very damaged. This caused a severe depletion mostly of the earliest specimens of the collection. The second move in 1998 was much more successful because of conscientious planning on the part of the staff charged to make and supervise the move.

Figure 1. Palaeontological Collection storeroom shared with the sample preparation laboratory.

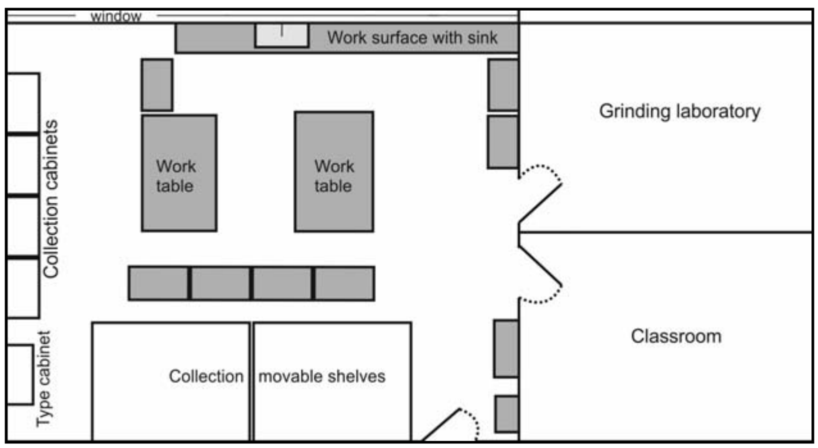

Figure 2. Sketch of the Palaeontological Collection storeroom. Collection furniture is represented in white. In grey are depicted sample storage cabinets and shelves, field equipment cabinets, work tables and the work surface.

The Paleontological Collection is used mainly by the staff of palaeontologists, undergraduate and graduate students of the Facultad de Ciencias but it also receives the visit of foreign researchers interested in different taxa.

Until recently, the care of the collection belied its value to science and education, languishing due to lack of proper management and support. Fortunately, that is no longer the situation and the Collection has begun to be recognized as an important resource to science that needs to be preserved for future use (Williams and Cato 1995). The new understanding of the stewardship responsibility of the Facultad de Ciencias and its staff to the Uruguayan palaeontological patrimony has been the beginning to achieve success in this task.

Historical condition of the Collection

The Palaeontological Collection at Facultad de Ciencias has faced several problems in terms of physical location, lack of financial and human resources and lack of knowledge on best practices in collections care and management. The most important of these are described below.

Location

The Collection is located with no physical division from the specimen preparation facilities (Figure 1) as it would be desirable (Jessup 1995). The same room functions as the collection storeroom, sample repository and dirty laboratory where fossil samples are cleaned, washed and conditioned to be included in the Collection. Also, this is where palaeontological samples shipped from the field are left for preparation in a variety of enclosures, and where field equipment is stored. This room also communicates to the grinding rock laboratory, whose door is not always kept closed thus generating dust problems (Figure 2). Due to this situation, the collection storeroom is used by many different people with different aims that in some cases oppose to the expected conditions in a collection storing area.

No air conditioning, no pest control and no smoke detectors are available in the facility.

Storage furniture and specimen containers

The specimens of the collection are stored in two modules of manual drive racking shelves for big sized materials (Figure 3A), four cabinets with forty drawers each (Figure 3B) and a cabinet for types. All of them are metal made but do not hermetically seal either because of their original construction (modules of movable shelves) or because of aging. It is difficult then to maintain cabinets dust-free.

Small specimens such as invertebrate shells and small vertebrate remains have been traditionally kept in open cardboard trays or boxes. Also plastic bags, tubes and glass tubes have been used. Big fossil vertebrate remains have often lain free over the shelves or in cardboard boxes.

Figure 3. Collection cabinets. A. Movable shelves for large fossil vertebrate storage. B. Cabinets for small vertebrate and invertebrate fossil specimens.

Staff assigned to collection management activities

No trained professionals have taken care of the Palaeontological Collection and no collections care positions ever existed at the institution. Instead, the collection has been cared for by historical accident as nobody was directly responsible of this task as found by Simmons and Muñoz-Saba (2006) for many Latin American collections. Today, the situation has not changed institutionally except for that one researcher of the palaeontology staff has been recognized as responsible for the care and management of the collection. As a university, the staff must teach, do research and outreach. Due to these other duties only a very small proportion of time can be spent (usually less than 5 hours per week) on the collection management and care activities. Under this scenario, improvements in the condition of the collection can only be achieved slowly.

Resources

No regular institutional funds are received for the expenses of the collection at least for the moment. Usually small amounts come from departmental budget and research grants of the palaeontology staff. These are used to cover minimal expenses generated by the collection management activities, mainly for boxes to hold specimens and minor supplies. To date, the collection has not received money to do major investments such as new and better storage furniture nor permanent institutional funds to enroll a permanent professional whose only labour be the care of the collection.

Collection management and care

Almost no regular and planned collection management activities have taken place until very recently, at the beginning of 2009. Also, until this date, the keys of the cabinets were kept in a public place and no control existed on the access to the specimens. This situation led, over the years, to the misuse and deterioration of the collection, including the specimens, their labels (Figure 4) and containers. Disorder and overcrowding in the shelves and drawers started to result (Figure 5). Many specimens were displaced from their assigned location, being regarded as lost for a long time, thus preventing their use by researchers. Fortunately, little irreversible damage was caused.

Documentation

Specimen information is recorded in handwritten catalogues since the origins of the Collection (Figure 6).

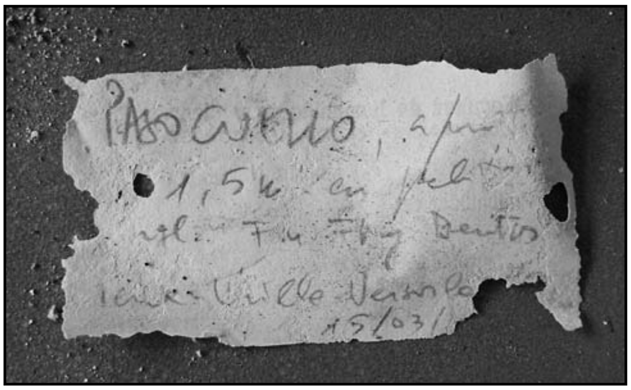

Figure 4. Specimen label showing damage from silver-fish.

These catalogues have been photographed for back-up but several attempts to digitize them have failed. The lack of data standards and explicit procedures along with the use of different software by different people along the years has led to several incomplete catalogues that are not useful when the data is to be retrieved and cross-referenced.

Field notebooks are retained by the collectors and no mechanism is available yet to hold the notes by the institution upon retirement or departure.

Advances in the management of the Palaeontological Collection

Past curatorial neglect in the Palaeontological Collection at Facultad de Ciencias can be explained at two levels. One is the lack of awareness of the value of collections and the need for preserving them at the institutional level. The other is the traditional absence of trained professionals in collection management along with the ignorance about best practices in this discipline at the staff level. At least the latter began to change after the participation in early 2009 in the Natural History Collections Management Training Program for Latin American and Caribbean Professionals held at the National Museum of Natural History, Smithsonian Institution in Washington DC during six weeks.

On return from this training, the prime goal was to start to rectify the historical condition of the Palaeontological Collection and to begin improvements in its care through the implementation of best practices in collections management. This was intended to contribute to the utility of the collection (Williams and Cato 1995) and to ensue through a preventive conservation approach the long-term preservation of its specimens (Rose and Hawks 1995).

Figure 5. Cabinet drawers before the collection management activities, showing overcrowding, specimen open containers, improper storage and drawer disorder.

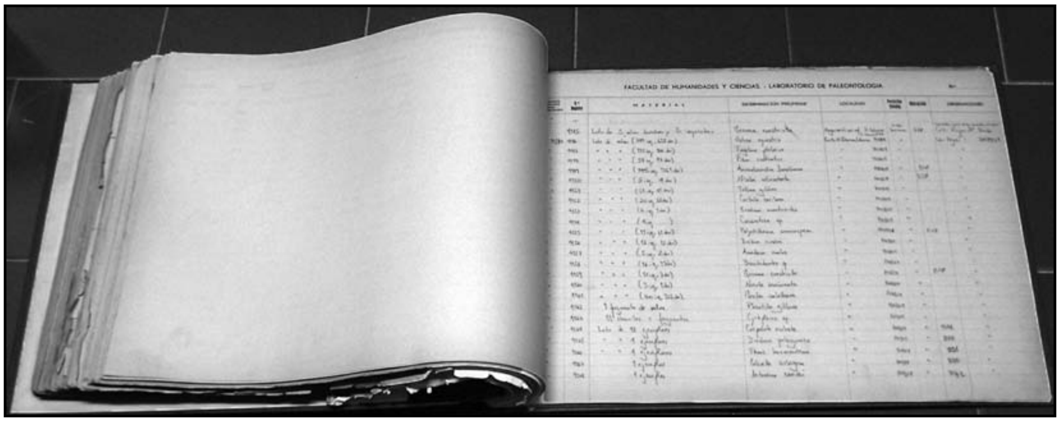

Figure 6. Handwritten catalogue of the Palaeontological Collection.

A plan of short, medium and long-term collection management goals was developed, being the detection and mitigation of the effects of some agents of deterioration (Waller 1995) one of the priorities. This plan was presented and discussed with colleagues and students who supported and committed to the tasks. Conservation awareness has been the key to the success of this effort.

The activities began with the voluntary help of palaeontology students and young researchers who received some basic training. Approximately five hours a week were spent by the team in the collection since the beginning of the process. The Palaeontological Collection does not receive an institutional budget so the work started with limited expenses and supplies. No cost and low cost actions were taken first and hopefully, the verifiable current improvements in the care of the collection will help to change this situation.

Controlled access to the Collection storeroom and specimens

Traditionally, almost every person willing to enter the collection storeroom and have access to the specimens was able to as the keys remained in a public place. This changed with the start of the collection management plan. It was decided that the keys to access the collection cabinets were to be kept by the designated collection manager in order to control who has access to the specimens, and when and why. This simple action not only changed the perception of lack of control formerly associated with the collection but was the start point to achieve improvements in the care of the collection.

Routine cleaning and maintenance of the collection room

The importance of housekeeping in the care of the specimens and in terms of pest control was not obvious in the past. The variety of people that use the laboratory, some of them without knowledge on the consequences of an inadequate behavior in terms of cleaning, also conspires against best practices in this issue. Routine cleaning in the collection storeroom now occurs almost daily. This helps to keep the floor and work surfaces clean thus avoiding the accumulation of dust and dirt that may act as pest attractors and accumulate over and inside the collection cabinets. Education of the users of the collection area in this issue has also been important despite which some problems persist in terms of the avoidance of organic residues (food or beverages) in the storeroom.

Checklist of the catalogued specimens in the cabinets

When the collection management activities started it was noticed that the majority of specimens were outside their assigned place in the storage furniture. Many of them were in the incorrect place, thus preventing their being found or greatly increasing the search time. The reduction of entropy in the collection in terms of returning each specimen to its place allowed then a more efficient use of the specimens (Simmons and Muñoz-Saba 2003). This was a very time consuming task as it was complemented with the specimen cleaning and container conditioning. Drawers and shelves were cleaned before re-placing the specimens.

Storage enhancement and efficient use of space

Most financial resources were spent in the enhancement of storage containers as these represent the primary protection for specimens from multiple agents of deterioration. Many open storage containers were replaced by lidded boxes and tubes (Figure 7) to prevent air interchange and allow a stable internal environment and protection of the specimens (Rose and Hawks 1995). These containers also provide isolation to specimens and labels from dust and silverfish as the cabinets are not hermetically closed. The enclosures are also intended to serve as buffering

Figure 7. Storage after collection management activities showing specimens inside lidded boxes and tubes.

before making a decision regarding the need of an active system of environmental control (Waller 1995; Weintraub and Wolf 1995).

Most specimens in the collection are organized in a taxonomic and stratigraphic order. Maintaining this organization, specimens were rearranged in the cabinets and shelves taking into account their size in order to achieve a more efficient use of space. Formerly, small specimens could be stored next to larger ones increasing also their risk of damage. Currently, the movable rack is only used for oversized fossil vertebrates whereas in cabinets with drawers small vertebrate remains and the majority of fossil invertebrates are stored (Figures 7A, 8). Previous overcrowding and disorder inside drawers has also been minimized (Figure 8).

Status specimens

As a way to enhance the scientific value of the collection and the documentation of fossils a bibliographic research is ongoing for the first time in order to link specimens to the articles where they were published. When a specimen has been published, a reference to the article is linked to the number of the specimen. Also the article (paper or digital) is stored for reference. Then, if a researcher is interested in consulting a particular specimen, we can also provide him with the published information about the specimen. Since this research started, over 500 specimens of the Palaeontological Collection have been linked to publications. In order to facilitate the task from now on, every researcher is asked to provide a reprint of their publication for the collection archives.

Environmental monitoring

Two data loggers are available in the collection storage facilities to record temperature and relative humidity as a need to monitor the environment in which the specimens are stored. They are located in the microenvironment around specimens (Weintraub and Wolf, 1995). One logger is situated over a shelf inside the large fossil vertebrate movable rack and the other is inside a drawer of the fossil invertebrate cabinet. The positions were chosen to give a more proximal indication of the conditions experienced by the fossils in their primary storage units. Appendix 1 shows the plots of temperature and relative humidity readings obtained during the period June 2009 - December 2010. Maximum and minimum values of these parameters were recorded weekly (with some exceptions) on an Excel™ spreadsheet and data analyzed.

Figure 8. Cabinet drawers after the collection management activities.

The temperature readings plot shows that collection specimens are exposed to temperature variations which roughly correlate with the seasons in Uruguay. The maximum and minimum values of temperature experienced by the specimens during the 18 months of readings are 26·5ºC and 14·8ºC in the vertebrate shelf and between 27·2ºC and 14·7ºC in the invertebrate drawer. This amplitude of readings reduces within a particular season and the values tend to fluctuate less. Thus, in shorter intervals the specimens are exposed to less variation on temperature. Moreover, despite the extreme values recorded showing a difference of 13ºC, appendix 2 shows that a maximum temperature range between 19ºC to 20·9ºC and a minimum temperature range between 17ºC to 18,9ºC are the more frequently recorded values in the collection storage.

The relative humidity readings plot shows that specimens experienced large variations in the time interval considered. The extreme values recorded are 44% and 85%. It can also be seen that in short intervals of readings, minimum and maximum values of relative humidity are still very distant (see for example the period February 2010 - April 2010) when the specimens faced large variations of relative humidity in short intervals of time. Appendix 2 shows that the majority of minimum values of RH concentrates in the interval 44%-50% whereas maximum values show higher variation with a higher frequency at the range 61%-70%.

The measured environmental parameters (especially relative humidity) can be regarded as non optimum conditions for the long term preservation of specimens in the collection. Both temperature and relative humidity changes can result in stress damage or accelerate chemical processes of deterioration (Erhardt and Mecklenburg 1994; Weintraub and Wolf 1995; Simmons and Muñoz-Saba 2003).

Environmental monitoring in the Palaeontological Collection is still in a diagnostic phase. More loggers are needed to achieve a more complete environmental scenario and longer term data before making a decision to intervene. So far, these data do show for the first time that the fossil specimens at the Palaeontological Collection in the Facultad de Ciencias may not be in appropriate environmental conditions. Despite this, which could be deduced from the collection storeroom characteristics described above, the loggers provide objective environmental data. This record of readings may be useful to inform the institution authorities about the conditions faced by the specimens in the collection and the need to take corrective actions to provide them with appropriate environments.

Other agents of deterioration

Apparently no serious pest problems exist in the Palaeontological Collection. Occasionally some insects or spiders are found in the collection storeroom and so far only the activity of silverfishes has been detrimental to some labels inside the cabinets (Figure 4). A considerable problem is dust which deposits inside shelves, drawers and on specimens. Some of them have been washed with water, brushed or cleaned with compressed air. Both pest and dust consequences are expected to be minimized with the substitution of open boxes by lidded ones.

Light and radiation can still be a problem for some cabinets and specimens contained. One of the cabinets is located next to a window and it may receive direct sun light and heating from the glass. For some catalogued specimens damage of this kind has been eliminated as they were replaced in exhibition cabinets by other specimens with less scientific value but with similar attractive features for the public.

Use of the collection

Before 2009 there were no agreed rules to receive researchers from outside the institution willing to use the collection. Currently, researchers make contact with the staff specialist and are then directed to the collection manager in order to indicate which material is required and arrange a schedule of visit. The researcher is then registered and asked to leave a copy of the photographs of the specimens consulted for the institution. Although the specimens removed from the cabinets are annotated, it is not necessary to leave a card because visits are more or less sporadic and do not overlap.

If a specimen is removed from its cabinet for a longer period when a local researcher is studying it, either a card is left on the shelf or drawer or its provisional location is recorded in the catalogue.

It was traditional for the fossils of the research collection to be used in education (i.e. in Palaeontology courses). Currently, this is avoided as the extensive manipulation by students may cause deterioration and the loss of small specimens over the years. However, some material may be used under controlled conditions if no specimens from the didactic collection are available to show a particular morphology or taxon.

For outreach activities moulds, casts, overrepresented specimens or those with no scientific value are used in short exhibits for school groups, student and teacher groups and general public. This occurs regularly at the faculty or stands may be assembled in other institutions. At least two people attend these activities in order to keep damage of specimens to a minimum, especially with large groups. An explanation of the value of fossils as patrimony and the need to preserve them in collections is addressed in the activities.

Future goals in the management of the Palaeontological Collection

Although many improvements have been achieved in the management and care of the Palaeontological Collection of the Facultad de Ciencias, other goals are yet to be reached.

One of the most urgent needs is the development of a policy and the establishment of clear procedures to govern the care, documentation and use of the collection. A written policy available for all users will establish standards that regulate the activities of the users and provide a framework for decision making. This will help to avoid the improper use of the collection and solve many aspects related to the collection that are currently arising as problems (i.e. legal and ethical issues).

Another important goal is to improve the documentation as it provides the value of the collection. The digitization of the written catalogue is urgently needed to protect the information of the collection, to facilitate cross-referencing and to search more efficiently in the collection's data. Before entering this task a definition of data standards and procedures is essential. The achievement of databasing will eventually set up the discussion on digital imaging of specimens and on the possibility of posting collection data on the web.

Among other goals are the installation of new free-standing data loggers that monitor the environment of the collection storeroom and inside lidded boxes. This will aid in the monitoring of the data in different places of the collection and evaluate buffering properties of the new supplies. In terms of environmental monitoring it is also intended to relate the obtained readings with the available local climate information and the external conditions of the collection storeroom in order to aid in the correct interpretation of data.

Conclusions

The care and management of Palaeontological Collection at Facultad de Ciencias were relegated to a very low priority at the institution almost since its creation. This may be attributed to ignorance, lack of collection management professionals and financial resources. Also, this time consuming task has not been adequately valued at the institution. Fortunately, the importance of preserving the collection for the long term and the need to implement internationally agreed best practices in collection management has been recently recognized by the members of the staff directly responsible for the Palaeontological Collection. These have been the pillars to begin regular and supported activities to improve the care of the Palaeontological Collection and enhance its patrimonial value.

This venture has required human resources, financial resources and time to spend. Although a long way is to be covered to achieve the degree of development and professionalism of other collections around the world, the improvements reached so far are to be viewed as a start point in the sustained care of the collection.

Beyond the tangible improvements such as the acquisition of archival materials, housekeeping and environmental monitoring, the collection management activities have also become a formative activity for palaeontology students and young researchers. Them, the future users of the collection, are learning through the collection management activities the importance of caring for it for the long term and its value to science and society.

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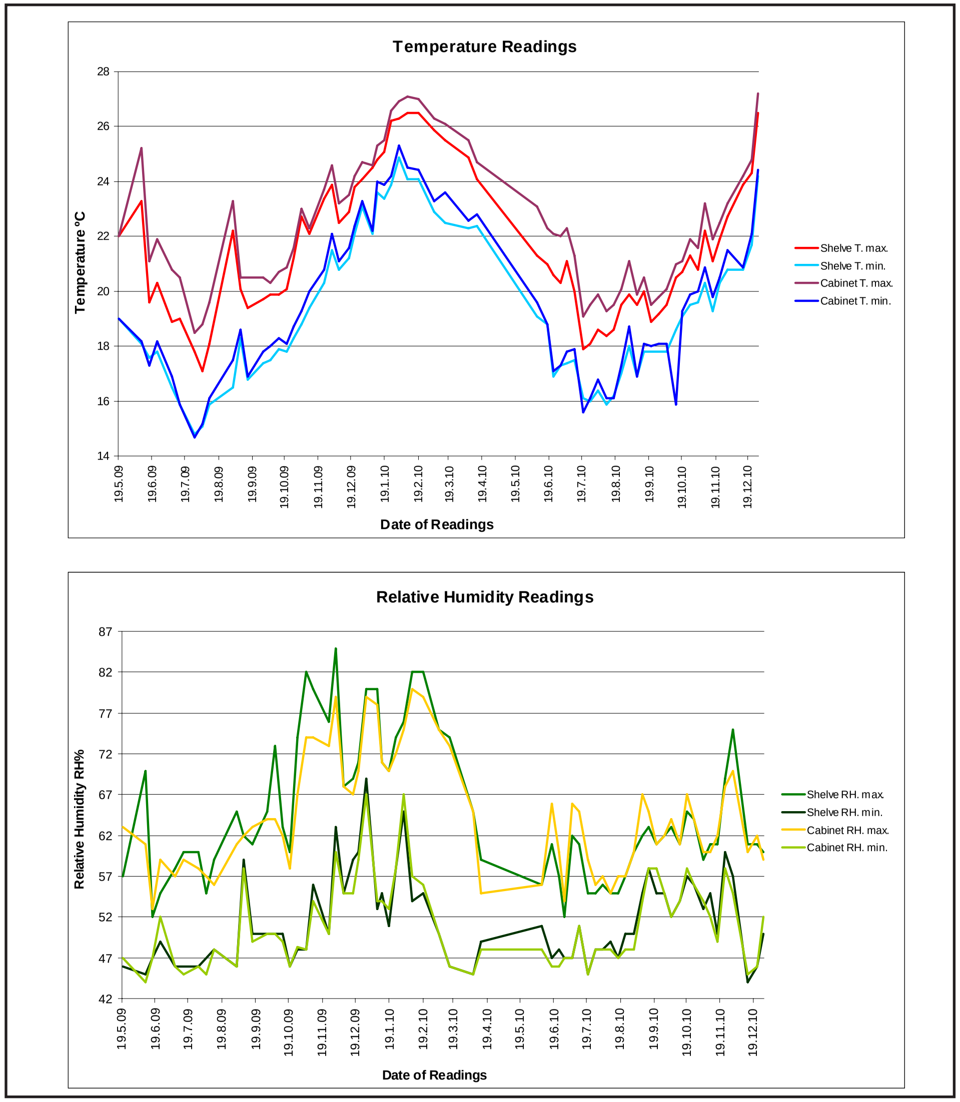
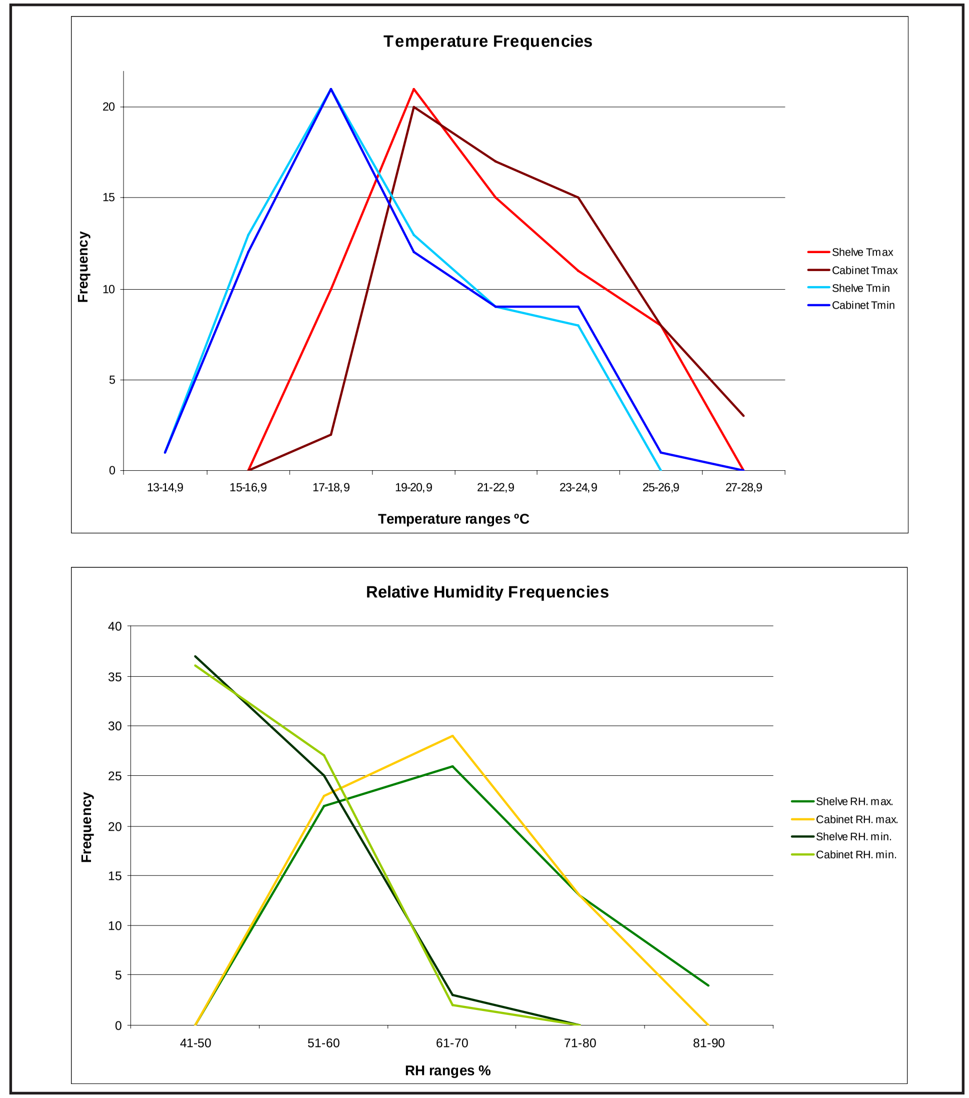
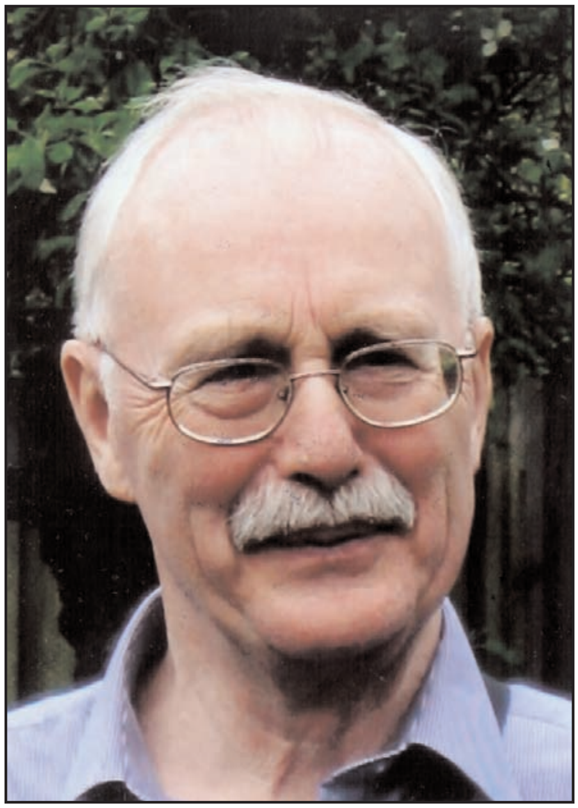


Appendix 1. Temperature and relative humidity graphs for the period May 2009 - December 2010 in the specimen storage furniture from the Palaeontological Collection in the Facultad de Ciencias. Maximum and minimum readings were taken on a weekly basis. One of the loggers is situated on Ab2 vertebrate movable shelve and the other inside B23 invertebrate cabinet.



Appendix 2. Temperature and relative humidity frequencies for the period May 2009 - December 2010 in the specimen storage furniture from the Palaeontological Collection in the Facultad de Ciencias.

BARRIE RICKARDS (1938-2009)



Barrie Rickards in 2004

Barrie Rickards, who died on November 5th 2009, was internationally known both as a palaeontologist and as an angler and fishing writer. We pay tribute here to Barrie's reputation in both professions. However, many people will have their strongest memories of Barrie as a teacher, not least on the Cambridge University Sedbergh mapping course. So here we also celebrate Barrie's educational influence on generations of Earth Sciences students.

Barrie was born in 1938 on the eastern outskirts of Leeds. He went to primary school there and then in Hook, on the River Ouse in east Yorkshire. Barrie describes in his autobiographic novel *Fishers on the Green Roads* (Medlar Press, 2002) how a boyhood freedom to roam over the Yorkshire countryside nourished a talent for observing, documenting and interpreting the natural world. Indeed, he spent more time in this outdoor education than in formal study, first at primary school and then at Goole Grammar School. He was more distinguished as a cross country runner and a footballer, having trials for Wolverhampton Wanderers FC. He did, however, show enough aptitude for science to get into Hull University, where he got a B.Sc. in Geology in 1960. An undergraduate mapping project across the Dent Fault and Howgill Fells, then mostly part of west Yorkshire, stimulated his curiosity for Early Palaeozoic fossils. This interest led to a Ph.D at Hull in 1963, for a meticulous revision of Silurian graptolites and their biostratigraphy. With his academic reputation growing, Barrie held short-term posts at University College London, the University of Cambridge, the Natural History Museum, and Trinity College Dublin. He particularly impressed Oliver Bulman, the graptolite expert and Woodwardian Professor in Cambridge, who lured him back to the Geology Department - "the Sedgwick" - in 1969.

Barrie spent the rest of his career in Cambridge, as successively Lecturer, Reader and then Professor in Palaeontology and Biostratigraphy. His research work was recognised by the Geological Society with the award of the Murchison Fund (1982) and the

Lyell Medal (1997) and by the Yorkshire Geological Society with the John Phillips Medal (1988). Barrie was Curator of the Sedgwick Museum from 1969-2000, and a Fellow of Emmanuel College from 1978.

Barrie's experience among the collections at the Natural History Museum in London made him a natural choice as a Curator at the Sedgwick. His skills as a collector, as well as those linked to the collaborative work with other researchers and the mentoring of PhD students working on the faunas of his beloved Palaeozoic black shales, resulted in the accession of large numbers of new type, referred and figured specimens into the collections. He had a habit of commandeering batches of 'X' numbers from Mike Dorling and then proceeded to fastidiously curate his research specimens in preparation for formal accession into the Museum collections. These specimens would be wrapped carefully in his office and then boxed up (using surplus cardboard boxes taken from local supermarkets or the wine cellar at Emmanuel) ready for transfer to the Museum. The problem with this technique was that he frequently had the specimen and its vital identification ticket (name, provenance, collector, date, reference), rather loosely wrapped together in paper. The risk of separation of ticket from specimen are, of course, rather obvious and caused many a fraught moment among the collections care staff of the Museum. Barrie genuinely loved the Museum and its collections and would glow with enthusiasm as he showed visitors or students around the galleries. And his title 'curator' stayed with him until the very end - some of his last contributions to appear in print were in *Cambridgeshire* a monthly magazine for which he acted as a fishing correspondent. An angler of tremendous renown he may have been, but his byline always included 'Curator at the Sedgwick Museum' hinting that he was also an angler of 'fish' in ancient rocks as well.

Barrie's internationally renowned geological research, published in over 275 papers and 5 books, focused on the palaeobiology of graptolites, collected by him in areas from Australia to Argentina and from Canada to Russia. He had a legendary ability to find distinctive graptolite fragments, even in unpromising rocks. He used their rapid evolution to accurately date and correlate Ordovician and Silurian strata. He used new techniques to shed light on their behaviour. Working with doctoral students and young research fellows, Barrie used scanning electron microscopy to show that graptolite skeletons were actively constructed by the colony of animals that inhabited them, meaning that they were more like floating beehives than typical shelly fossils. His collaborations on their hydrodynamics started with simple models in the Emmanuel College swimming pool before progressing to wind tunnels and computer modelling. His study of the enigmatic fossil *Promissum pulchrum* with Dick Aldridge and Johannes Theron found that, rather than being the oldest land plant as was previously considered, this organism was an exceptionally preserved conodont, consequently revealing the complete anatomy of this primitive vertebrate.

Barrie's activities as an angler eclipsed even those as a palaeontologist. He wrote more than 800 fishing articles and about 30 books. His guides to fishing technique became veritable bibles to a generation of anglers. Angling and geology came together in his campaigning on environmental issues, particularly over drainage policy. He was an expert on fisheries management, personally managing a succession of lakes and rivers, and was a scientific adviser to the Anglian region of the Environment Agency in the 1990s.

Underpinning Barrie's geological and fishing work was a quiet but infectious enthusiasm for his subject, and a patient skill in transmitting his enthusiasm to others. The many students who passed through Barrie's care in Emmanuel, Christ's and Girton colleges may remember occasional supervisions covering the lecture topics, but many more that diverged in surprising and stimulating ways. Barrie thought that his role was primarily to nurture students' interest in geology. Then they would be motivated enough to learn what lecture material they needed in their own time. This approach was evidently successful, with many of Barrie's students now in influential academic and industry positions.

Greatly outnumbering his supervision students are those who have been taught by Barrie in the field on the Sedbergh mapping course. Around 1500 students passed through this course in the 35 years that Barrie taught on it. Indeed, it was Barrie who set up the course in 1970, when "the troubles" necessitated a move from its former venue in western Ireland. He spotted that the juxtaposition of a Carboniferous sequence with a folded and cleaved Lower Palaeozoic sequences - by the Dent Fault of his old B.Sc. project area - would provide varied geology and a good educational challenge. Forty years later, with the course still running in the same area, we can judge that Barrie was right.

Barrie's field teaching style matched the informality of his supervision style. However, informality was underpinned by an insistence on rigorous field obser-

Sedgwick Museum staff in the mid 1990s. Highest on step: Chris Hall (exhibition designer), on his left: Mike Dorling (Collections Supervisor), on his left (silly hat): Steve Laurie (Mineralogy & Petrology Assistant). Front row, left to right: Ken Harvey (Photographer), Barrie (Curator of Palaeontology, Dave Norman (Director), Nicola Payton (General Museum Assistant), Pamela Phillips (IT Manager), Manuel Garcia Garrascosa (Spanish intern), Chris Collins (Conservator), Rod Long (Palaeontology Assistant).
Missing: Graham Chinner (Curator of Min & Pet), Nick McCave (Woodwardian Professor)

vations and on neat and careful recording in map and notebook. "Good penmanship" was his favourite maxim. Although he knew every square inch of ground in the mapping areas, he never tired of demonstrating the rocks to a new intake of students. As in supervisions, his groups would learn more than just geology, with Barrie always the first to spot a sundew or a dipper, a buzzard's nest or a red squirrel. Despite its capture by Cumbria in 1970, the Sedbergh area was to Barrie forever Yorkshire, and somewhere that he loved and belonged.

Barrie was a Yorkshireman by character as well as birth. He was generous to others but thrifty in spending on himself. He used the same trusted rucksack and wax jacket for over thirty years. When the jacket zip jammed for good in later life (of both Barrie and the jacket) he perfected a wriggled vertical entry technique to extend its useful life. He liked proven technology, preferring his Morris Minor van to more modern vehicles, and the pen to the computer keyboard. He could be confident and forthright, but was more naturally gentle and shy. His students, colleagues and friends will remember him particularly for his integrity, honesty, and an infectious sense of humour, there till the end.

This tribute has been adapted with the help of John Maclennan and David Norman from the Geological Society obituary by Nigel Woodcock and Alex Page available at www.geolsoc.org.uk/gsl/society/history/obituaries/page6863.html

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