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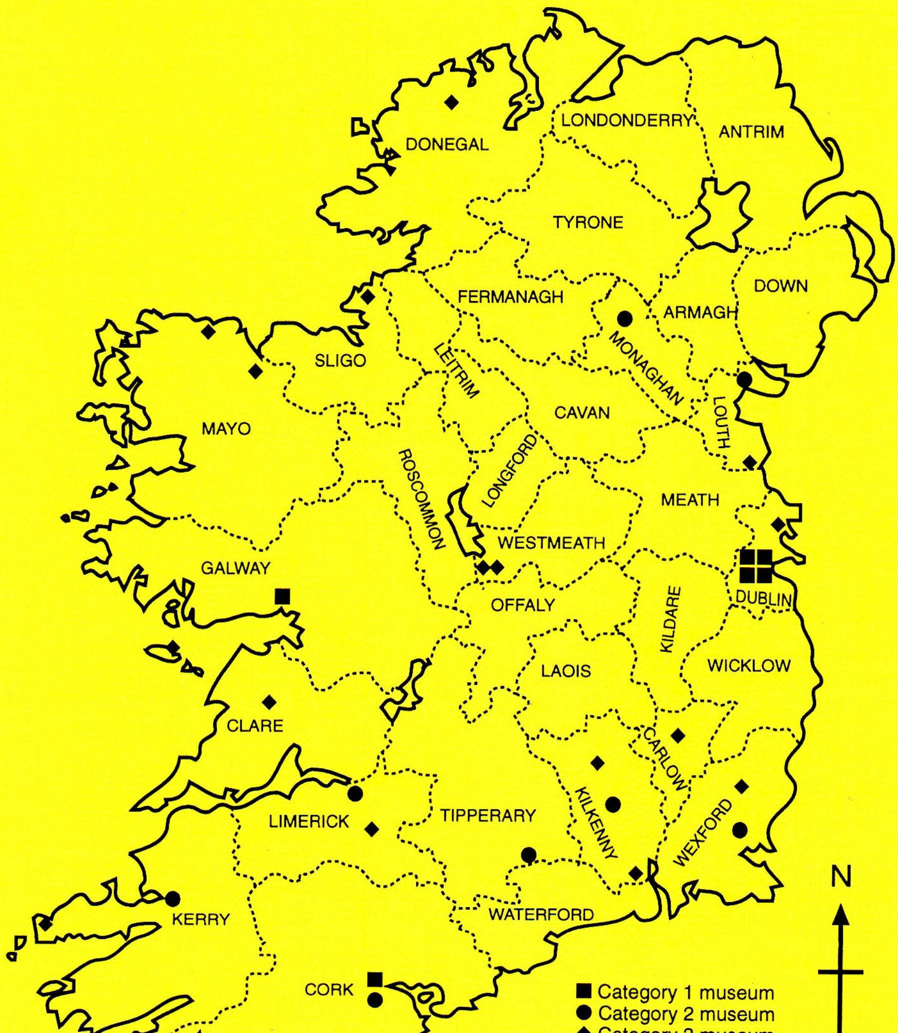

Distribution of museums with geological collections in the Republic of Ireland

GEOLOGICAL CURATORS' GROUP

Registered Charity No. 296050

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.

1998 COMMITTEE

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Cover: Map showing the distribution of museums in the Republic of Ireland that contain geological collections. See article by Matthew Parkes and Patrick Wyse Jackson, p. 377-388.

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CONTENTS

GEOLOGICAL CURATORS' GROUP - December 1998

BRINGING THE FORESTS BACK TO LIFE - PALAEOBOTANICAL MODEL MAKING AT THE NATIONAL MUSEUMS AND GALLERIES OF WALES.

by Annette Townsend, Christopher J. Cleal and Barry A. Thomas

Townsend, A., Cleal, C.J. & Thomas, B.A. 1998. Bringing the forests back to life - palaeobotanical model making at the National Museums and Galleries of Wales. *The Geological Curator* 6(10): 353-361.

Based on techniques used for preparing displays of modern-day plants, model-making has proved a useful tool for developing exhibitions of fossil plants. The most useful medium for such modelling proved to be wax, combined with card, paper and sometimes tinned copper wire. To help with their long-term conservation, careful records need to be kept of the construction materials and methods for each model. To demonstrate the problems inherent in the modelling of different types of plant structure, details are presented of how the various parts of the Carboniferous treelike club-moss *Lepidodendron* were produced.

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Introduction

Vegetation has a crucial influence on the Earth's environment, controlling the composition of the atmosphere, influencing climate, reducing erosion and thereby limiting the amount of sediment entering the seas, and ultimately providing the wherewithal for all the animals that live on land. Without plants, the Earth's surface would still be a bare and inhospitable place. To understand how the Earth's environment has evolved it is therefore vital that we understand the history of vegetation, a history that is most directly seen in the plant fossil record. Palaeobotanists are able to take fragmentary fossil remains from long extinct vegetation and in many cases reconstruct whole plants. We can then view them as living organisms, to give a clearer and more botanically meaningful impression of what past vegetation was like.

The problem for the educationalist, including the designer of museum displays, is that plant fossils often look so singularly dead and uninteresting. They are usually flat and black, and often preserved on a grey rock matrix. It can be difficult to make them come alive in the mind of the viewer. One solution is to produce illustrations of what we believe the plants looked like and this can be of significant value (Figure 1). The two dimensional illustrator can apply many techniques to produce accurate illustrations giving an illusion of life, while conveniently concealing any uncertain features. In Cardiff there is an active programme of illustrating fossil plants in colour, through which artistic skill and scientific information have been combined. The results of this work can be seen in publications (e.g. Thomas and Cleal 1993), and in static illustrations and film-loops as part of exhibitions such as our Museum's *The Evolution of Wales*. However, such illustrations still tend to look somewhat 'flat', especially in the context of museum displays.

Similar problems have also been encountered by botanists working with Recent plants (Herbert 1977): it is normally impossible to use living plant specimens for long-term museum displays, pressed herbarium specimens do not make attractive display items, and two-dimensional displays offer little more than can be obtained from books. The National Museums and Galleries of Wales (NMGW) has consequently built-up a large collection of carefully crafted wax models, dating from 1908 to the present day, which recreate the plants in a life-like form and which have been used to great effect in displays such as our *The Natural History of Wales* (Spillards 1996).

It seemed a natural development for us to start modelling selected fossil plants in wax. The aim of this paper is to describe the practical experiences and problems that we have encountered in this programme, and to discuss

Figure 1. A reproduction of a colour reconstruction by Annette Townsend of part of the Late Carboniferous palaeoequatorial lowland forests, showing giant club mosses growing in the back swamp. The plants are shown in various stages of growth from small juveniles, represented as leafy 'poles', to fully mature plants with an apical crown of branches.

some of the exhibition and educational uses to which the models can be put. Some Mesozoic plants have been reconstructed, but most have been based on the remains of the Late Carboniferous Coal Measures forests and it is these which will be discussed here. In particular, we will concentrate on the giant club-mosses, which were the dominant 'trees' in these forests (Thomas and Cleal 1993; Cleal and Thomas 1994).

The giant club-mosses

The Carboniferous club-mosses dominated the Coal Measures swamps by growing up to 50 metres high and forming a crown of branches (Figure 2). Although they resembled trees in appearance, they grew rather differently. Sporelings grew upwards and rapidly expanded in thickness until they looked like small poles covered in leaves. These stems increased in height and girth until they were about 30-40 metres tall. They then underwent a series of apical divisions, each division producing two smaller branches until the smallest terminal shoots were no more than a few millimetres thick. In contrast to angiosperm and gymnosperm trees, therefore, size of branch is no indication of age.

This unusual and rapid growth pattern could not be achieved by increasing the amount of wood in the stem, as in true trees. It was instead the result of having a

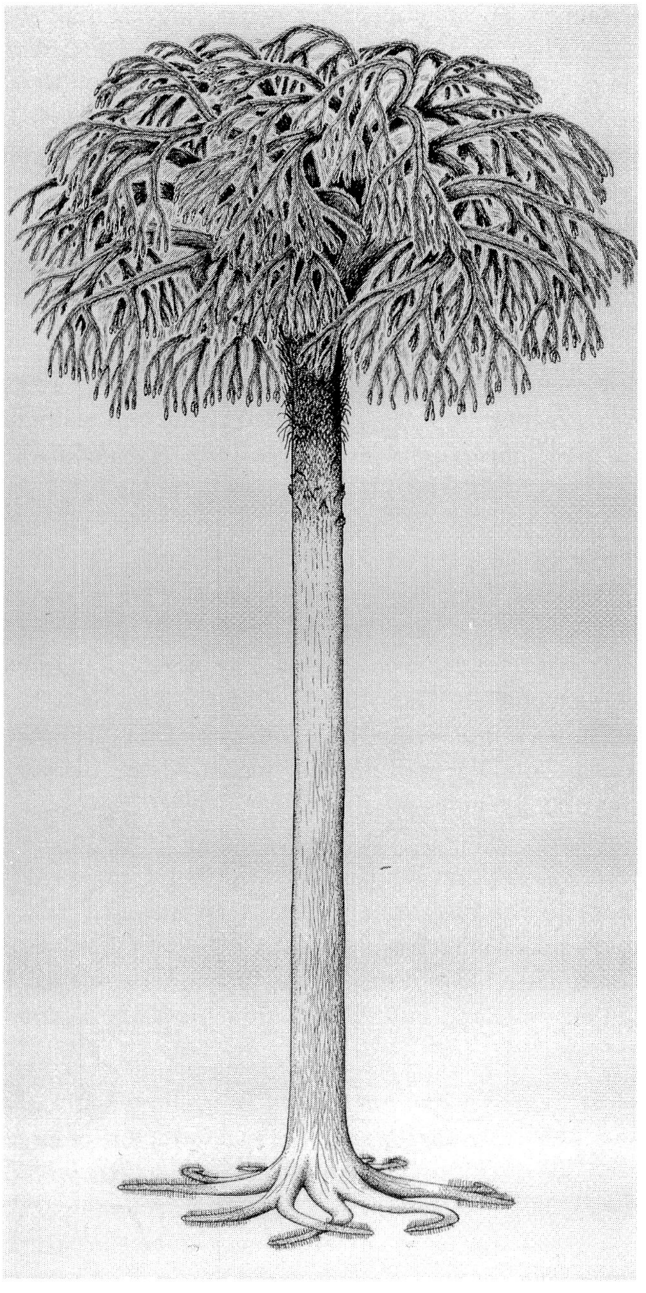

Figure 2. A pen and ink reconstruction by Annette Townsend of a fully mature giant club moss from the Late Carboniferous palaeoequatorial lowland forests. These plants were up to 50 metres high.

support system of thickened cells in the outer parts of the stem, which could be more economically produced than wood. The growth pattern, especially the expansion in girth, produced a series of leaf, 'bark', shoot and fructification abscissions that resulted in these parts becoming fossilized as isolated organs. Each type of organ has to be treated separately for taxonomic purposes because the number of organs found connected are very few. Therefore, each type of organ may have its own generic name and within each genus there will usually be many species.

Lepidodendron is the generic name given to a common Carboniferous lycophyte stem that has longitudinally elongated leaf cushions. When the leaves have been shed, three leaf scars are left in the centre of the cushions showing a vascular bundle and two lateral scars marking the aerating canals (parichnos) that ran into the leaves. Such aerating canals most probably facilitated gaseous exchange associated with photosynthesis and recycling of oxygen and carbon dioxide.

The terminal shoots of arborescent club-mosses remain leafy and all species are very similar and difficult to distinguish. They are in fact usually identified as one of only four species which has to be wrong considering the much larger number of species recognized of stems with recognizable leaf cushions.

Arborescent lycophytes reproduced by forming spores in specialized cones. *Lepidodendron* formed them terminally on the ends of its ultimate leafy shoots. The cones, which are called *Flemingites*, varied in size from about 10 to 100 cm in length and had helically arranged sporophylls each with a sporangium attached to its upper surface. They were heterosporous and monoecious (i.e. produced both megaspores and microspores within one cone). Individual sporangia produce only one kind of spore and usually it is the more apical ones that are microsporangiate.

The arboresent lycophytes with their tall axes and large aerial branching crowns clearly needed an extensive rooting system to provide for both the physiological needs of the plants and their stability in the soft sediments in which they grew. Such systems which are physiologically, but not morphologically, true roots are given the name *Stigmaria*. They spread out more or less horizontally from the bases of the main stems by dichotomous branching. As they spread, the stigmarias increased in girth partially through wood production but mainly by the formation of extra cortical tissues. Each growing stigmarian apex was a rimmed depression terminated by a protective plug of parenchymatous tissue. True roots were formed by the growing apices and radiated in all directions. When fully grown the roots could be up to 0.5 metres or more long and the vertical ones may have projected out of the sediment into the overlying water. The roots had a large central canal which provided a pathway for gases and possibly permitted gaseous exchange with the surrounding waterlogged sediments or the overlying water. As the stigmarian axes expanded through secondary growth, the older roots were shed leaving characteristic circular scars on their surfaces. There are virtually no characters that can be used to distinguish the stigmarian bases of different species of parent plants so practically all of them are placed in the same species *Stigmaria ficoides* (Sternberg) Brongniart.

Making the models

Planning

Modelling a fossil plant proved to be very different from duplicating a plant from real life. With a living plant it is possible to see every detail. The plant can be physically dissected and each section used as a template for its wax imitation. All the information is available and the finished work is simply a display of the artist's dexterity. Modelling fossil plants, in contrast, involves much more interpretation, as so much of the detail is unknown or has been distorted by the fossilization process. The fossil plant models are therefore a culmination of fact, interpretation and skill.

The creation of each model began with a meeting where the palaeobotanists briefed the artist of the necessary background information. With the giant club-mosses, it was vital to understand their environment, growth and reproduction. Next the visual information (fossils, photographs, illustrations, etc.) was collected together. In the case of *Lepidodendron*, there was also an excellent series of fossil specimens held in the museum's collection.

At this stage notes were made of all the reference information, for inclusion on the conservation records (see later). The approximate dimensions, main colours and the structural requirements of the model were determined. The early awareness of these issues was crucial, because some models need to be free-standing and correctly supported. A basic form was then made to fit all these initial requirements. If any concerns arose about the long-term survival of materials which were to be used, the botanical conservator was consulted.

At various times during this planning phase, the palaeobotanists were consulted about areas of uncertainty. By working mainly in-house in the botany laboratory, a close working relationship developed between all parties, so problems could be discussed and dealt with as they arose. Regular meetings were held to discuss the progressing work and, when a model was near completion, there would be a final meeting to decide on exact colours and paint effects. The palaeobotanists sometimes needed to reconsider their preconceptions as to what the plant originally looked like, having previously only seen them preserved as flat black compression fossils or as thin sections through a petrifaction, and this would often instigate a debate over the feasibility of the model. It was, therefore, important for the artist to be versatile in approach because last minute alterations were often required.

Materials used

Before the project began, written information on wax modelling of living plants was gathered, and the botanical conservator consulted about the materials she used when repairing damaged models. Several wax models by the botanical artists Eveline Jenkins and Roy Herbert from the existing collection were examined to gain further understanding. Having recognized certain structural weaknesses and poor materials in these older models, the new ones were constructed to minimize these problems, making them easier to maintain in the future and thus extending their life span. There was, nevertheless, much experimentation needed before the best methods had been established.

Wax has been repeatedly found to be the best medium for modelling living plants as it is extremely manipulable and has a life like quality. It also has the advantage over modern plastic polymers that it can be reworked, allowing the artist to sculpt directly without creating unalterable casts. A mixture of pure white bleached beeswax and paraffin wax was used, the proportions of the two waxes depending on the complexity of the area being modelled. Beeswax was best for fine detail, but has a very fast setting time and was difficult to use alone. Adding paraffin wax increased the working time, but too much paraffin affected the strength of the mixture, eventually causing the model to fracture. A few drops of Canada balsam added to the wax gave it more flexibility. The ingredients were melted together in metal baking trays over an electrical hob with controlled temperature settings. Oil paints were mixed directly into the molten wax to achieve the desired colours.

Most models were constructed in sections and only assembled towards the end. The main structure of large sections was formed from any material that would remain inert whilst in contact with the surrounding wax coating. Good materials were found to be cardboard, paper, tissue, plastic, glass and fabric, all of which could be coated with molten wax using a paintbrush. Paper was particularly good as it absorbs the wax and forms a solid bond which will not separate over time. Metal was generally avoided, but tinned copper wire proved to be useful for plant stems and leaves. Copper is strong enough to support the weight of a model and retain its correct position, but is also very malleable and can be stretched to remove kinks, cut to the desired length, and tapered by dipping into concentrated nitric acid. The use of tinned copper prevented any undesired chemical reactions with the wax.

Smaller leaves and other plant organs were constructed from sheets of suitably absorbent material dipped into molten wax and then slowly withdrawn, allowing the surplus wax to drain off. Required shapes could then be cut from these waxed sheets either with scissors or a surgical scalpel. Fine details such as surface hairs were achieved by dipping thin nylon or cotton threads into the wax.

The resulting parts were then assembled to produce the whole model. An essential piece of equipment for this process was a gas iron (a small pen-shaped tool that can be refilled with butane lighter gas) which enables the artist to work directly without spending valuable time re-heating cooling tools. It has a temperature control and a variety of different heads including a Bunsen flame, hot air torch and purpose shaped soldering tips. Parts of the model were fused together using metal tools heated to the correct temperature over the Bunsen. The hot air torch was also used to fuse sections of wax together, without having physically to touch the surface. Other surface effects were created using lino cutting tools, sandpaper and metal files.

Finally, the entire model was painted and sometimes varnished. Special attention was given to the painting of leaves and other flat structures, because exhibition lighting would often shine through the thin wax, thereby revealing the inner components of wire and paper. This would give it a somewhat lumpy and unreal appearance. Oils are usually best for painting the models because they give a good even coverage and have a long drying period, making them easy to blend and remove. Good colours are crucial for the plants to appear real, but are unfortunately the most uncertain factor. An attempt is made to relate colours to the living plant families, but sometimes complete guesswork is inevitable. To make the plant look even more convincing, different finishes can be created by thinning the paints with white spirit for a matt effect, or adding linseed oil for a glossy sheen. Varnishes are also available in matt or gloss, and are used to strengthen the paint work, and protect unpainted areas from blooming whilst in storage.

Modelling the trunk (Figure 3)

It was obviously impossible to reconstruct an entire *Lepidodendron* tree and so separate models of the main parts of the plant were made. To represent the trunk, a life size cross section was considered the most appropriate solution for the available gallery space. In this particular reconstruction, the aim was to suggest the different layers of tissue exposed during the ageing of the trunk. Bearing in mind the size of the model, cardboard and paper seemed to be the most suitable materials to construct a stable hollow shell.

Two rectangular sections of card were assembled together, one left flat at the back and the other bent into a smooth curve around the front. The top and bottom parts were cut out of heavy cartridge paper and fused to the card with tissue paper and molten wax. In order to illustrate individual layers the model was cut radially in half and one side in half again, with each segment repositioned to create different thicknesses. At this stage the only decision made about the colouring was

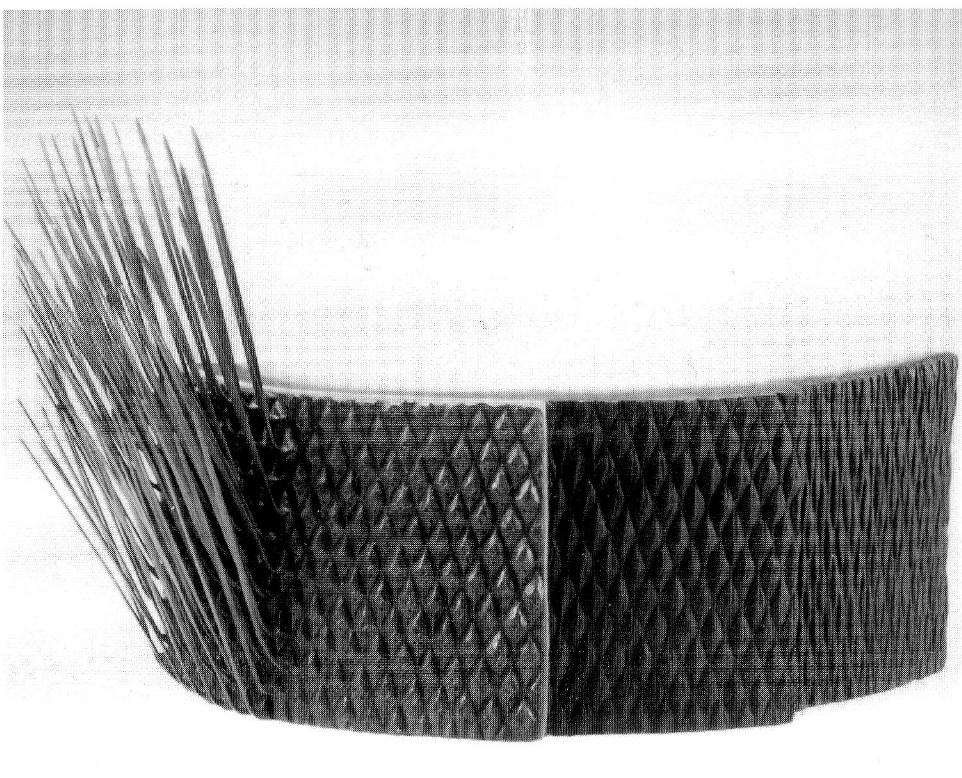

Figure 3. This model of part of a trunk of *Lepidodendron* shows four 'surfaces' representing types of preservation that can be found in the fossil record: far left, with leaves still attached (such large trunks with leaves still attached tend to be rare); middle left, after leaves have been shed; middle right, after the outer layer of leaf-bases has been sloughed-off; far right, after the outer layer of periderm has been removed.

that the left half showing the outer leaves and leaf-cushions would be green, and the right half brown showing the inner layers of periderm. The molten wax was therefore prepared accordingly and painted onto the cardboard structure to achieve a uniform covering.

Referring directly to the fossil material, small sections of pattern were sketched to represent each of the surfaces, then repeated into larger areas using tracing paper and a light box. To save time, the images were transferred straight onto the front of the model by fusing the tracings with a hot metal tool, thereby leaving a smooth surface with clearly visible pencil outlines. The surface features were built up with extra wax or gouged out with a lino-cutting tool. These methods were applied until a satisfactory effect had been achieved, then the finer details were sculpted with metal tools. Finally the surfaces were smoothed down with white spirit to remove any small imperfections.

To enable the leaves to stand upright, thin tinned copper wires were stretched and cut, allowing a surplus length which could be firmly attached inside the trunk. Each of the wires were sandwiched between layers of tissue paper and coated with wax. Using the wire to represent the midrib, leaf shapes were cut from the surrounding waxed tissue paper. The edges were then sand papered leaving a slightly curved surface to give the leaves a fleshy, life-like appearance. Using a hot metal needle, small holes were pierced from the front to the centre of the trunk. Then by easing the surplus wires through each hole the leaves could be correctly positioned on the leaf cushions. A flap was cut out of the back panel of the model to give enough working space to secure the leaves from the inside by bending back the surplus wire. The leaves were fused on by carefully brushing molten wax onto where they join the outer surface of the trunk. Although the back panel would not be visible when the finished piece was displayed, the flap was re-closed to conceal the untidy workings and prevent unnecessary damage. It was also left slightly visible and included on the conservation records, so that it can be easily opened by a conservator for future repairs, if the need ever arises.

Modelling the cones (Figure 4)

To demonstrate this part of the plant, it was decided to model both a complete cone and a number of isolated sporophylls. The complete cone proved to be a relatively easy task. Although some models may appear to be complex, it is often the case that once a technique has been determined other areas are simply a matter of repetition. The *Flemingites* cone was constructed with a single wire running through the length of the model giving it strong support. The central block was built up

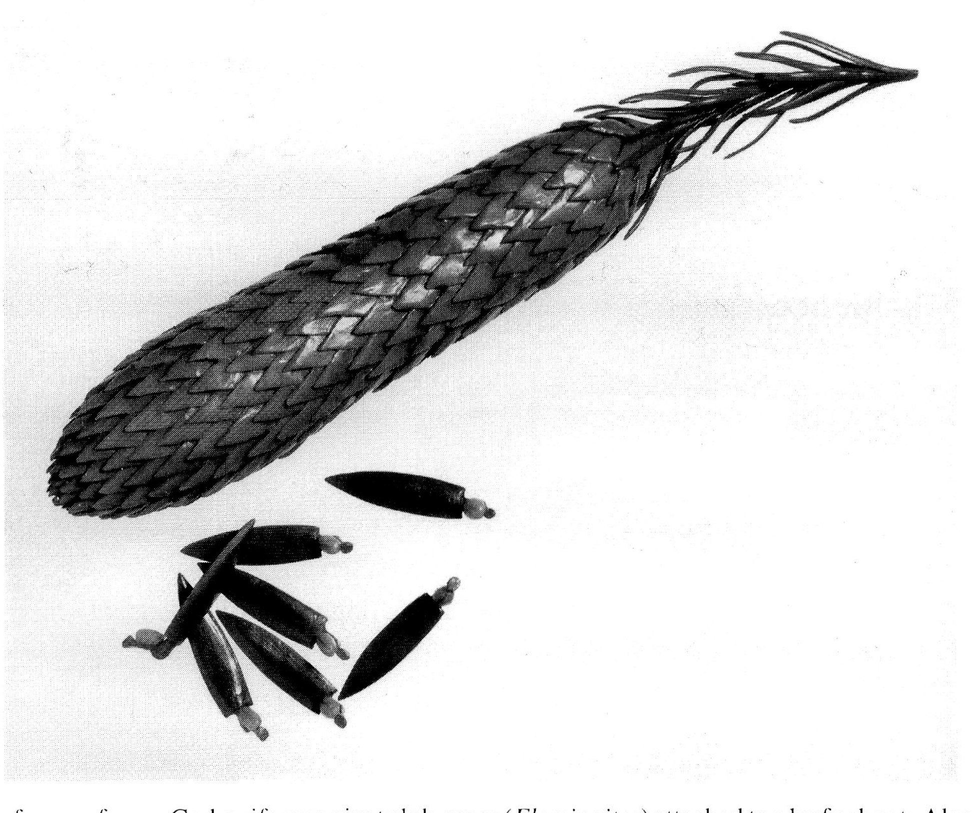

Figure 4. Model of a cone from a Carboniferous giant club-moss (*Flemingites*) attached to a leafy shoot. Also, seven isolated sporophylls from another club-moss cone (*Lepidocarpon*), which were shed as an aid to dispersal.

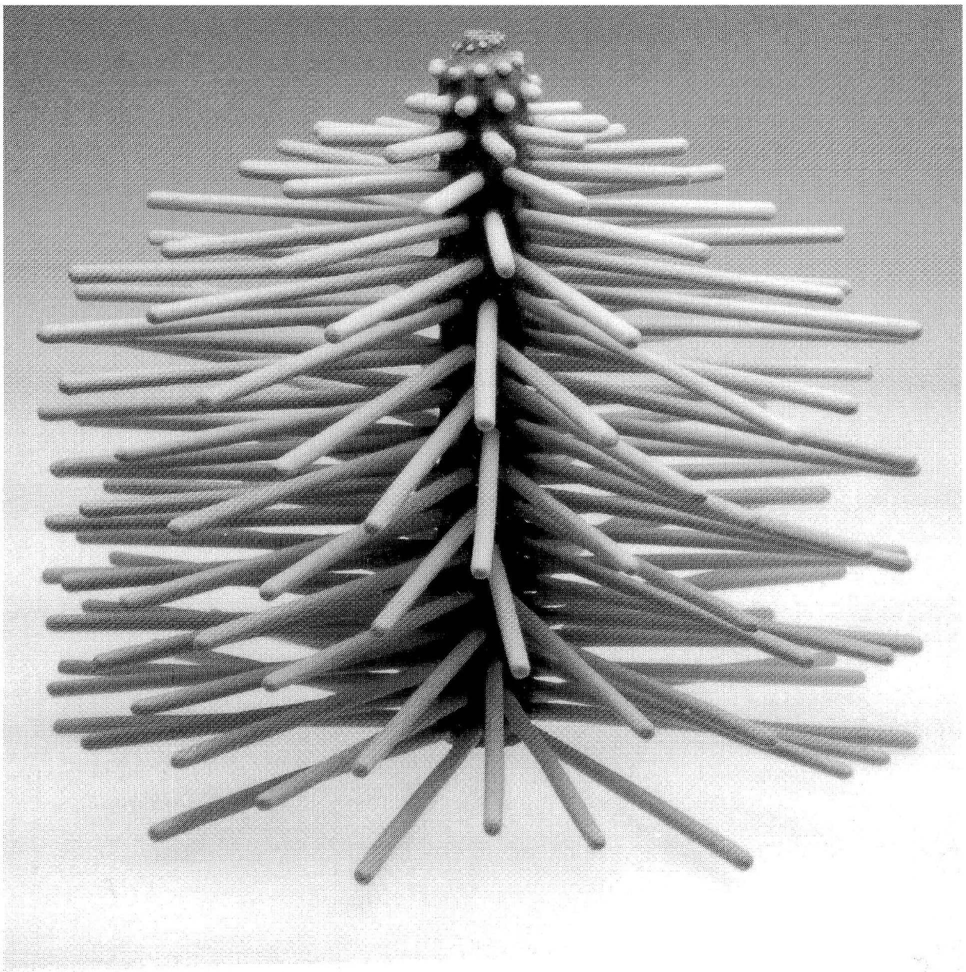

Figure 5. Model of the terminal part of a *Stigmaria* rooting structure, showing the helically arranged true roots arising ar right angles to the main axis.

by brushing on layers of molten wax until the correct thickness was achieved. Modern conifer cones in the Museum's herbarium were used as a reference point for the outer helical configuration of the sporophylls. Work began at the apex of the cone, attaching small waxed triangles of tissue paper into the desired pattern, and slowly advancing downwards to maintain the even taper of the cone. The cone was attached to a short length of leafy shoot (see below).

The accompanying seven isolated sporophylls were difficult to make because of their small size. Nevertheless, by employing very simple techniques and carefully manipulating the equipment, they were completed quickly. Each sporophyll also has a central wire which runs its whole length and is built up with a body of tissue paper.

Modelling the rooting structures (Figure 5)

The *Stigmaria* model illustrates the apex of a main rooting branch and the helical arrangement of its smaller lateral appendages. The model was constructed in a vertical position and later displayed horizontally. The main axis was made from a paper rectangle rolled into a tube, and secured in position with molten wax. The apex was closed to form a rimmed depression and further coats of coloured wax were applied to achieve a satisfactory shape. The base end of the hollow tube was left open to provide a point from which the model could be secured to a display mount. To create the smaller lateral roots many lengths of wire were stretched and cut allowing a short surplus length. Molten wax was brushed onto each wire to increase its diameter, then by rolling and sand papering the surface imperfections were removed. Working from the base upwards, each wire was carefully eased into holes pierced in the central tube. Molten wax was then applied to the adjoining areas to fuse the smaller roots in position.

Modelling the leafy shoots (Figure 6)

Several equal lengths of thick wire were used to form the internal structure of the *Lepidodendron* branch. The lower parts of the thick wires were grouped together to form the base section and wrapped with thin wire to bind them securely. At each dichotomy the group of wires were divided in half and bent outwards to create a fork. This process was repeated until each single wire formed an apex. The structure was then coated with

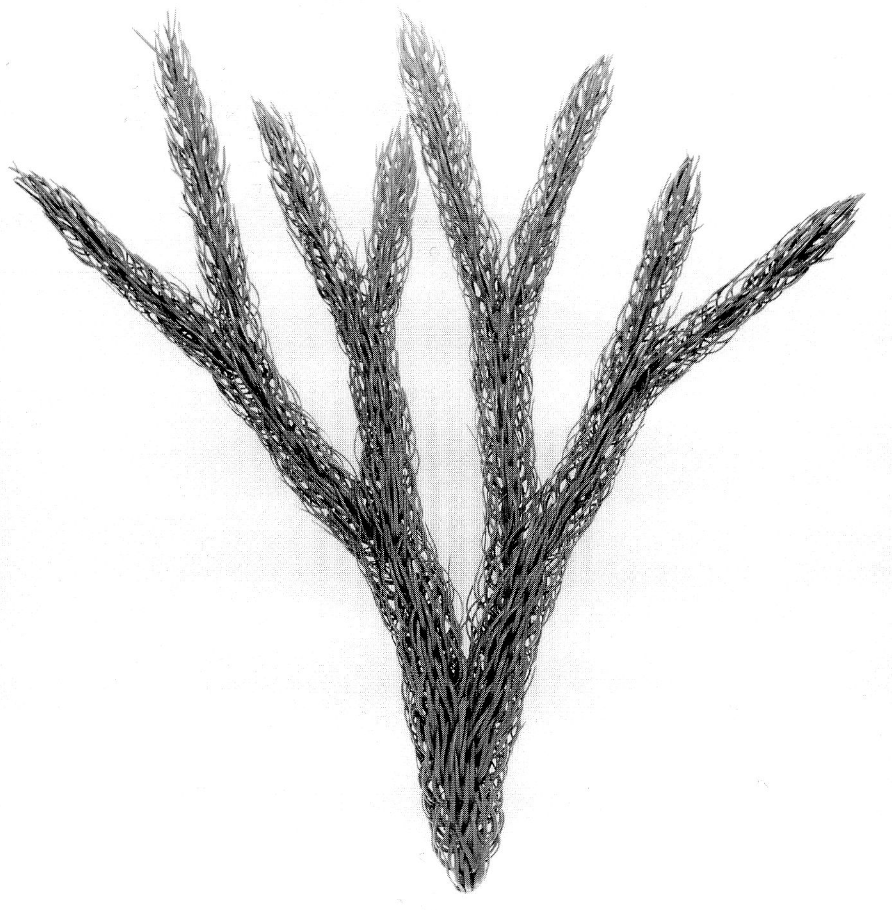

Figure 6. Model of the terminal part of a dichotomising shoot from a mature *Lepidodendron*, showing densely packed, helically arranged leaves.

coloured molten wax. Similar versions of the *Lepidodendron* trunk leaves were constructed by employing the same technique on a smaller scale. Starting at each apex the smallest leaves were individually fused onto the stems with a hot metal tool. Continuing in a spiralling pattern, the length and width of the leaves were gradually increased toward the base of the model.

Conservation records

The Museum's experience with its collection of botanical wax models has shown that details of how a model is constructed can be crucial for its long-term conservation and later repair work. The exact quantities of bees wax and paraffin wax, the particular methods of construction, and other 'hidden' materials used in its internal construction are in many instances unknown. With technology constantly replacing artistic interpretation, competition has increased over the commissioning of exhibition displays and many skilled wax modellers have therefore become reluctant to pass on their techniques.

When a model was finished any relevant details were noted in the conservation record files. This included a diagram showing what materials were used in different parts of the model, and the month and year the model was made. Any surplus wax and spare parts were attached to the records, which can be used as replacements if the model is damaged, or for chemical analysis if additional wax needs to be prepared for more substantial repair. The model was then photographed, packaged securely in an acid free box, given an accession number and entered onto the museum computer database.

Conclusions

The usual construction time for a model was ten to twenty-five days, depending on its complexity and size, and was thus a significant investment in resources for the museum. The most obvious potential use of these models is in the gallery displays of the museum, where they help bring to life the vegetation of the Coal Measures forests in the minds of the viewing public. With smaller plants, it is possible to show exactly what they must have looked like in life, and can be placed next to the fossils in a display. For the larger plants, such as the giant club mosses, a three-dimensional reconstruction would have been impractical, at least in the sort of detail that we were trying to achieve. In such instances, the models of the parts of the plant were combined with two-dimensional reconstructions of the whole plant.

The models have also proved useful in more informal displays, such as those laid on by the Museum during 'Science Week'. We were reluctant to hide the models in glass-cases and so ran the risk of them being damaged by being touched by overcurious members of the public. This necessitated the display being permanently manned while the public was present. However, the impact that the models made was considerable, and enabled concepts such as fossilization, and the relationship between these extinct plants and their modern counterparts to be explained much more clearly.

One of the most important functions of museums is to explain to the lay public the concepts that lie behind the specimens that are in their care. In the case of plant fossils, it is vital that realistic images of the extinct organisms are re-created, to show what they looked like when they were living plants. Model making can play a central role in this, but will only be fully successful if the models look life-like. Stilted, lifeless models are little better than the original fossils. To achieve this, it is vital that model-makers and palaeobotanists collaborate closely at every stage if we are to achieve fully our goal of 'bringing the forests alive'.

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ST PETERSBURG MUSEUMS.

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The Geological Curator 6(10): 362 [1998]

Last September I was able to visit St Petersburg where I saw (finally as I'd been trying for 22 years) the famous Siberian "frozen" mammoths and other Pleistocene specimens at the wonderful Zoological Museum beside the River Nevsky. Here too were excellent Recent fish and tunicate displays. Over the road was the fabulous Hermitage with its geological and mineral treasures.

At the VSEGEI Geological Museum, I met Nina Michailovna Kadlets, the curator, and was shown the leather-bound 1897 International Geological Congress Memorial volume with signatures of some now very famous palaeontologists and geologists. There is an excellent series of posters giving the history of VSEGEI and geological mapping. Among their treasures I saw the D.V. Obruchev collection of Devonian fishes of the Leningrad district and A.P. Karpinsky's collection of Permian *Helicoprion* tooth whorls. To back up the comprehensive mineral displays there was an astonishing full wall map of the (now defunct) U.S.S.R. executed in minerals (lapis, malachite etc.), and there was an excellent building stones collection giving background to the wonders of St Petersburg buildings.

Catalogues of the collections are available for a reasonable price (around US$5):

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PYRITE OXIDATION AND MUSEUM COLLECTIONS: A REVIEW OF THEORY AND CONSERVATION TREATMENTS.

by Andrew Newman

Newman, A. 1998. Pyrite oxidation and museum collections: A review of theory and conservation treatments. *The Geological Curator* 6(10): 363-371.

The literature relating to the causes of pyrite oxidation is extensive and widely dispersed, and the conclusions drawn often appear contradictory. Different mechanisms for the oxidation process are advocated, many of which are supported by experimental evidence that is difficult to evaluate. The range of literature relating to the problem of pyrite oxidation in a museum context is more limited and has resulted in a consensus about conservation treatments, although these have yet to be proven successful in the long term. This review will build upon the earlier critiques published by Howie (1977*a*, *b*, 1992) and Waller (1987) and consider the most recently published work. The review is necessarily selective concentrating on the literature which has significance to museum collections.

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Introduction

Howie (1977*a*, 1992) stated that the oxidation of pyritic specimens in museum collections is one of the most potentially damaging conservation problems encountered by curators and conservators of geological material. However the problem is not confined to geological specimens, vulnerable specimens may be contained within a range of collections For example, Oddy (1977), described problems caused by pyrite oxidation in archaeological collections.

The oxidation process and its consequences are recognisable by the presence of a white, yellow or greenish efflorescence, often accompanied by deep cracks in the specimen (see Figures 1 & 2). There is always a sulfurous smell present. It appears as if the specimen is being forced apart internally which results in its fabric or form being distorted. The products of the oxidation reaction are acidic and are capable of damaging associated labels and storage furniture (see Figure 2).

In order to reduce damage to specimens, to minimise further damage to affected specimens and to determine a conservation strategy, it is important to have a clear understanding of the current knowledge of the mechanisms of pyrite oxidation and the factors which influence reactions and their rates.

Possible mechanisms for the chemical oxidation of pyrite

A number of different mechanisms, either acting independently or in conjunction with each other, have been proposed for pyrite oxidation over recent years. These are a) molecular, b) bacteriological and c) electrochemical. Experimental work has also indicated that a number of factors will influence the rate of the reaction. The relationship between the reaction, its rate and any subsequent damage to specimens in a museum environment will be discussed later in this article.

Waller (1987), Howie (1992) and Lowson (1982) described a broad based oxidation process which results in a variety of ferrous-ferric-sulfate-hydroxide-hydrate phases and sulfuric acid. Waller (1987) gave the predominate overall reaction at high RH as:

$$2FeS_2+70_2+n+m2H_20 \rightarrow 2FeS0_4 \cdot nH_20+2H_2S0_4+mH_20$$

Also at low and moderate RH and 25C the following reaction is quoted.

$$FeS_2+H_2O+30_2 \rightarrow FeSO_4 \cdot H_2+SO_2$$

Both the oxidation products are hydrated and the sulfuric acid is in solution in water. It is important to note that the hygroscopic nature of the oxidation products have the potential to facilitate the reaction by the absorption of water.

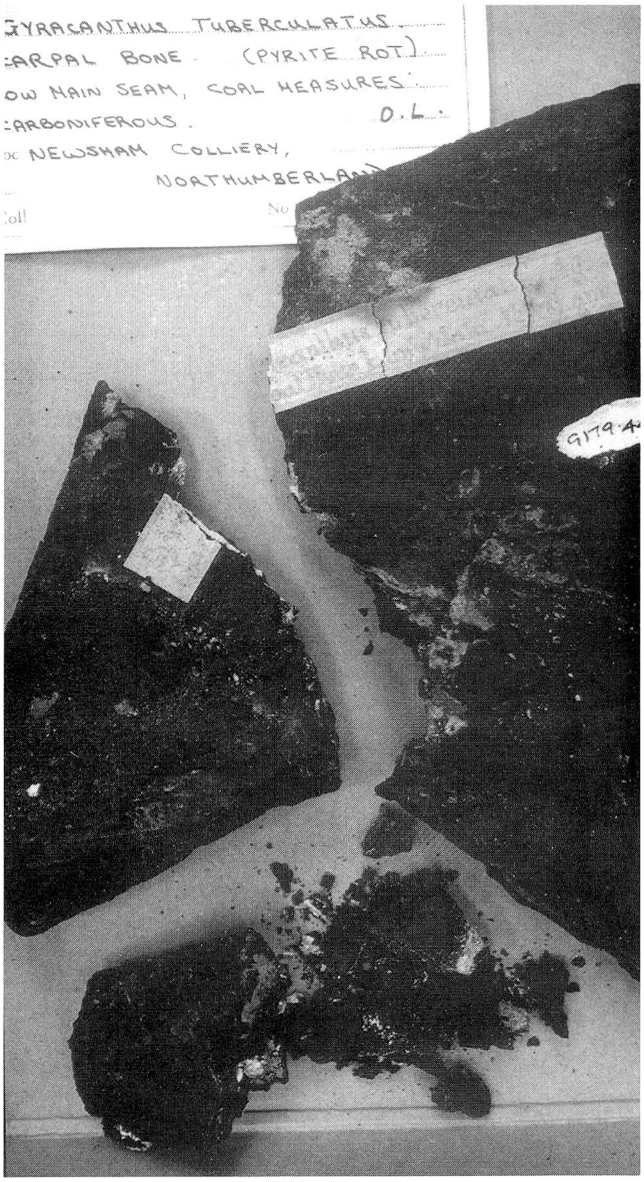

Figure 1. *Gyracanthus tubercalatus* bone. NEWHM: G179.44. Before treatment.

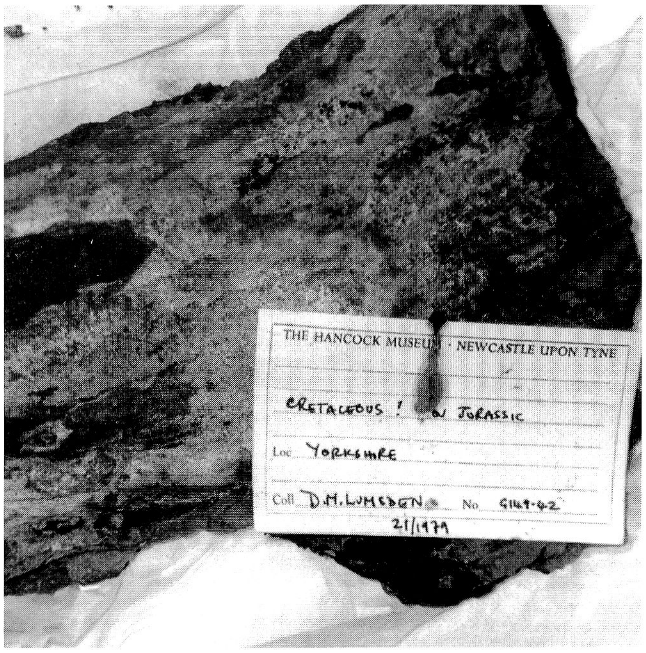

Figure 2. Fossil wood. NEWHM: G149.42. Before treatment. Note damage to label.

Smith and Shumate (1970) and Pugh, Hossner and Dixon (1984) after practical studies presented a case for two reaction pathways for oxidation, firstly, one which involved chemical activity alone and secondly, a path which consisted of the oxidation by ferric ions which are formed from ferrous ions by bacteria. Nordstrom (1982) also makes a clear distinction between organic and inorganic mechanisms. The possible role of bacteria in relation to the rate of reaction is discussed later in this article.

An electrochemical mechanism was discussed by Howie (1986*a*, 1992), Peters (1984), Bang (1994) Luther (1987) and Lowson (1982). Howie (1992) stated that it might "contribute as much as 50% of the oxidation mechanism". This may explain the apparent susceptibility of specimens which are associated with carbon (Bang 1994). This vulnerability was demonstrated by Howie (1979*b*) who showed experimentally that "the carbonaceous pyritic specimens showed a tendency for some oxidation to occur below 50% RH". Bang (1994) stated that the reason why framboidal pyrite (Rust 1935; Wilkin and Barnes 1997; Schopf, Ehlers, Stiles and Birle 1965; Love 1958) when associated with organic matrices was very susceptible was that each framboidal spheroid reacts like a galvanic system when moisture enters it by capillary action. It was concluded that in this system pyrite is oxidised anodically creating acidic conditions which lead to the chemical and mechanical breakdown of the framboidal pyrite spheroids. This interesting theory does not account for the loss of specimens which are not associated with carbon. The above work has lead to the possibility of new treatments using plasma-ashing methods (Hollahan and Bell 1974; Bang 1994) to remove the carbon from specimens, so disrupting the electrochemical process. This technique will be discussed later in this article.

The literature does not provide a consensus view as to which of the above mechanisms controls the oxidation process. It is probable, however, that all of the mechanisms discussed play a role in particular environments. However, the fundamental driving force of pyrite oxidation remains unclear despite many years of study.

Factors controlling the rate of pyrite oxidation

The reviews by Howie (1992), Waller (1987), Nordstrom (1982) and Lowson (1982) as well as the experimental work by Morth and Smith (1966) Smith and Shumate (1970) and Khawaja (1975) concluded that the oxidation reaction, its rate and subsequent damage to specimens was probably dependent on a number of factors. These are the surface area, availability of water, temperature, pH, bacteria and oxygen concentration, in an aqueous or gaseous state. The role of trace element distribution was discussed by Caruccio (1972).

Surface area

Experimental work by Howie (1979*b*, 1992), Pugh, Hossner and Dixon (1982) Smith and Shumate (1970) and Khawaja (1975) indicated that the surface area of the pyrite influenced the rate of the oxidation reaction. These authors stated that microcrystalline or framboidal pyrite (Rust 1935; Schopf, Ehlers, Stiles and Birle 1965; Love 1958; Wilkin and Barnes 1997) is more reactive than massive, due to the available surface area upon which the reaction can occur. The study published by Howie (1979*b*) showed that compact pyrite had "little tendency to absorb moisture and oxidise even at high RH during the test period", which was 105 days. He stated that specimens with "microcrystalline and framboidal pyrite showed a wide variation in their capacity to oxidise". Pugh, Hossner and Dixon (1984) reported that "a two fold increase in reaction rate occurs for the frambroidal pyrite compared with the massive". Khawaja (1975) from the basis of an extensive study showed that it was possible to classify pyrite by its rate of oxidation. Every sample of highly oxidisable pyrite studied had a grain size of less than 10 microns with associated carbon, moderately oxidisable pyrite had a grain size in the 15-25 micron range, with little associated carbon and pyrite that was weakly oxidisable, had a grain size of over 25 microns with no associated carbon. Curracio (1972) described a study carried out on the stability of pyrite in relation to mine drainage. He stated that "size alone is not the answer, coarse grained pyrite was mechanically ground to 0.5 microns and after 3 weeks the ground sample was still yellow and bright and showed no signs of decomposition". If this work is accurate it appears to indicate that the relationship between surface area and reactivity may not be direct in all cases. Lowson (1982) also stated that the published experimental data is not really sufficient to support a clear link. The possibility that framboidal pyrite may play an important role in an electrochemical mechanism for oxidation (Bang 1994) has been mentioned earlier.

The role of water

Morth and Smith (1966) quoted a study carried out by Kim (1964) which showed that that over a limited temperature range the rate of the oxidation reaction varied in a linear fashion with absolute humidity of water in the vapour phase, suggesting that water was a reactant. Studies by Morth and Smith (1966) and Smith and Shumate (1970) showed that the oxidation rate increased steadily as a function of RH. They also suggested that the role of water may be to dissolve the oxidation products from the pyrite surface, which would otherwise inhibit the oxidation reaction on a dry surface. Studies carried out by Waller (1989) showed that oxidation rates increased exponentially as RH increases from 10% to about 60%. Water is also significant in that it enables ferrous sulfate, a product of the oxidation reaction to hydrate at an RH of about 60% (Waller 1987) which results in a molar expansion. The importance of this process to the stability of museum collections is discussed later in this article.

Temperature

Waller (1987), Morth and Smith (1966) and Smith and Shumate (1970) showed the relationship between temperature and the oxidation rate. This was represented graphically by Morth and Smith (1966) and Smith and Shumate (1970). These results showed clearly that the reaction proceeded more quickly with an increase in temperature. The authors calculated that the oxidation rate will approximately double for each 10°C rise in temperature at a constant RH.

pH

Waller (1987), Howie (1992) and Smith and Shumate (1970) discussed the role of pH on the rate of the reaction. Howie (1992) stated that under alkaline conditions oxidation products can build up on the reactive surface of the pyrite and slow the rate of the reaction. Waller (1987) stated that there is little or no dependency of the oxidation rate on pH over the range $-1<pH<4$ and at higher levels the oxidation rate will increase as a function of pH. Smith and Shumate (1970) showed experimentally that as the pH increased the oxidation rate increased rapidly. They were not able to explain these results as conventional wisdom would suggest the opposite would be true (Howie 1992). Nordstrom (1982) stated that in aqueous environments below a pH of 3 the oxidation rates are independent of pH and above 4 rate limiting steps, described in the paper, are pH dependant.

Oxygen concentration

Morth and Smith (1966) and Smith and Shumate (1970) showed experimentally that if the oxygen concentration in water surrounding the reactive site on the pyrite increased the rate of the reaction also increased. They also stated that the presence of nitrogen gas reduces the rate of oxidation. Waller (1987) did not deal with this subject in detail but mentions oxygen concentration as a possible factor controlling oxidation rates.

Sulfur reducing bacteria

The possible role of sulfur reducing bacteria in effecting the oxidation reaction has been considered by Pugh, Hossner and Dixon (1984) in lignite specimens and

Siverman (1967) in pyrite concentrates from coals. Nordstrom (1982) and Smith and Shumate (1970) also proposed a mechanism for oxidation involving bacteria.

Pugh, Hossner and Dixon (1984) described a number of studies (Temple and Koehler 1954; Lorenz and Tarpley 1963; and Wilson and Zuberer 1976) which considered the role of bacteria such as *Thiobacillus ferrooxidans* and *Thiobacillus thiooxidans* on the oxidation rate of various iron sulphides as well as carrying out their own experimental work. They noted that the results of these studies were very variable and other factors must play a role. However, they concluded that the presence of *Thiobacillus ferriooxidans* can "significantly increase pyrite oxidation".

Silverman (1967) described a practical study from which he concluded that two methods of bacterial oxidation of pyrite occur. Firstly a method which required physical contact between bacteria and pyrite particles for biological pyrite oxidation. The second is an indirect method which involves "bacteria oxidising ferrous ions to the ferric state thereby regenerating the ferric ions required for chemical oxidation of pyrite." Smith and Shumate (1970) also described a direct and indirect method of biological oxidation. They also showed that sulfur reducing bacteria require a high RH to operate.

Trace elements

The possibility that trace element distribution may play a role in the oxidation reaction and subsequent stability of pyrite was discussed by Caruccio (1972). In his study 18 samples of pyrite were analysed, these included both reactive and inert samples. The results showed that there was more titanium in the stable samples than in the reactive ones and silver was present in the reactive samples and absent from the stable ones. Caruccio asked the question whether titanium stabilises pyrite or silver causes pyrite oxidation, however, Smith and Shumate (1970) stated that trace elements and other metals were not a major factor influencing reactivity.

Discussion of pyrite oxidation mechanisms and factors influencing the rate of reaction in relation to museum specimens.

As can be seen from the selective review given above, the literature concerning pyrite oxidation and factors controlling its rate is extensive and to some extent contradictory. The original impetus for research on pyrite oxidation related to its possible involvement in explosions in coal mines and more recently in relation to acid mine drainage water, a source of environmental pollution. Despite the bias of the research to mining problems it is possible to apply much of the consequent results to the museum situation and use the data to draw conclusions as to the safest environmental parameters in which to store vulnerable pyritic specimens.

The different mechanisms and reaction pathways proposed for pyrite oxidation are important because if they are applicable to a museum environment they will influence conservation strategies.

The fact that increased temperatures speed up the oxidation reaction has been demonstrated by Waller (1987), Morth and Smith (1966) and Smith and Shumate (1970). It is therefore important to store specimens at the lowest practical temperatures. The common use of small scale portable dehumidifiers (either based on a heat pump or desiccant wheel) must be a cause for concern as both are responsible for elevated temperatures in store rooms.

The effects of changes in pH and oxygen concentration are difficult to determine in relation to museum collections as the existing work (Morth and Smith 1966, Smith and Shumate 1970) relates only to aqueous environments. However, a reduction in oxygen concentration in a storage environment should reduce the reaction rate. It is difficult to relate changes in pH to museum collections, however, it is probably not a significant factor.

There is clear evidence that bacteria can play a role in the oxidation of pyrite (Pugh, Hossner and Dixon 1984; Silverman 1967; Smith and Shumate 1970). However, the possible role of bacteria in the oxidation of pyrite associated with museum specimens has been reviewed and considered unlikely by Howie (1979*b*, 1992). This view is based on the fact that bactericides do not protect specimens and attempts to culture bacteria from oxidising museum specimens has been unsuccessful. Smith and Shumate (1970) stated that in a low pyrite to water ratio system the oxidation mechanism may be mainly bacteriological and in a high pyrite to water system the mechanism will be mainly chemical. Museum collections are analogous to a high pyrite to water system.

The possibility that trace elements play a role in pyrite oxidation (Caruccio 1972) has yet to be proved. The study described is limited with a small sample size. Caruccio (1972) does not prove a link between trace element distribution and pyrite stability. Other workers (Smith and Shumate 1970) dismissed the possibility. Therefore, it is probable that trace element distribution has no known significance for the stability of museum collections.

The damage caused to pyritic museum specimens by high RH has been recognised for many years. It was considered an important factor by Radley (1929) and Bannister (1933), although, both authors postulated that other factors played a role. Bannister and Sweet (1943) concluded that "it has become only too obvious that a damp atmosphere speeds up the decomposition of pyrite". They recommended that specimens should never be treated with acid or washed in water.

Morth and Smith (1966) and Smith and Shumate (1970) showed experimentally that the rate of the oxidation reaction increased steadily with an increase in RH. Howie (1992) reviewed a paper by Wexler (1965) which stated that a mono-layer of water will form between 0% and 30%-60% RH and a multi-layer between 30%-60% and 90% RH on the surface of pyrite. Howie (1992) concluded that at between 30% and 60% RH sufficient water vapour is present to allow partially aqueous oxidation reactions to occur on the surface of the pyritic specimens. He stated that from this evidence the critical level of RH was possibly 30%. Waller (1987) calculated that the oxidation rate will double every 26% increase in RH. Experimental work by Howie (1979*b*) seemed to indicate that for many cases above a critical level of about 60% RH moisture absorption increased markedly in museum specimens and damage occurred. This related to work by Waller (1987, fig. 2) who showed the effect of RH on the hydration reactions that occur in the oxidation products. At about 60% RH a molar volume expansion of 256% occurs. This expansion is responsible for the cracking and damage associated with pyrite oxidation in museum specimens.

It is unclear to what extent the electrochemical mechanism of pyrite oxidation (Bang 1994) is influenced by RH in a museum environment. However, Howie (1979*b*) showed that specimens associated with carbon become unstable at a level of below 50% RH, about 10% lower than those without carbon. This may imply that for such specimens the electrochemical mechanism is playing a more significant role (Bang 1994). Therefore collections with a high carbon content need to be stored at levels of RH as low as possible, preferably less than 30%.

Work by Pugh, Hossner and Dixon (1984), Smith and Shumate (1970), Khawaja (1975) and others stated that the surface area of the pyrite will influence stability, while others (Lowson 1982) disputed the available evidence. However, this relationship is seen in museum collections (Howie 1979*b*, 1992). Specimens containing fine grained pyrite are more vulnerable than those with the massive form. The stability is again RH dependant and so levels in store rooms again need to be as low as possible.

Summary

From the above review it is apparent that RH is the critical environmental factor which controls the stability of pyritic museum specimens. A level of not more than 30% has been recommended (Howie 1992) to provide protection. However, a practical study of the pyritic collections of the Hancock Museum, Newcastle upon Tyne has shown that after treatment with dry ammonia gas and storage in an environment with a RH of about 40% the collection has remained stable since 1985. (A more detailed account of the success of this conservation programme will be published separately). For most collections, without the use of micro-climates, 40% RH is a more realistic target for easily available dehumidification systems. Relative humidity of these levels will also prevent the damaging hydration reactions occurring in the oxidation products. Temperature also speeds up the rate of the oxidation reaction and so it is important not to allow store rooms to become too warm. Other factors may influence the rate of the oxidation reaction but may not have a direct effect on specimen survival. Once the main causes of instability of pyritic specimens in museum collections have been identified it is possible to determine the most effective conservation treatment.

Review of conservation treatments

Before a critique of the various conservation treatments is given it is important to consider the reasons for treating specimens. An effective rational for conservation treatments is given by Waller (1987), who refers to Radley (1929) and Gordon (1947). Both authors stated that the oxidation products are hygroscopic and enhance oxidation rates and Gordon (1947) stated that the removal or neutralisation of the acid decay products is essential to prevent the hydration reactions occurring and causing damage to specimens.

Howie (1977*a*, 1992) and Waller (1987) reviewed many of the conservation treatments which have appeared in the literature. Papers by Cornish and Doyle (1984), Bang (1994), and Booth and Sefton (1970) illustrated other techniques.

The literature described a number of methods which consist of four main approaches, firstly the neutralisation and or removal of the of the decay products, secondly placing a physical barrier between the specimen and atmospheric oxygen, either through coating the specimen or by placing it in an anoxic microenvironment. The third method involves disrupting the electrochemical process by reducing or removing the carbon content of specimens or providing some cathodic protection (Bang 1994). Treatment processes may consist of a combination of the above. The final method (Booth and Sefton 1970; Rixon 1976) presupposed the complicity of bacteria and concentrated on its inhibition.

The neutralisation of the products of the oxidation reaction has been an important part of the treatment process for many years. Bannister (1933) and Bannister and Sweet (1943) recorded that ammonia vapour was being used in the Mineral Department of the Natural History Museum, London. The same method was advocated by Rixon (1976). Firstly the products of decomposition were removed and then the specimen was exposed to vapour from 0.880 ammonia solution for several days. Secondly, the specimen was dried at 50°C and finally coated with Bedacryl 122X. Problems with this approach were highlighted by Howie (1977, 1979*b*) who stated that for large specimens, ammonia vapour only resulted in superficial neutralisation. He also stated that the air above ammonia solutions can have a RH of 70% and that even in these conditions oxidation reactions may occur. One solution to this problem is given by Birker and Kaylor (1986) and Waller (1987) who advocated the use of polyethylene glycol 400 as a humectant to reduce the RH in the ammonia vapour to a level which no longer causes concern. Another solution discussed by Howie (1977*b*, 1979*a*) was the use of dry ammonia gas, which provided effective results. Waller (1987) calculated that damage would occur, due to expansion during the reaction, when the specimen was acclimatised to an RH of less than 20%, which is virtually never the case. An account of the use of dry ammonia gas on pyritic material held by the Hancock Museum, Newcastle upon Tyne, will be published separately.

Rixon (1976) advocated the use of morpholine (1, 4,-tetrahydro oxazine), as a 5% solution in industrial methylated spirit to neutralise the decay products on specimens that were too large to be placed in a gas chamber. Howie (1977*b*) stated that such a process could be effective but it was difficult to use, because of its high toxicity (Clydesdale 1990) and its ability to dissolve consolidants and glues.

A further method to neutralise the products of the oxidation reaction is the use of ethanolamine thioglycollate (Cornish and Doyle 1984). The chemical was proposed because it will react with and remove acidic pyritic oxidation products as well as soluble and insoluble iron compounds. It is also soluble in ethanol or propan-2-ol as are the products of its reactions with pyrite oxidation products. The chemical can be an effective treatment in particular circumstances. An evaluation of this method will be published separately. The application of ethanolamine thioglycollate in the treatment of large specimens is described by Cornish, Doyle and Swannell (1995).

A different approach to the problem of the products of the oxidation reaction is to attempt to remove them rather than neutralise them. Such a procedure was proposed by Gordon (1947). He stated that some success had been achieved using concentrated hydrochloric acid. However, great care had to be taken to be sure that no other minerals were present which may be effected. The mechanical removal of the oxidation products from a specimen might also be an option, however this is normally only attempted together with neutralisation.

The coating of specimens with waxes or soluble plastics is a traditional method of attempting to preserve specimens and has been used by itself or as part of a treatment process (Bather 1908; Radley 1929; Rixon 1976). Howie (1979*b*) experimentally tested the effectiveness of a number of plastic films. A number of pyritic museum specimens were coated with Butvar B98, Bedacryl, Vinylite and compared with a control sample. The results of this work showed that such films were ineffective in preventing deterioration. The reason for this was that all such films are permeable to water vapour to a greater or lesser extent (Thompson 1978), they are easily damaged by abrasion, and once oxidation starts are broken down by the decay products. Radley (1929) also expressed reservations about the effectiveness of such films. A different form of the barrier method is the storage of vulnerable specimens in inert liquids such as mineral oils, liquid paraffin, glycerol, carbon tetrachloride (Bather 1908) or silicone fluids (Rixon 1976). Richardson (1842) and Bather (1908) described the practice of keeping specimens under water. However, the latter author recorded that such a storage medium does not prevent the disintegration of specimens. Rixon (1976) described how, because the removal of mineral oils and liquid paraffin from specimens was difficult, they were often transferred to glycerol. However, this medium is hygroscopic and difficult to maintain successfully in the long term. It proved a problem to remove when specimens were transferred to silicone fluids in the early 1960s. Such a programme was carried out in the Natural History Museum in London and the specimens are now mainly stable 37 years later, with very few showing signs of problems (Tiffany Foster, pers. comm. 1997).

The use of anoxic microenvironments described by Burke (1996) is a possible new way of preserving specimens. He detailed the materials that are needed to form a barrier film and commercially available oxygen absorbers. It is clear that such an approach needs a long-term and detailed evaluation to determine its effectiveness. The existing literature only deals with the effect of varying oxygen concentration on pyrite oxidation in the aqueous phase (Morth and Smith 1966, Smith and Shumate 1970). However, it is likely that that a similar dependence will occur in air. Potential problems with the suggested oxygen absorber, 'Ageless', produced by the Mitsubishi Gas Chemical Company, are that its effectiveness reduces at low relative humidities and that it generates heat when removing oxygen from an environment. Particular types of 'Ageless' may cause increased relative humidities, and determining oxygen concentration in the micro-climate over the longer term may be difficult. Also, the removal of oxygen from a sealed microclimate will result in a 20% volume reduction, which may cause problems. The greatest difficulty is that which is common to all micro-climates, in that the specimens are safe as long as they are not being used. As soon as a specimen is removed for research or some other purpose it will become increasingly unstable in its new environment. The above methodology requires therefore more evaluation as to whether it is applicable to the storage of pyritic specimens in museums.

Bang (1994) proposed the use of a plasma-ashing (Hollahan and Bell, 1974) as a conservation treatment. The rationale behind such an approach is that by the removal of carbon, the electrochemical process responsible for the decomposition of specimens is disrupted. The paper described a number of experiments on fossil material and the apparent success that had been achieved with part of a whale vertebral centrum, however other specimens did not provide conclusive results. The problem with such an approach is that it tends to make specimens brittle and so some sort of artificial strengthening is required. It is also difficult to treat large specimens. Bang (1994) also discussed the possibility of preserving specimens by placing them in a dense mist of electrons providing cathodic protection. The above is interesting as it may provide a new approach to the conservation of pyritic museum specimens. However, the method is still new and it requires extensive evaluation.

As has been stated earlier the complicity of bacteria in the oxidation of pyrite in dry environments, (and so museum specimens), is considered unlikely (Howie 1979, Smith and Shumate 1970). However, as part of this review it is worth mentioning treatments that were used when such a view was considered correct. Booth and Sefton (1970) described the use of 4-chloro-m-cresol as a way of inhibiting the growth of Thiobacilli and Ferrobacilli and so preserving pyritic museum specimens. Rixon (1976) described the use of Cetrimede and Savlon as anti-bacterial agents.

Conclusion

From the above review it is possible to conclude that for museum specimens oxidation has a chemical/ electrochemical pathway. The main cause of damage to specimens are the hydration reactions that occur in the products of the oxidation reaction. The oxidation rate as well as the hydration reactions are directly related to levels of RH. The electrochemical processes are enhanced by the presence of carbon which forms a galvanic corrosive system. Stability of specimens will probably be achieved by storage in a RH of less than 30% although in practice levels up to 40% may also give protection.

The treatment currently recommended is neutralisation and removal of the products of the oxidation reaction, using ammonia vapour, with PEG 400 as a humectant, dry ammonia gas or ethanolomine thioglycollate. Specimens, once treated, must be stored in a low RH environment. The use of plasma-ashing or anoxic environments provide an interesting line of research but are as yet unproven.

The literature lacks any long term evaluation of treatment methods and studies need to be carried out to determine the effectiveness of what is currently seen as best practice. An account of the successful conservation programme carried out on the pyritic collections of the Hancock Museum, Newcastle upon Tyne will be published separately. The methods used, dry ammonia gas and storage in an RH of 40-43%, has stabilised the collection since 1984. However, whether the treatment process, the storage conditions or a combination of both are responsible for specimen stability is unclear. An unpublished review of treated specimens in the Natural History Museum, London (Adrian Doyle pers. comm. 1997), concluded that treatment methods (ethanolamine thioglycollate, ammonia vapour with PEG400) were effective. However, without detailed records of the condition of specimens before treatment definite conclusions were difficult to achieve. Studies are at present being carried out at the Canadian Museum of Nature (Robert Waller pers. comm. 1996) which consider oxidation as a function of RH and chemical treatment. Preliminary results imply that none of the chemical treatments reduce oxidation rates by more than ten fold. The suspicion is that the stability of specimens relates more to preventing the RH dependant hydration reactions occurring in the products of the oxidation reaction rather than the oxidation reaction itself. The implication is that whilst treatment will help to reduce the oxidation reaction, the main way to stabilise specimens is to keep them in a level of RH which will prevent the hydration reactions occurring.

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CASTING A DINOSAUR TRACKWAY FROM THE BENDRICKS, BARRY, SOUTH WALES, U.K.

by Caroline Buttler and Stephen Howe

Buttler, C.J. & Howe, S.R. 1998. Casting a dinosaur trackway from the Bendricks, Barry, South Wales, U.K. *The Geological Curator* 6(10): 373-376.

The Bendricks, just to the east of Barry, South Wales, is the only known Upper Triassic dinosaur footprint site in Britain and the most extensive trackway site in the country. Prior to 1996 all the trackways discovered both at the Bendricks and elsewhere in South Wales, were of animals walking with a bipedal gait but in the autumn of that year a quadrupedal trackway was found on the surface of a fallen block at the eastern end of the section, below high tide level. Due to the thickness of the bed in which the quadruped trackway was preserved, and the problems that cutting and storing large slabs of footprints pose, the decision was taken to attempt to take a mould of the trackway *in situ* from which one or more permanent casts could be made. The cast was taken between tides using a silicone rubber with a very fast catalyst.

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Introduction

The Triassic and early Jurassic strata of South Wales include a well-developed marginal facies (littoral facies of some authors) which, although limited in outcrop, is well exposed at a few points along the Vale of Glamorgan coast. At the Bendricks, just to the east of Barry, the marginal facies of the Upper Triassic Mercia Mudstone Group comprises a sequence of generally horizontally bedded, fine-grained red siltstones, yellow/grey sandstones and coarse conglomerates, that unconformably overlie folded Carboniferous Limestone. Tucker and Burchette (1977) recognised two sub-facies within this sequence, one consisting of fairly coarse conglomerates and cross-bedded sandstones with well sorted pebbles, and the other of finer thin-bedded sandstones, siltstones and marls. They interpreted the coarse conglomerates as representing braided stream channels and bars, and the sandstones as sheet-flood and overbank deposits. The dinosaur footprints occur in the finer sediments along with widespread ripple marks and mudcracks.

Although dinosaur footprints were first discovered in the Triassic deposits of South Wales at Newton Nottage, near Porthcawl in 1878 (Thomas 1879) and again nearby at Nottage sometime before 1927 (Lockley *et al.* 1996) they were not recorded at the Bendricks until 1974 (Tucker and Burchette 1977). Here an area of approximately 25 square metres was found to contain over 450 mainly small (5-6 cm long) tridactyl footprints and 10 larger (10 cm long) tetradactyl footprints that form a distinct trackway, Tucker and Burchette assigned all to the ichnogenus *Anchisauripus*. Since 1974 further examination of the Bendricks outcrop has revealed that dinosaur footprints occur over a much more extensive area than was first realised (Howe 1994) and this locality, the only one known of late Triassic age in Britain, is now recognised as being the most extensive dinosaur footprint site in the country and, perhaps the best site in Europe for such early dinosaur trackways (Benton and Spencer 1995). Its importance led to its designation as a Site of Special Scientific Interest (SSSI) in March 1996. Further fieldwork in 1996 showed that the site contained at least four ichnotaxa distributed through ten stratigraphical levels (Lockley *et al.* 1996), and also that further footprints occur at similar horizons within the Triassic outcrop between the Bendricks and Sully Island, 3 km to the east.

Due to damage by ill-informed fossil collectors, the surface discovered in 1974 was lifted in 1977 and removed to the National Museums and Galleries of Wales (NMGW) where, after cleaning and conservation, nearly 90% of the original surface was eventually re-laid within the *Evolution of Wales* gallery. Two well-preserved parallel trackways, discovered on a surface below high water mark at the western end of the section in 1990 were also removed as they would ultimately have been degraded and destroyed by marine erosion. Part of these can also be viewed within the same exhibition.

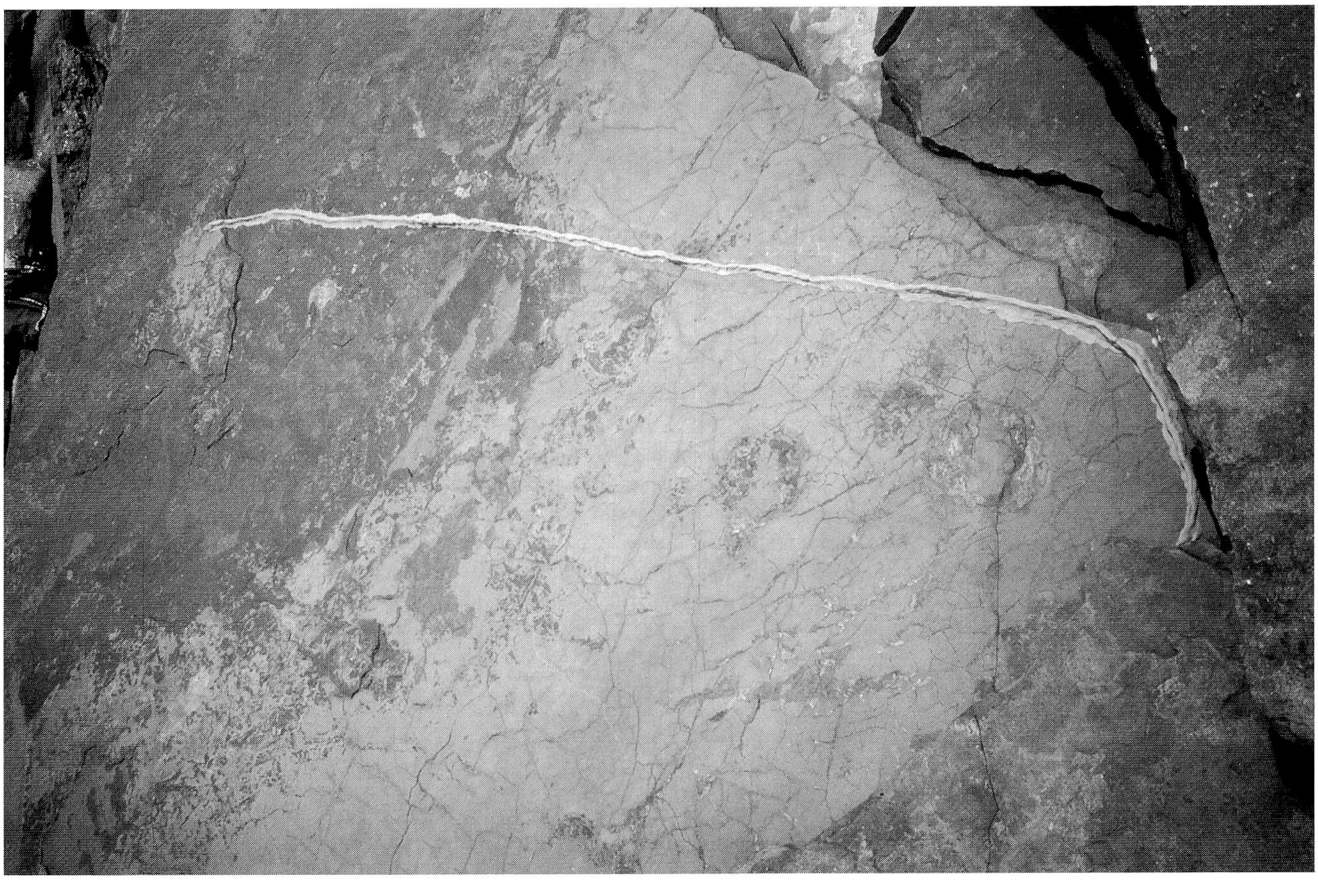

Figure 1. The trackway, with plasticine wall prior to application of silicone rubber. Actual size = 55 cms across.

New quadrupedal trackway

Prior to 1996 all of the trackways discovered at the Bendricks and elsewhere in South Wales were produced by animals walking with a bipedal gait. However, in the autumn of that year a single quadrupedal trackway was found at the eastern end of the Bendricks section on the surface of a fallen block. This had split apart to expose a fine grained red siltstone surface covered with fine mudcracks, and into which was imprinted a 174 cm long trackway which showed the impression of 6 four-toed tracks, including the clear impression of the manus prints just in front, or sometimes slightly overlapped by those of the following pes. These tracks have been assigned to the ichnogenus *Pseudotetrasauropus* (Lockley *et al.* 1996) and are considered to be those of a prosauropod dinosaur. Because the block lay on an exposed part of the foreshore, well below high tide level, it was subject to heavy marine erosion and the footprint surface would rapidly have been destroyed. Due to the thickness of the bed in which the trackway was preserved, and the problems that cutting and storing large slabs of footprints pose, the decision was taken to attempt to take a mould from the trackway *in situ* in order to produce a permanent cast.

Moulding the trackway

Two major problems needed to be overcome; firstly that the moulding had to be completed between tides, and secondly that the weather could affect the moulding process. The position of the block on the middle foreshore meant that the tidal window was estimated to be a maximum of about six hours, and the only time when a low tide occurred in the middle of the day was during a period of high spring tides. After investigating different moulding media it was decided that silicone rubber would provide the best definition of the footprints. However, the moulding had to be done in April and the cool showery weather meant that the air temperatures would slow the curing rate of the silicone rubber, possibly preventing completion of the mould between tides. To solve this problem Dow Corning Silastic 3481 silicone rubber was used with a very fast catalyst (Silastic 81VF), the catalyst reducing the curing time of the rubber by several hours.

We arrived at the locality as the tide was receding from the block. Before the moulding could begin, the surface of the slab had to be allowed to dry which, due to the cool weather, took longer than had been calculated. The area was prepared for moulding as the trackway dried and bounded by a plasticine wall 4 cm high, to contain the silicone rubber. Silicone rubber and the catalyst were mixed in 500 g lots and poured onto the inclined slab, beginning at the highest point, and allowed to flow downwards until a thin skin covered the whole trackway. This was then given one hour to cure. More silicone rubber and catalyst were then mixed with

Figure 2. The trackway with the first coat of silicone rubber.

Silastic Thixo additive, the resulting mixture having a texture of butter-cream icing which could be spread thickly on top of the thin skin. If this had been used from the outset, without the initial thin layer, definition would have been lost. Gauze bandages were laid and gently pushed into the top surface of the rubber to protect the mould from tearing. This top layer took approximately one hour to cure, after which the mould was removed gradually from the block and rolled ready for transport back to the museum, where it was then laid flat. Only a few small pieces of sediment adhered to the mould and, other than that, no damage was done to the block or trackway.

Two heavy showers of rain during the moulding of the trackway might have posed problems. Fortunately the rock surface was not exposed during either of these showers because the first occurred just after the thin layer had been applied, and the second during the application of the thick upper layer and throughout the duration of the showers a plastic sheet was held over the area to prevent it getting wet. Water did pond slightly at the bottom of the specimen but this was easily mopped up and did not damage the mould in any way.

Casting

Two casts have so far been taken from the mould, one for the NMGW and the other for Professor Martin

Figure 3. Applying the second coat of silicone rubber.

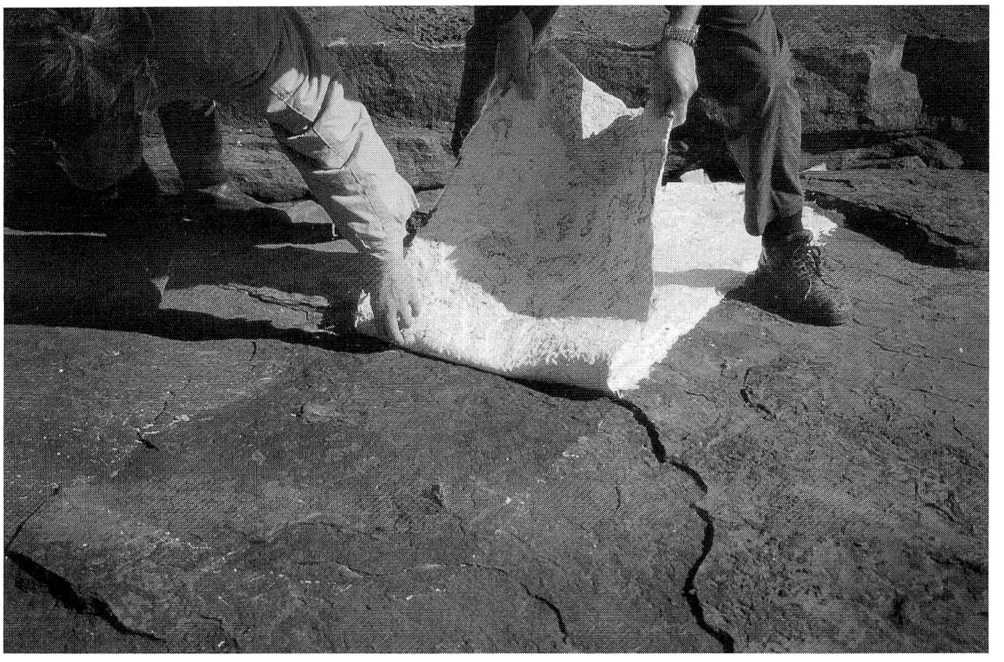

Figure 4. Removing the mould from the rock.

Lockley (University of Colorado at Denver). Prior to casting the mould was cleaned with water and a non-ionic detergent (Synperonic N). Casts were made using Gelcoat GC150PA polyester resin, opaque colour was added to the Gelcoat to provide a base. The surface of the cast was painted with acrylic paints to simulate the natural colour as far as possible. The back of the cast was strengthened with fibre glass and correx (fluted plastic sheeting) was used to give it rigidity.

Acknowledgements

Dow Corning kindly donated the silicone rubber products used for the project. We would like to thank Dave Tweedie (Replication Technologies) for advice on moulding and to Mike Lambert (NMGW) for assistance in moulding the trackway. We are grateful to Bob Owens (NMGW) for critically reading the manuscript.

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A SURVEY ON THE STATE AND STATUS OF GEOLOGICAL COLLECTIONS IN MUSEUMS AND PRIVATE COLLECTIONS IN THE REPUBLIC OF IRELAND.

by Matthew A. Parkes and Patrick N. Wyse Jackson

Parkes, M.A. & Wyse Jackson, P.N. 1998. A survey on the state and status of geological collections in museums and private collections in the Republic of Ireland. *The Geological Curator* 6(10): 377-388.

A simple postal survey of 73 museums, heritage centres, individuals and other establishments was conducted to assess the state and status of geological collections across the Republic of Ireland. There were 31 locations with a collection, assessed under three categories: 1) educational or institutional geological department, 2) County Museum/Local authority funded museum and 3) other collections including private ones. Excepting the National Museum, the specialised geological museums were mainly directed towards internal functions, with little outreach or community emphasis, and with a resource based lack of curatorial strength. The County Museums had little knowledge or practical concern for their geological collections, but a desire for assistance was clear. With the other collections the lack of appropriate knowledge to assess or use the geological collections was apparent. All but the specialised geological museums commonly confused archaeological specimens with geological ones and this misapprehension is evidently widely held. Some preliminary recommendations for improving the status of geological collections are suggested.

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Introduction

As geological curators, we had been aware of a general lack of documentary data on geological collections in Ireland, as well as perceiving a widespread lack of appreciation of geology in both the museum community and the general public. Wyse Jackson went some way towards addressing this by organising a meeting on Geology in Irish Museums in 1990 (the first Geological Curators' Group excursion outside the U.K.), the results of which were published in this journal (Volume 5, No. 7).

Subsequently, we proposed to conduct a detailed survey and sought funding from the recently established Heritage Council for such a project. Unfortunately, with a broader pilot survey of museums in general being undertaken, and many other competing demands on funding, no support was available. Consequently, a much modified and restricted survey was conducted in an attempt to get a crude picture of the state and status of geological collections. Much inspiration was derived from the work of Doughty's (1979, 1981) more extensive survey of U.K. museums.

Our survey, tailored to suit both our perception of museum and geological provision in Ireland, and the resources available, was limited to a simple postal survey. It was decided to be as inclusive as possible and any collection has been included, irrespective of whether the establishment where it was held would pass any particular definition of a museum. Therefore the term 'museum', used subsequently must be taken as including a wide variety of establishments linked simply by possessing a collection of geological objects.

The analysis of the results is presented here, together with our conclusions and observations on the significance of them. However, we caution against placing too much weight on any one statistic of the answers. In many cases it is the information that has been left out, the unanswered questions or the comments received that are most revealing. The results are a first sketch picture. Further work on assessing geological provision in museums in Ireland is planned, ultimately with the intention of further raising its profile and image.

Methodology

A five page questionnaire was drawn up, designed to be as simple as we could make it, for busy curators to complete, and as open as possible for those with more information available to provide it freely. The content was restricted simply to geological (specimen and archive) collections and associated public aspects of their provision. No attempt was made to identify details

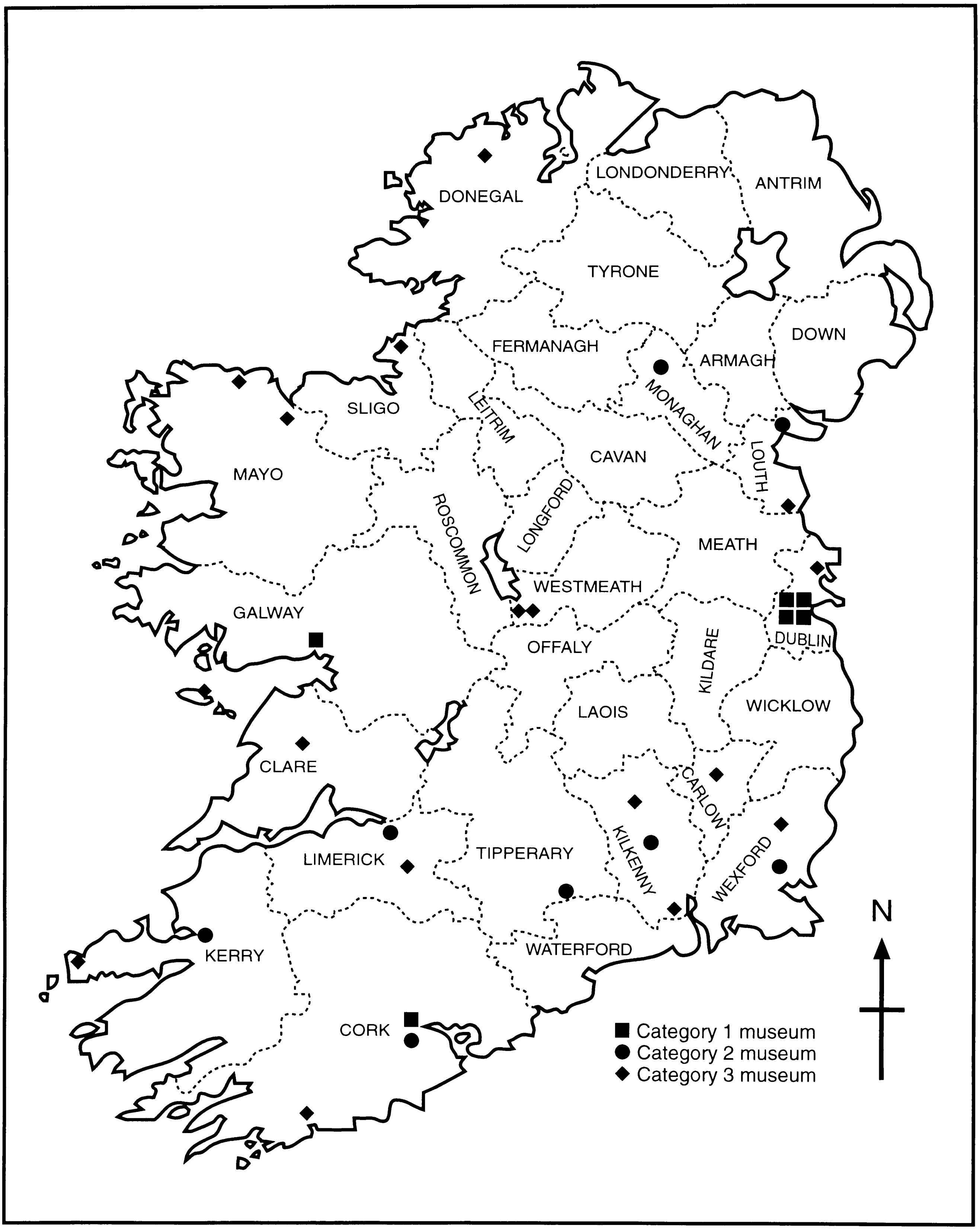

Figure 1. Map showing the locations of the museums and collections surveyed.

of the governance, funding, status, staffing or characteristics of the museum as a whole. The questionnaire was then sent out in July 1997 to all the museums known to us. We also sent it to a large selection of other heritage centres, private houses, tourist attractions, institutions and individuals whom we thought might have some geological collections, however small. A listing of Heritage Sites in Ireland issued with the magazine *Archaeology Ireland* in 1997 (Anon. 1997) was used, along with a natural history archive listing (Nelson 1990). Question 25 asked respondents 'Are you aware of any private collections that we may not have any knowledge of? If so please could you provide a name or address for us to contact'. This led us to several other collections of which we were unaware.

In order to gain a complete picture rather than a representative sample, considerable effort was put into following up the initial questionnaire, and a second questionnaire was circulated in November 1997 to all those who did not respond at first, and a third circulated in March 1998, to a diminishing number each time. Additional possible locations were also circulated as they became known to us. Some of the more significant places were contacted by phone, and then in July 1998 a last effort to ensure complete coverage included sending questionnaires again and phoning round all non-respondents. Many of these of course had no geological collections but had simply not bothered to return the questionnaire with a 'no' response. We did not supply S.A.E's. for respondents; it would be interesting to know what effect on the response rate this might have had.

Categorisation of respondents

The full list of museums and centres which we circulated is given in Appendix 2, broken down into those with collections and those without. Addresses of those holding geological collections are given, and they are divided into three categories. This separation is a necessary measure to make sense of the results within the overall picture, in order to compare like with like. Retrospectively, some measure of the museum identity

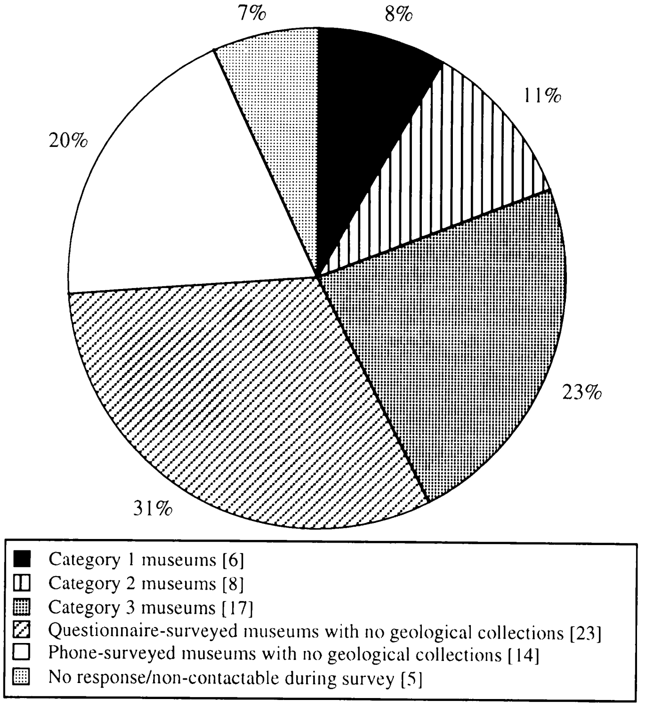

Figure 2. Pie-chart showing the percentage of museums in six categories.

would have been useful, but intuitively the three categories are the most natural characterisation.

Category 1 Museums

This group includes all the establishments whose primary concern is geology, or whose museum is entirely geological. Essentially this is all the geology departments of Universities and Colleges, some of which have museums open to the public, others of which are largely research or teaching collections [Trinity College Dublin = TCD, James Mitchell Museum in University College Galway = JMM, University College Dublin = UCD, University College Cork = UCC]. Two exceptions are included. The National Museum of Ireland (NMI) is obviously a far greater institution, with collections of many types, but it has significant geological collections, geological staff and is most appropriately linked here. The Geological Survey of Ireland (GSI) is likewise a far larger entity than its collections, but falls most neatly into this group.

Category 2 Museums

This category numbers only 8, and includes all local authority or County museums. In essence, they are all comparable institutions, with at least one full-time Curator, and other unifying features.

Category 3 Museums

In this bucket grouping are all other establishments having some geological collections; we received responses from 17 but know of another 3 with geological collections. Whilst further subdivision of these would be possible, an initial appraisal of the questionnaire responses suggests that it would not have been of benefit. Therefore included in this group are a number of small privately run museums, some private individuals' collections, heritage centres, large estate houses and a diversity of establishments broadly classed under 'heritage'.

Responses and results

Category 1 Museums [6]

In some respects the surveys of these museums revealed little that was not already known to us, yet it is advantageous to look at the information in an aggregate form, and also to collate the existing published source material. The National Museum of Ireland obviously has varied collections, but this survey considers the 100,000 (out of 5 million total) specimens held by the Geological Section and the section itself, in isolation from the remainder.

A number of recent directories contain listings of some of these collections: Bode and Burchard (1985): NMI; Cleevely (1983): GSI, NMI and TCD; Nudds (1994):

NMI, JMM, TCD and UCC; Webby (1989): GSI, JMM, NMI and TCD.

In this category over 90% of all specimens are geological. The history and contents of the collections have been summarised: Monaghan (1984, 1992) for the NMI; Harper (1992, 1996) for the James Mitchell Museum (JMM) in University College Galway; Sleeman (1992), Parkes (1995), Parkes and Sleeman (1997) and Herries Davies (1995) for the GSI; Nudds (1982*a*, *b*, 83, 84, 88, 89), Wyse Jackson (1989, 1992, 1994) for the Geological Museum in Trinity College Dublin (TCD).

In condition (Q4), most of the collections were classified as 'good'= sound and clean, although specific parts such as ammonites were classified as 'indifferent' or 'bad'. In the case of the GSI collection many specimens subject to pyrite decay had already disintegrated, leaving only 'good' specimens.

As might be expected Q5 revealed a variety of classification systems in operation for the arrangement of material in storage. Most mineral collections used Hey's classification, fossils were largely ordered systematically (by taxonomic phyla, then by geological system, and geographical location), with type specimens kept separately. The question however, failed to illustrate the situation known to us in most of the museums, that of extensive collections accessioned but not curated, and the innumerable problems of lack of space. The difference between the aspiration of having collections logically classified and ordered, and the reality of unsuitable spaces is considerable, even in our 'own' collections.

Overall, Q6 illustrated the variety of storage conditions, with most museums having some in each of the classes: drawered cabinets; shelved cabinets, cardboard boxes; crates and packing cases. Extremes range from the GSI fossil collections almost entirely in purpose built steel cabinets, to the NMI which has some 80% in crates and packing cases. The class 'other' was cited for display specimens, and for the very large specimens which fall outside the shelf/drawer capacity. Q7 the adjunct to this, showed that most museums had purpose bought trays or boxes for the specimens in cabinets and drawers.

The physical buildings were examined by Q8, which showed that half of the museums had collections in more than one building, but these were largely classed as secure. Two had 'outside' stores. One in UCG, has been organised by Parkes, and contains collections of material, which is either reference material for completed research or yet to be worked material, much of which is uncurated except as discrete collections.

The cataloguing examined in Q9-11, yielded a picture of varied coverage, from one completely uncatalogued collection (UCD) to effectively 95-100% catalogued. The GSI, JMM and UCC have had curatorial 'restoration' projects in recent years and largely have computerised catalogues. In TCD and NMI, a mix of computerised and paper records (hand written ledgers, labels, lists, registers) is recorded. Half of these museums claim to follow Museum Documentation Standards.

The awareness of status material in the collections varied greatly too. The GSI catalogue of Type Figured and Cited specimens (Parkes and Sleeman 1997) is the most recent, but the TCD palaeontological collections have been the subject of six catalogues to date (Nudds 1982*a*, 1982*b*, 1983, 1984, 1988, 1989), with another in preparation by Wyse Jackson. The mineralogical collections in TCD were the subject of several nineteenth century catalogues (see Wyse Jackson 1992 for details). The NMI collections are the subject of 450 publications covering about 2000 status specimens. The manuscript catalogues of the Griffith Collection described by M'Coy are available for consultation and may be published soon. Important status material is known in JMM, and it was reported that there are probably some in UCC and UCD, but no catalogues are published.

Conservation was addressed in Q14-15. Although most museums had no special problems, the NMI, had most common problems, and pyrite decay was a general problem. TCD also had uranium minerals kept in lead cases, and Jarrow amphibian specimens requiring silica gel. All museums had no conservator on staff or access to trained conservation support, including the National Museum, which has a new conservation unit, but no geological conservator. The only way that specific tasks such as single ichthyosaur specimens in UCC and UCG could be conserved was at the considerable expense of bringing over a conservator from the UK or sending the specimens to the UK.

All museums, however, have trained geological staff (Q16) with at least a geology degree, many with Ph.D. qualifications. No specific mention of museum studies qualifications was made and it is assumed that none were held. UCD has all trained geologists on the academic staff, but no one person with responsibility for collections. Collections were largely viewed in the context of teaching alone, although research work obviously generates important collections within the department.

As might be expected, Q17 informed us that each museum held some archival material. The GSI archives are of course extensive and have been catalogued in recent times to a basic level. They constitute a section of the National Archives. Within the other museums, photographs, instruments, field notebooks, manuscripts and predominantly maps are widely held. Information on these holdings is largely contained within the published reports on the collections.

Half of the Category 1 Museums have an acquisition policy (Q18), but no copies of written or published policy were requested. However, for the JMM, the west of Ireland is the main focus, and for TCD the acquisition is mostly linked to staff and student research interests. All establishments undertook identification of specimens for public enquiries (Q19), a service which is advertised through the Thumbs-Up leaflet of the GCG and through the local media during geological events including Irish Geology Day/Week. Likewise all allowed access to collections (Q21) for academic researchers, and 5 of 6 to the public too, albeit under supervised conditions. Volunteers, or occasional work experience students (Q22) only operated in two (NMI, TCD) museums with close supervision, and often working with data rather than specimens.

Q23 examined the amount of displayed collections against that in storage. Almost all had some material on permanent display and some temporary displays, but each is summarised below. The National Museum is undergoing major changes and at present little is displayed, except in the Natural History Museum. The Geological Section public exhibition area on Merrion Row has suffered extended closure due to staffing issues, despite having exhibitions in place. A joint GSI/NMI display in the GSI is currently changing. The new Collins Barracks site will have new permanent geology exhibitions in 2002. At present most of the geology collections are stored in the Beggars Bush Building. Of the other museums, TCD has permanent displays in the museum and temporary exhibitions in teaching laboratories during the summer, as well as temporary displays in cases within the impressive entrance hall of the Museum Building. However, only a minor percentage of the collections is on display. The GSI as mentioned is in a process of change, but it is likely that some display area will be incorporated within a new Public Office. Some permanent displays may be supported by temporary exhibitions. Again most of the collections are in storage. UCD has permanent displays within the Department, limited by available space, and most of the collections are in storage. The JMM and UCC have much on permanent display, but also much in storage. In summary, despite considerable displayed material, all have the majority of their collections in storage.

Monetary valuations of specimens for insurance or purchase (Q24) were held by 4 of 6 museums, but in one case it was a general valuation for the entire collection, while in others it was for only special cases.

Questions 26-28 concerned the Irish sales and promotion of geology, and as might be expected all museums had been involved in Geology Day/Week events in the past and had hosted lectures or meetings on geological themes. The NMI had all the aspects of sales listed in Q26, but all the others had some limited sales of maps and guides, except UCD where free literature was distributed. Much of this may be related to the significant input into the Irish Geological Association (IGA) by staff and students.

Category 2 Museums [8]

The geological collections noted by these 8 museums average less than 1% of total collections. Listings provided (Q3) indicate that most represent a small sample of mostly locally derived rocks, minerals and fossils. It should be noted that most of these museums had between 5 and 20 specimens only. The degree of information available about specimens was quite variable, but overall the picture was of odd 'curios' or unconnected specimens probably donated, rather than any purposefully collected suite of material. Almost all was described as in 'good' condition (Q4).

The holdings of geological material were so small that most were just kept in general storage, without any classification system (Q5). Storage conditions (Q6) were in cardboard boxes for 7 of 8, although one was in archival, acid free boxes. A few also held collections in crates and packing cases, trays, whilst one had large specimens in acid free tissue on open shelving, and some on display. Only one had specimens within purpose bought trays (Q7), although one had specimens individually wrapped. All held their material inside the museum building (Q8), as opposed to within outside stores.

In terms of cataloguing (Q9), 5 had the specimens catalogued, one had not, and two had some material catalogued. The responses to Q10 varied considerably, perhaps indicating the question was poorly phrased. However, as far as we are aware, all local authority museums have been supplied with, or are anticipating using the same software for cataloguing. The answers to Q10 might indicate different degrees of progress with the computerisation of documentation. Five of eight said their system followed MDA standards.

No type, figured or cited material was known to be held (Q12), and again no general publications about the museum collections (Q13) were noted. Q14 indicated that none held material requiring special treatment or conservation conditions, although one commented they would like to get a survey done. Q15 indicated 3 of 8 had no conservator on staff nor access to one, and one stated they had a conservator on staff, but of the others 2 said they had access to outside conservators, and 2 said yes, which could have been a staff conservator or more likely access to one.

In terms of geological training of staff (Q16), 7 had none, and one had taken some geomorphology courses in a Geography degree. Effectively, Q17 indicated that none of these museums held any geological archival material. Q18 looked at acquisition policy, and 5 of 8 did not include geological specimens in their policy, whilst 3 said that the local rocks, fossils and minerals fell broadly within their policy, but had not been actively pursued to date. Identifications of geological specimens for public enquiries (Q19) were offered by 5 of 8, within their abilities, and as might be expected most would direct (Q20) people to the National Museum of Ireland, or to UCC Geology Department in the case of Cork Museum.

Q21 assessing access to the collections showed almost all were willing to allow public access to the collections, and for researchers, although one commented it had never arisen. None of the museums had volunteers working on the geological collections (Q22). The situation varied as regards collections on display or in storage (Q23), with many museums in the process of change, but about half were permanently displayed and half in storage. 7 of 8 (Q24) had no valuations for geological specimens, probably reflecting the insignificance of the collections overall.

In terms of promotion of geology within the museum setting, Q26 showed that of the 8 only 2 said they had retail points in the museum, and none had geology items as part of this. Only 1 museum had taken part (Q27) in Irish Geology Day (or Week in some years), when they displayed a model of a local mine. Q28 yielded more information than anticipated. Although only 1 museum had hosted lecture(s) on the local geology or landscape, 3 indicated that they had hosted temporary exhibitions on geological topics, or will shortly be doing so.

Category 3 Museums [17]

This disparate group of museums is difficult to appraise by tallying the answers to questions, as many were not completed in full because they were not appropriate to the individual museum. Some responses are perhaps more representative of the picture than forced statistical analysis.

Of the 17 museums in this category the percentage range (Q2) of geological holdings is from the 95-100% down to Athlone Castle Museum whose geological collection consists of one catalogued specimen! Hence comparisons of some aspects looked at in our questionnaire are difficult. Those with 90-100% geological collections include Athlone Mineral Engineering Department, where they are held for teaching purposes alone, and Dunmore Cave where all the specimens are part of a public display to explain the formation of caves and the calcite formations within them. However, most of these museums had very small holdings by percentage, apart from one private collection and one private Museum with an extensive collection of foreign specimens. Another private collection was composed of specimens from the local region.

In Q4 11 classed their specimen condition as 'good', and 2 as 'indifferent', and one as both. For system of classification (Q5) used, 3 had no answer, 4 had only material on display, 6 had no system, 2 were in an administrative/space system and only 2 were systematic, one by geological system, one by country of origin. One respondent without a system noted there was "no system as long as they were out of the way!".

Q6 yielded a varied picture, with 1 collection stored in drawered cabinets, 6 in shelved cabinets, 3 in cardboard boxes, 1 in crates and 5 in open or enclosed display. Only 4 had specimens in purpose bought trays or packaging, one had some in such and 7 did not (Q7). 13 museums had collections inside (Q8), with none in outside stores.

Seven museums claimed some degree of cataloguing, often quite simple, whilst 7 said no to Q9. Of the former, 3 followed MDA standards (Q11) with only one providing a sample of computerised records. Only one museum claimed to have status material (Q12), but descriptions provided of material indicate that at least some of these museums have significant collections, although many were also minor suites of old cabinet collections, local curios and so forth. None knew of publications relating to the collections (Q12, 13), except one mention (without a date given) in an Irish Museums Trust Guide.

In terms of conservation, (Q14) none had material requiring special treatment or conditions, although several commented on this being as far as their knowledge went. One response to Q15 was yes and one other stated that conservation support was brought in as required, and interpreting these responses, we assume that this support would be from an archaeological perspective. Other than Athlone Mineral Engineering Department, no museum had geologically trained staff.

Q17 asked about archival material, and aside from one or two respondents who had relatively modern maps and publications, only two museums had items worthy of archival treatment, one being correspondence on 1950s pollen coring of Lough Gur, the other being photographs of Sir Henry Gore-Booth's Arctic exploration from about 1880-90.

Q18 asked about acquisition policy, and six expressed some kind of policy existed, although for about half this was effectively a personal collecting choice. Comments indicated that those museums with a formal policy only collected items of local geological interest, or by default if offered specimens. 11 said no, and 3 said yes to Q19, if they identified geological material, but only 2 said they would or had sent material to the National Museum of Ireland, and 2 to other institutions if requested (Q20). In Q21, 2 museums would not allow public access, 9 would allow access to public and research academics, whilst 2 commented they had never been asked. None of the museums (Q22) had volunteers working on the geological collections.

In Q23, 12 museums had material on permanent display, 1 on temporary display, two responded as not applicable to them, and only one collection was in storage. 12 responded that they had no monetary valuations for geological specimens (Q24). For the promotion of geology (Q26), 10 definitely had none, 3 had a shop or sales point, and 4 sold guides or books including geology. One of the 16 museums had taken part in Irish Geology Day events in the past, whilst 14 had not. Perhaps surprisingly, 5 of the museums had hosted lectures or meetings on local geology or landscape, and 9 had not.

The overall picture

In a simple blanket survey like this it is to be expected that the responses are not as clearly defined as one might like. However, it was only intended as a 'broad brush picture'. In compiling the results, it has become appparent that in many cases the comments and particularly the omissions are often far more revealing than the answers, or the fact of whether 7 or 8 of 16 had a particular feature. Much of the following summary is effectively our subjective analysis, a reading between the lines of the questionnaire.

Geology is relatively strong and vital within a small number of institutions. The 4 third level educational departments have long traditions, and established positions within their institutions (in so far as any department is secure in current circumstances - we reflect of course on the possible fate of Geology at Queen's University Belfast). Even without a dedicated museum, UCD has geological displays to attract and explain in their main entrance area. The others have discrete museums, of which only TCD is signposted and clearly open to a public prepared to make an effort to seek it out. Each suffers from the problems of a lack of security, and a lack of resources currently to make more use of the museum. They largely remain as facilities for the departments, for staff and students, and as repositories of research material. However, special events and meetings do make use of the museums, and some school visits take place at each of them.

In the NMI, geology has a reasonably high profile, and plans for the new museum situated at Collins Barracks include a considerable area devoted to earth science. One can only hope that adequate staffing resources are to be given to geology, considering that in Merrion Row where geology is presently situated there has been a dedicated Geology exhibition space, but which has remained closed for much of the time as a result of low staffing levels of Attendants.

The GSI is wholly focussed on geology, and for some years has had the 'Down to Earth' exhibition. Although this received school group and meeting use, its usage had been in decline, and it had begun to show signs of age. Currently, the whole exhibition area, library, and Public Office space is being re-organised, and it is hoped to have an exhibition area, with more temporary exhibitions and greater usage through increased promotion. The fossil collection is now very well organised and secure following a major curation project by Parkes (see Parkes and Sleeman 1997). However, as a collecting institution, in the past if not actively doing so today, there are woeful inadequacies in the quality of specimen organisation and documentation. There is information about the many specimens, but both data and samples are difficult to retrieve without considerable effort, even for those working within the Survey. It is largely related to the collector as the key factor, and hence with retirements and moves, much personal contextual information is being progressively lost.

The picture of geology outside these institutions is a rather different story. Within Category 2 Museums, the geological specimens were very small in number, and generally kept in cardboard boxes, with inconsistent standards of documentation. Most had little knowledge of the value or insignificance of what they held, and no background or training to discriminate. Although some had had exhibition or displays of local geology, it was clearly a difficult task for curators to make sense of their local geology without any experience.

By contrast to the rather negative overall assessment of geological provision within County Museums, there was clearly an aspiration to encompass geology within the museum for several respondents. Some had begun moves to seek assistance in this regard, and clearly would readily accept expert help if it was available freely.

Category 3 Museums yielded a similar, if less consistent, picture with variations depending on the character of the museum, the age and purpose (or lack of it) of the collection and the motivations of the people concerned. In nearly all these museums, the funding and purpose was either private, without income generation being the prime motivation, or effectively State supported such as Dunmore Cave and the Céide Fields. The latter example had one of the smallest collections, of local rock types, but was one of the best in the provision of information. Copies were supplied of the material they give to enquirers, and the display texts.

In general, despite apparent interest in the collections, there was a lack of appropriate knowledge, weak documentation, much material on display without any appraisal of conservation needs. There was also negligible promotion of geology despite a strong focus on geology in the case of some publicly accessible museums. However, from a positive viewpoint there were comments indicating some awareness of a lack of knowledge, and an openness to professional advice about the geological collections.

Common Themes

The pervasive lack of appreciation of geology is most apparent, not in the answers to the questionnaire actually relating to rocks, fossils or minerals etc. but in the persistent and pervasive linkage of geology and archaeology. Many archaeological artifacts are made of geological materials, and there have been recent trends in research exploring this, such as the Irish Stone Axe Project in UCD (Cooney and Mandal 1998). However, it is really a limited inter-disciplinary area. Yet so many of the respondents, from all but the geological organisations, misunderstood the geological nature of specimens and included archaeological specimens in their responses which were of no relevance whatsoever to the survey. This mirrors a subjective opinion that we have held about the population in general from other experience.

The four third level geology teaching departments, the National Museum and the Geological Survey all have significant collections, of national and some of international importance. In our opinion however, the allocated resources to the museum function are generally inadequate, and even within the organisations, appreciation of the longer term necessity for maintenance and upkeep of collections is limited. It would be easy to criticize without recognising the problems of space, old buildings, and competing demands on limited resources, but the curatorial needs have been marginalised or ignored. To restore collections to some order it has been necessary for external funds to be sought. In UCG and UCC this has been through FAS employment schemes, which have brought their own problems to curation. In the GSI, the Heritage Council funded thorough curation of the collection.

Recommendations for improving the status of geology in Irish Museums

Further consideration needs to be given to the survey results, and the need for a more focussed follow up survey assessed. For the present, we consider that some or all of the following steps could significantly improve the state and status of geology in Irish Museums:-

Category 1 museums

• Make museum displays relevant to the new Geography Leaving Certificate syllabus.

• Invest in expanding 2nd level, and National School visits/use of the museums.

• Develop or borrow good quality travelling exhibitions.

• Produce attractive posters/ postcards/appropriate books for sale or promotion, ie particular well illustrated, popular books of relevance to schools syllabus.

• Consolidate and expand curatorial cover. Initiate a pastoral role of curatorial cover for other museums, possibly through a peripatetic curator.

Category 2 museums

• Prioritise implementation of good local geology displays.

• Alter acquisition policy specifically to incorporate local geological specimens.

• Seek advice and assistance in promotion of geology.

• Organise lectures/ meetings/ events with geological theme (especially in connection with Irish Geology Week (in 1999) or Day (in some years).

Category 3 museums

• Seek specialist assessment of the scientific importance of collections.

• Seek specialist advice on promotion of geology by use of available collection and other local resources.

• Seek specialist advice on conservation, documentation and identification of collections.

Irish Museums Association/ Heritage Council

• Organise short training courses for museums to facilitate geological awareness, and better collecticns management/curation/conservation of geological specimens.

• Lobby for national funding of a peripatetic geological curator.

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Appendix 1. The questionnaire as sent to all establishments, but with different initial notes, depending on whether it was first, second, third or final request. The spacing allowed for each question was different according to our expectations of data that would be forthcoming.

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Questionnaire

This questionnaire is designed to acquire data on the state and status of holdings of geological material of any sort in County and smaller Museums, and any other collections in heritage centres, visitor attractions, society or private collections. It is intended to compile results and make a report available to the Heritage Council, the National Committee for Geology, the National Museum and any interested party. It is also planned to publish the results in The Geological Curator, the journal of the Geological Curators' Group, and possibly within Museum Ireland published by the Irish Museums Association. The results will be compiled and individual confidentiality will be maintained, so please give as much information as you can.

Please would you answer the following questions as fully as possible; even if the answer is an approximation or a guess, it will be more useful than leaving the question blank. If the space allowed is inadequate to answer a question properly, please use the reverse of the questionnaire and put the question number by the extra information.

Please return the questionnaire to Dr Patrick Wyse Jackson, Dept. of Geology, Trinity College, Dublin 2.

Name of museum or establishment ____
Address ____
Telephone ______________________________ Fax ______________________________
E mail ____
Name of Curator/Manager/Contact Person ______________________________________

(1) Are there any geological specimens (rocks, minerals or fossils) amongst your collections? If the answer is NO please see (17).
(2) If there are, what percentage of your total collections do they represent?
(3) Please describe as completely as possible what geological specimens you hold. You might note the approximate numbers, whether fossils, rocks or minerals, the age and types if known, if they have thin sections or other special features. Are the specimens of local origin, Irish or international? If you are able to attach printouts, photocopies, or listings please do.
(4) Using the following classification please describe the condition of the majority of your geological specimens:-
(a) 'Good' = sound and clean (b) 'Indifferent' = sound but dirty or exposed to risk
(c) 'Bad' = specimens deteriorating physically due to pyrite disease, fragmentation, constant abrasion, or other causes
(5) Please describe if possible what system of classification is used to arrange material in storage. Is it for example based on geological system, or on taxonomic hierarchy for fossils or some other administrative/space system?
(6) Please describe as best you can, what sort of storage conditions material is kept in? Is it for example in:-
(a) Drawered cabinets (b) Shelved cabinets (c) Cardboard boxes
(d) Crates and packing cases (e) Other (describe)
(7) Are individual specimens contained in purpose bought trays or packaging?
(8) Is material inside the museum (or other building) or within an outside store?
(9) Is the material you hold catalogued?
(10) Please describe the type and quality of the cataloguing as best you can.
(11) Does your cataloguing system follow Museum Documentation Association standards?
(12) To the best of your knowledge, is any of the material you hold type, figured, cited or other status material? If so please describe and give references to publications where known.
(13) Please give references for any general publications or directories listing your collections?
(14) Does any of the material you hold require special conservation conditions or treatment? If so please describe as fully as possible.
(15) Do you have a trained conservator as a staff member, or access to trained conservation support?
(16) Does anybody on your staff have any geological training or background? Please describe as fully as possible.
(17) Whether you have specimens or not, do you hold any archival earth science information such as maps, photographs, instruments, biographical sources, correspondence etc. relating to geology or geologists, or any natural scientists? If so please describe as fully as possible, and attach copies of any catalogues or listings if possible.
(18) Do you have an acquisition policy, with any reference to geological materials?
(19) Do you identify geological material for public enquiries?
(20) If not, do you have alternative arrangements such as sending material to the National Museum for identification?
(21) Do you allow access to geological collections to:-
(a) the public (b) academic researchers
(22) Do you have any volunteers who work on the geological holdings? If so, what supervision or constraints operate to prevent inadvertent damage?
(23) Is any of your geological material on display, or is it all in storage? If on display, is it 'permanent' or part of a temporary exhibition or display?
(24) Do you have any monetary valuations for geological specimens e.g. for insurance purposes, or for the purchase of a particular specimen of significance?
(25) Are you aware of any private collections that we may not have any knowledge of? If so please could you provide a name or address for us to contact.

(26) Please note which of the following you have concerning promotion of geology:
(a) A shop/sales at reception (b) Guidebook/book/postcards/other printed material for sale
(c) Sale of replica dinosaurs/related goods (d) Sale of mineral or fossil/replica specimens
(e) Other (please describe)
(27) Have you taken part in Geology Day on any occasion?
(28) Have you ever hosted any lectures or meetings on local geology or landscape?
(28) Are there any further comments or observations relating to this survey that you want to make?
****

Appendix 2

Category 1 Museums

• Cork Geological Museum, Department of Geology, University College Cork, Cork
• Department of Geology, University College Dublin, Belfield, Dublin 4
• Geological Museum, Trinity College, Dublin 2
• Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4
• James Mitchell Museum, National University of Ireland, Galway
• National Museum of Ireland, Collins Barracks, Dublin 9

Category 2 Museums

• Cork Public Museum, Fitzgerald Park, Mardyke, Cork
• Kerry County Museum, Ashe Memorial Hall, Tralee, Co. Kerry
• Limerick Museum, Limerick
• Louth County Museum, Jocelyn Street, Dundalk, Co. Louth
• Monaghan County Museum, 1-2 Hill Street, Monaghan
• Rothe House Museum, Parliament Street, Kilkenny
• Tipperary South Riding County Museum, Clonmel, Co. Tipperary
• Wexford County Museum, Castle Hill, Enniscorthy, Co. Wexford

Category 3 Museums

• Athlone Castle Museum, Athlone Castle, Athlone, Co. Westmeath
• Ballymore Historic Features, Ballymore, Camolin, Co. Wexford
• Bray Heritage Centre, Bray, Co. Wicklow [no survey details but known to contain geological material]
• Céide Fields Visitor Centre, Ballycastle, Co. Mayo
• Ceim Hill Museum, Ceim Hill, Cooldurragha, Union-Hall, Co. Cork
• Celtic & Prehistoric Museum, Ventry, Dingle, Co. Kerry [no survey details but known to contain geological material]
• M. Doran, Belleek Castle Hotel, Ballina, Co. Mayo
• Dunmore Cave, Mothel, Ballyfoyle, Co. Kilkenny
• Dysert O'Dea Castle, Corofin, Co. Clare
• Glenveagh National Park, Church Hill, Letterkenny, Co. Donegal
• Ionad Arann, Cill Ronain, Inismor, Co. na Gaillimhe
• Lissadell House, Ballinfull, Co. Sligo
• Lough Gur Visitor Centre, Holy Cross, Brough, Co. Limerick
• Millmount Museum, Old Drogheda Society, Drogheda, Co. Louth
• Musaem Chorca Dhuibhne, Baile an Fheirtearaigh, Co. Chiarrai
• Newbridge House, Donabate, Co. Dublin
• School of Mineral Engineering, Athlone Institute of Technology, Athlone, Co. Westmeath
• G. Spencer, Silverspring, Mooncoin, Via Waterford
• Tullowphelim Historical Society Museum, Bridge Street/ 56 Dublin Road, Tullow, Co. Carlow
• Valentia Heritage Centre, Knightstown, Valentia Island, Co. Kerry [no survey details but known to contain geological material]

Surveyed Museums/Sites with no geological collections

It should be noted that of these museums, some reported specific objects or maps/archival material which we felt was insufficiently 'geological' to count within the scope of the survey. Examples include Chinese snuffboxes at the Chester Beatty, photographic and topographical maps at the Royal Society of Antiquaries, early maps at Castletown House and archaeological material in Galway City Museum.

• Blarney Castle Estate, Blarney Castle, Co. Cork
• Bunratty Castle and Folk Park, Newmarket on Fergus, Co. Clare
• Castletown House, Celbridge, Co. Kildare
• Cavan County Museum, Virginia Road, Ballyjamesduff, Co. Cavan
• Chester Beatty Library, 20 Shrewsbury Road, Dublin 4 (moving shortly to Dublin Castle)
• Coole Park Visitor Centre, Coole Park, Gort, Co. Galway
• Donegal County Museum, High Road, Letterkenny, Co. Donegal
• Doon Archaeological and Nature Peninsula, Castlecarra, Clogher, Claremorris, Co. Mayo

- Dublin Civic Museum, 58 South William Street, Dublin 2
- Galway City Museum, Spanish Arch, Galway
- Ireland's Historic Science Centre, Birr Castle, Birr, Co. Offaly
- Killaloe Heritage Centre, Killaloe, Co. Clare
- Kilmallock Cottage Museum, Chapel Height, Kilmallock, Co. Limerick
- King House, Boyle, Co. Roscommon
- Knock Folk Museum, Knock, Co. Mayo
- The Famine Museum, Strokestown Park, Strokestown, Co. Roscommon
- Longford Museum and Heritage Centre, 1 Church Street, Longford [This museum is closed pending new premises, and may have geological collections in storage, but could not complete the survey questionnaire at this stage.]
- Pighouse Collection, Corr House, Cornafean, Co. Cavan
- Portumna Castle, Portumna, Co. Galway
- Roscrea Heritage Centre, Roscrea, Co. Tipperary
- Royal Society of Antiquaries of Ireland, 63 Merrion Square, Dublin 2
- Sliabh an Iarainn Visitor Centre, Drumshanbo, Co. Leitrim
- Westport House, Westport, Co. Mayo

Miscellaneous collections

There are a few collections or geologically interesting locations which have not been included in other categories. We note the Office of Public Works (Dúchas) offices at 51 St. Stephen's Green, originally the site of the Museum of Irish Industry in the mid 1800s. Here the entrance lobby has a series of panels of polished building stones from Ireland adorning the walls (Wyse Jackson 1993). The Botany Department of University College Dublin has specimens of plant fossils from Kiltorcan. Muckross House Gardens and Traditional Farm, in Killarney, Co. Kerry has a collection that was made for a former exhibition on County Kerry but it is not classed as part of their current collections.

The Royal Irish Academy, responded to the survey with details of their holdings. We have not included them in analysis, as it is functionally outside the scope of a 'museum'. Many of their journals and maps have been transferred on permanent loan to other libraries and universities. However, they do have 18th and 19th century monographs and memoirs, geological maps and also the Praeger Papers, including photographs. They also have three volumes of Ganly Geological Correspondence (1837-43), and a collection of sketches of geological subjects by the geologist/artist G.V. Du Noyer (1817-69). The Royal Society of Antiquaries also hold Du Noyer works and notebooks, though this was not recorded on their questionnaire.

Museums with no collections (not based on returned surveys)

The following museums and sites are recorded as having no geological collections based on phone calls to request return of the completed questionnaire. In these cases it is not always certain that the appropriate person was contacted and there may be collections at some locations.

- Barryscourt Castle, Carrigtwohill, Co. Cork
- Ionad an Bhlascaoid Mhoir (Blasket Centre), Dun Chaoin, Co. Kerry
- Castlepollard Museum, Castlepollard, Co. Westmeath
- Clonalis House, Castlerea, Co. Roscommon
- Connemara National Park Visitor Centre, Letterfrack, Co. Galway
- Donaghmore Museum, Donaghmore Museum, Co. Laois
- Emo Court, Emo, Co. Laois
- Glendalough Visitors Centre, Glendalough, Co. Wicklow
- Grianan Aileach Visitor Centre, Burt, Co. Donegal
- Lackagh Museum, Turloughmore, Co. Galway
- Leenane Cultural Centre, Leenane, Co. Galway
- Malahide Castle, Malahide, Co. Dublin
- Parke's Castle, Fivemile, Bourne, Co. Leitrim
- Ulster Cultural Institute, Glencolumbkille, Co. Donegal

Non respondents/ Non contactable during survey

- Ardagh Heritage Centre, Ardagh, Co. Longford
- Bray Heritage Centre, Bray, Co. Wicklow
- Carlow Museum, Town Hall, Carlow
- Castle Matrix, Rathkeale, Co. Limerick
- Sligo County Museum, Stephen Street, Sligo

THE ROX PROJECT:
A MUSEUM EARTH SCIENCE EDUCATION PACKAGE.

by Alistair Bowden

Bowden, A. 1998. The ROX Project: a museum Earth Science education package. *The Geological Curator* 6(10): 389-394.

The National Curriculum has fundamentally altered the education system. Pressure on schools to accomplish set targets has resulted in the death of the casual museum visit. However, Earth Science is a subject which teachers find difficult to resource in schools. Museums which respond to the National Curriculum and offer an attractive, carefully structured package are ideally equipped to exploit the huge potential of the education market. The aim of the ROX Project is to provide a simple, comprehensive and enjoyable way for Key Stage 2 (age 7-11) school children to accomplish part of the National Curriculum. There are three phases to the package: ROX 1 is an introductory pack containing teachers' notes, a set of childrens' exercises and details of the later phases; ROX 2 is an intensive session at the museum with hands-on activities and a thorough worksheet on the Earth Science displays; ROX 3 is a loan box with videos, books and rock specimens together with exercises which develop the topics introduced in the previous sections.

Alistair Bowden, The Museum of Lancashire, c/o Clitheroe Castle Museum, Castle Hill, Clitheroe, Lancashire, BB7 1BA, U.K. *Received 29th April1998; revised version received 24th August 1998.*

Introduction

> "...museums need to respond to education reform. The National Curriculum emphasises practical experience, and schools may be willing to make use of museum services only where these serve the curriculum. The curriculum thus offers both the opportunity to market museum education services to schools which value practical experience, and to increase use of those services, and the threat that their use will fall if museums do not reappraise what they offer." (Para 57, Audit Commission 1991.)

Some time ago, planning began on an Earth Science education package at Clitheroe Castle Museum, Lancashire. The aim was to supply a perceived county-wide need for Earth Science resources. Drawing on the specialist skills of the resident curator, the support of museum education staff (Lancashire Museum Service to Schools) and previously published sources (e.g. Creary *et al.* 1992, NCC 1993 and Tuke 1991) a package of activities has been produced for Key Stage 2 (age 7-11) primary school children - the ROX Project. It is hoped that this paper will act as a stimulus to other curators and educational staff by providing an overall format, general principles and some important references.

The ROX Project is in a fluid state; the development of new opportunities and the fine tuning of existing activities is an ongoing process. Continuous evaluation is fundamental to this improvement (Wilkinson 1998). After the first set of exercises had been produced in the museum, staff from Lancashire Museum Service to Schools were used as guinea pigs and their opinions led to extensive changes. A small group of local school children then used the workshop as part of their rocks and soil course and the comments of staff and children were actively sought and amendments made. This formative evaluation has continued during every visit and the resulting improvements have been crucial to the ongoing success of the project.

The reaction of teachers and children alike has been excellent. This is a unique opportunity for teachers to engage in Earth Science topics and they have been very positive and helpful during the development. One slightly unusual bias seems to be that teachers who are already confident with Earth Science as a subject and have a collection of specimens which they use with their children, are using the museum visit to strengthen their own course. However, the majority of teachers have had no specific knowledge and have used the ROX Project as a significant part of their Earth Science course. The children have been enthusiastic without exception. Primarily they are away from school, they are in a stimulating environment of self discovery and they are allowed to keep their fossil plaster cast and their bag of fools gold - what more could be desired from a museum visit!

National Curriculum

The casual 'school trip' has been a basic staple of museum visitors for many years. However this has almost ceased to exist in the last decade. The introduction of the National Curriculum has placed considerable demands on school resources. As a broad range of specified standards now have to be accomplished, there is little chance that time and money will be expended on non-essential activities. Nevertheless, museums that offer a carefully structured package which helps a school to achieve specific parts of the curriculum (particularly if these are difficult for teachers to deal with in school), remain in a strong position to exploit the education market.

The status of Earth Science in the National Curriculum has changed since its introduction in 1988. Early versions contained significant statutory sections which teachers found almost impossible to complete; partly because of a lack of knowledge, but also because of the difficulty in resourcing the topics with quality specimens and supporting material. The post-Dearing National Curriculum (Department of Education 1995, SCAA 1995) has no actual Earth Science section. Despite this, Earth Science remains an ideal tool for teaching many parts of the curriculum.

Study topics and • Unit titles
Introduction
• Systematic enquiry
• Science in everyday life
• The nature of scientific ideas
• Communication
• Health and safety
Experimental and investigative science
• Planning experimental work
• Obtaining evidence
• Considering evidence
Life Processes and living things
• Life processes
• Humans as organisms
• Green plants as organisms
• Variation and classification
• Living things in their environment
Materials and their properties
• Grouping and classifying materials
• Changing materials
• Separating mixtures of materials
Physical processes
• Electricity
• Forces and motion
• Light and sound
• The Earth and beyond

Table 1. The Key Stage 2 Science National Curriculum

The ROX project is based on the Key Stage 2 science curriculum (Table 1) and is designed to complete a significant part of the 'introduction', 'experimental and investigative science' and 'materials and their properties' study topics. The introduction and study topics are further divided into unit titles and yet further into bullet points known as 'teaching points'; these are specific, attainable objectives. It is at this scale that museum activities have to be planned. A well-structured package needs to boast the maximum possible number of 'teaching points' to appeal to the education market.

ROX 1

The pre-course pack acts as a guide to the entire ROX project. There is material to introduce the actual subject of Earth Science to teachers and children which helps to maximise their time during the later museum visit, as well as information about ROX 2 & 3.

Many teachers are unfamiliar with Earth Science. A set of simple notes has been produced to provide a basic background knowledge on topics which may be raised by the children, so that teachers feel some degree of confidence when running exercises and dealing with questions. Information is short and simple and diagrams have been used extensively. The topics which have been covered in the teachers notes are as follows:

1. *Structure of the Earth.* Properties of the core, mantle and crust and a brief analogy.
2. *Plate tectonics.* Introduction to surface tectonics including the different types of plate margin.
3. *Minerals and igneous, sedimentary and metamorphic rocks.* How they form and a list of common types.
4. *Fossils.* Why they are useful and how they form.
5. *Geological time.* Introduction to the periods and significant events in relation to a 12 hour clock face.
6. *Earth Science in everyday life.* Household items related to their raw material.

Two sets of exercises are included for children. 'Rocks all around us' and 'Before and after' start in the home; they try to relate rocks and minerals to objects that children are more familiar with. The second set of exercises 'How do fossils form?', 'Fossil flicker book' and 'Fossil game' introduce fossilisation, a topic which is covered in a handling exercise during ROX 2, but is rather difficult to develop at that time (as the children are covered in plaster!).

The notes which give details of ROX 2 & 3 are designed to make these sections of the package run efficiently. A description of the museum visit, outline timetable and booking form are enclosed, as well as instructions on booking the loan box.

ROX 2

The museum visit is the most valuable part of the ROX Project. The underlying ethos is to allow the children to investigate and discover for themselves, with staff taking a facilitating role. This is more enlightening and enjoyable for the children and minimises the need to train the staff to 'lead' the activities. The essentially fluid nature of the activities also lends itself to adaptation depending on the age and abilities of children.

This intensive visit includes five exercises in the hands-on workshop and a worksheet led investigation of the Earth Science galleries. Groups are normally split in two and alternate between workshop and galleries after a short lunch break. The success of the visit depends on good planning and many pairs of hands. The overall co-ordination of activities is carried out by the curator. All additional help is provided by the visiting school (we recommend a staff to pupil ratio of 1:5), either by extra teachers or parents. Though most of the activities are self explanatory, the new staff are given a short introduction to give them some confidence and help them focus the children. The curator runs one or two exercises in the workshop which are less demanding, offers general support to all the staff and makes sure that all the activities run to schedule.

1. Mineral identification exercise

The children are asked to carry out a series of tests on six specimens and the results are noted on pre-printed sheets. Some of the instructions are simply observations (colour, shiny/dull, heavy/light), whilst others involve carrying out a simple test (streak test, magnet test) and in the case of the hardness test, it involves following a procedure on a separate sheet. The final part of the exercise is an acid test, and is as much a means of approaching health and safety issues as an identification test. This part is always supervised by the curator who follows an agreed COSSH procedure. The children all wear goggles and a rubber glove and an introduction to the use of acid is given, as well as demonstrating how to carefully carry out the test.

The second part of the exercise involves the children checking their results against an information sheet with the 'correct' answers and the names of the minerals. There are diagnostic properties to almost all the minerals and it is relatively easy to choose a name for each specimen. What is most interesting is the disagreement between children and the answer sheet over relatively trivial matters such as colour, shiny/dull; this leads on to an interesting discussion on the difficulties of classifying natural materials (a subject that the member of staff running the exercise is prompted to develop).

2. Gold panning exercise

Essentially this is a separating exercise using two finely crushed metallic minerals and sand, however the 'Klondyke' image is a successful way of capturing the childrens' imagination. They vigorously shake a small plastic bowl of sediment (which they are good at) and then patiently (!!!!) wash off the excess sand. After five

Figure 1. Gold panning exercise.

Figure 2. Sorting exercise.

minutes there is usually a concentration at the bottom of the bowls and with a little more care, magnetite and pyrite grains are left almost on their own. Then a magnet is used to remove the magnetite and the children have succeeded in separating three different materials. (Small bags are provided so that the children can keep the pyrite - a very cost effective way of raising enthusiasm!)

3. Sorting exercise

This is an activity which challenges the children to invent as many criteria as possible to subdivide the 15 rock specimens. This results in great discussion which is particularly heated if the group is running a competition to see whose criterion is fulfilled by the greatest number of rocks. Finally, the children try to match the samples to photos which have a short description, which leads on to further discussion. (This exercise is developed further in ROX 3.)

4. Fossil plaster cast exercise

Children have to follow instructions to mix the plaster and carefully pour the finished liquid into a soft rubber mould. Ammonites have been used throughout the ROX exercise as it is the process of fossilisation, rather than the different groups, that is important for children to understand. This is an opportunity to discuss the stages of fossilisation and eventually to keep a caste of an ammonite.

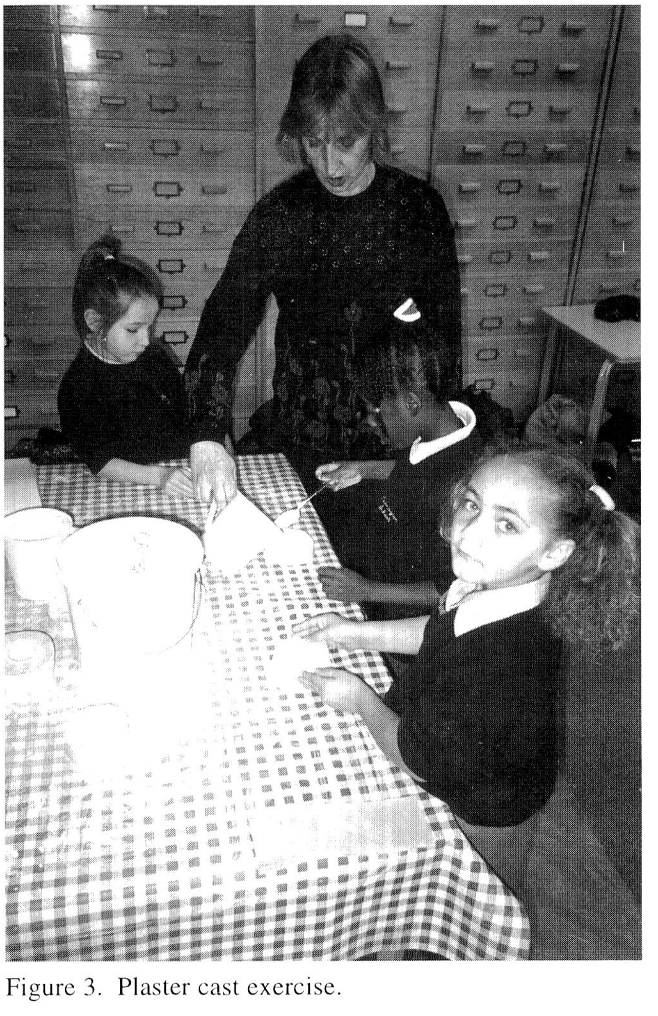

Figure 3. Plaster cast exercise.

Figure 4. Close observation in the mineral gallery.

5. 'Feely' bag exercise

Six mineral specimens are hidden inside cotton bags with elasticated tops. The children put a hand inside and feel the mineral within. They write as many descriptive words as they can think for each specimen on a pre-printed sheet. Then they look at some photos of the actual samples and try to guess which is which. Eventually they take the specimens from the bags and discuss who was right and why some specimens were misidentified. Two of the samples, calcite (Iceland spar) and ulexite have interesting optical properties which are tested over a pre-printed sheet with odd symbols.

Whilst one half of the group is busy in the education room, the other half is carrying out a detailed worksheet on the Earth Science galleries. This uses a graphic format and a variety of observation and recording techniques to maintain interest whilst studying the different topics to some considerable depth. Again this is carried out in small groups with a teacher helping to focus attention and offer help if either is required.

The entire visit lasts approximately 3-4 hours. The amount of work covered in such a short time is surprisingly large; a broad range of topics are covered to some depth and 'teaching points' are satisfied during every activity throughout the day. It is a thoroughly exhausting day for children and teachers (to say nothing of the greying curator). Even with the help of ROX 1 & 3, this session at the museum is still the backbone of the project.

In the near future, it is hoped that we will also be able to offer a visit to Salthill Quarry Geology Trail on the outskirts of Clitheroe (Bowden *et al.* 1997). This well established trail is an ideal location to lead a party of children. The quarry faces are well protected and the paths are well maintained, allowing the children to examine Lower Carboniferous limestones and abundant fossils in relative safety.

ROX 3

Lancashire Museum Service to Schools offers a loan service. A broad variety of original museum items and replicas in all subject areas can be booked in advance. A van delivers the required items and returns two weeks later to collect them. Three identical loan boxes have been specifically assembled to act as a follow up to the museum visit. There are two exercises which develop the rock topic and introduce plate tectonics.

The terms igneous, sedimentary and metamorphic rocks are introduced as a scientific way of classifying the rocks which have been seen previously. A video is included to act as a multi-media stimulus, prior to carrying out a book exercise and specially designed cards to help the children classify a set of rocks into igneous, sedimentary and metamorphic (an identical set to those used during the sorting exercise in ROX 2).

The second exercise is more of a demonstration. Two videos, one on mountains the other on volcanoes and earthquakes are used as a means of introducing the dynamic processes which occur at plate margins. During both videos there are numerous occasions where plate tectonics are mentioned and moving graphics are used to convey some of the colossal motions which are taking place. A world map with plate boundaries clearly marked is included so that, with the aid of the notes from ROX 1, teachers can describe some of the typical features of constructive and destructive plate margins and describe examples on the Earth today.

Conclusion

A carefully structured education package is now an essential tool in attracting the typical school group (Key Stage 2) to a museum. Earth Science is an ideal subject around which activities can be produced which accomplish many of the National Curriculum science 'teaching points'. As this is also a subject which many schools find difficult to teach without outside support, museums with geological expertise are in a perfect situation to exploit this potential market.

Acknowledgements

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Appendix 1: Note on materials

The pyrite used in the gold panning exercise is specially crushed on request by Burhouse Ltd., as it is important that a very constant fine grain size is used to entice the children to pan carefully and not pick out the large pieces by hand. All other geological materials were purchased from Northern Geological Supplies which offer good quality samples at a reasonable price.

Specimens were not extracted from the museum collections for three reasons, namely:-

1) Due to the early stage of our collection management, it was difficult to designate duplicate specimens.

2) Buying in material negates any ethical worries about removing accessioned material.

3) If any material is lost or damaged replacement items can be easily purchased.

Suppliers' Addresses

Burhouse Ltd., Quarmby Mills, Tanyard Road, Oakes, Huddersfield, HD3 4YP, U.K.

Northern Geological Supplies, 66 Gas Street, Bolton, Lancashire, BL1 4TG, U.K.

The videos and books used in ROX 3 are mainstream publications and similar materials can be ordered from any good book shop or educational supplier. All other materials have been produced in-house allowing total freedom to make amendments as constructive comments are received.

GALLERY REVIEW: SETTING THE STANDARD? THE EARTH GALLERIES AT THE NATURAL HISTORY MUSEUM, LONDON.

by Tom Sharpe, Stephen Howe and Cindy Howells

Sharpe, T., Howe, S.R. and Howells, C. 1998. Setting the standard? The Earth Science Galleries at the Natural History Museum, London. *The Geological Curator* 6(10): 395-403.

The second phase of the new Earth Galleries at the Natural History Museum (NHM) was opened in July 1998, marking the complete redisplay of the former Geological Museum at a cost in excess of £12 million. The Geological Museum had pioneered a new style of geology display in the early 1970s, and set a standard emulated by other national and local museums. While the Geological Museum exhibitions contained a wealth of specimens, those produced at about the same time by the NHM were often criticised for their lack of real objects. The Geological Museum passed to the control of the NHM in 1985 and is now known as the Earth Galleries. The new displays in the Earth Galleries are the latest product of the NHM's exhibition philosophy, and despite some shortcomings, do represent a new standard for the display of geological material.

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Background

The last 25 years have seen a revolution in the way museums approach geological exhibitions. Gone are the serried, systematic ranks of hand specimens with minimal and academic labelling; now the specimens, themselves often large and spectacular, are set in the context of a story and supported by well-written, accessible text, graphics, film, and animation. In 1973, the Geological Museum in South Kensington, then part of the Institute of Geological Sciences, set a new standard for geological exhibitions with the opening of *Story of the Earth* (Tresise 1973, Dunning 1974, 1975, Waller and Hart 1975). This gallery brought together various strands of geology, which at that time were being linked in the new unifying theory of plate tectonics. Its innovative approach took geological displays into a new era with its exciting presentation of large scale processes and its use of the spectacular. Most memorable were the huge artificial rock face (cast from an actual Moine outcrop in the Western Highlands) which formed the entrance, the erupting volcano, and the earthquake room, a shaking platform which recreated the ground motions during an earthquake. The gallery was the first designed specifically for the layperson rather than the geologist, and its success could be measured by a 60% increase in the numbers of visitors to the museum (Dunning 1974). The booklet accompanying the exhibition, with its synopsis of plate tectonics, became a recommended text on university courses in the early 1970s, while the style and design of the booklet set a new standard which is continued today in the popular publications produced by the Natural History Museum and the British Geological Survey.

The success of *Story of the Earth* led to a series of similarly-styled exhibitions at the Geological Museum such as *Britain before Man* in 1977 (Dunning 1978, Doughty 1978), and *British Fossils* in 1980 (Thackray and Velarde 1980, Doughty 1981) amongst others. These were specimen-rich exhibitions: for example, *British Fossils* with 1400 specimens on display was seen as 'a three-dimensional encyclopaedia of British fossils' (Thackray and Velarde 1980). A similar approach was taken by the Royal Scottish Museum when it opened its *Evolution* and *Minerals* galleries in 1975, carrying the new standard of geological displays north of the border (Waterston 1976, Dunning 1976).

At about the same time, the British Museum (Natural History) (now known as the Natural History Museum, here referred to as NHM) next door was reassessing its exhibition policy, with special regard to work being done, particularly in the United States, on the evaluation of exhibit effectiveness and the application of educational technology (Miles and Alt 1978, Miles and Tout 1979). The Museum developed a new 'exhibition scheme' in which an integrated approach to natural history was at the forefront (Miles 1978, Southwood and Hedley 1981). The first gallery to use this new approach was the *Hall of Human Biology* which opened in 1977 (Miles and Tout 1978). This exhibition aroused considerable controversy at the time because of its reliance on models and interactive exhibits rather than real specimens (Duggan 1978, Doughty 1978, Seddon 1979, Durant 1979, Halstead 1978). This was a recurrent complaint which again came to the fore with the opening of *Introducing Ecology* in 1978 (Miles 1979, Hamilton 1980, Sorsby, 1980, Swinney 1978). The philosophy of the NHM exhibition scheme was outlined by Miles and Lewis in 1983, but was again subject to criticism, some scathing (Donovan 1983, Hunkin 1983). Although the exhibition policy was defended by Gosling (1980) and Griggs (1984), the latter reported that both specialists and museum visitors felt that the new exhibitions should contain more specimens.

Following the incorporation of the Geological Museum into the Natural History Museum in 1985, several new exhibitions such as *Treasures of the Earth* and *Britain's offshore oil and gas* were opened, but the Geological Museum remained largely unaltered. On the upper floors were displayed cases of world ore deposits and British regional geology, exhibits which, it has to be admitted, were of interest mainly to geologists, but which were seen as innovative when the Geological Museum opened in 1935. Times, fashions and attitudes change, however, and in recent years these galleries were repeatedly criticised, particularly by Neil Chalmers, Director of the NHM, for their lack of attraction to visitors. Geology was seen by the visiting public as 'dry, static and dreary' and needed 'exhilarating exhibitions ... to present geology as a dynamic contemporary subject vital to our very existence'. However, visitor research commissioned by the NHM (Clarke 1991) showed that the Geological Museum had a rather unusual clientele. Of the people interviewed, 51% were either visiting the museum for study purposes or were there because they had a specific interest in geology. They were more likely to have pursued higher education, and were more 'upmarket', with a greater than normal representation of social class AB, than visitors to the Natural History Museum or the Science Museum. Clarke went on to describe proposed changes to the Geological Museum's exhibitions to make them more accessible to the other half of the museum's public. This stimulated a number of letters to *Geology Today*, most of which were critical of the museum's plans (Butcher 1992, Wilding 1992, Green 1992, Rothery 1992, Bamlett 1992).

However laudable the intent of the museum to provide new, exciting exhibitions, concern about changes to the galleries was expressed as early as November 1989 when the Geologists' Association met with NHM management (Robinson 1990, Osborn 1990). The Association were particularly concerned about the risk to the regional geology displays which, they felt, were a showcase to foreign visitors for the diversity of British geology. Robinson (1995) stressed the need for the museum to consider the amateur geologist in their plans for the galleries, pointing out that they used the specimen-rich displays of the Geological Museum to identify their own specimens, and therefore that the museum risked ignoring a particular section of the museum-visiting community: 'There must be a place for geological specimens on display as in the abundance given in the nearby galleries to tropical birds or insects ... It could be that we are catering for the absolute novice and the research-level specialist, but leaving the converted to fend for themselves.' When the regional geology displays were dismantled in anticipation of the construction of the new Earth Galleries, the removal of such systematic displays of specimens was likened by Frank Atkinson, a respected museum professional, to stripping a reference library of all standard works (Atkinson 1992). Concern about, and criticism of, the NHM management extended beyond its plans for the Geological Museum's displays to proposed changes to the museum's education service, staff redundancies, and what was perceived as the general downgrading of the profile of geology (Dunning 1990*a*, 1990*b*) within the NHM's new corporate plan (Evans 1990*a*, 1990*b*, Halstead 1990). This stimulated a number of letters to, and comments in, the *Geologists' Association Circular* and elsewhere.

Despite the controversy over the NHM's exhibition policy, many of the design and educational principles pioneered by the NHM in its galleries have been accepted and adopted, at least to some extent, by the museums profession, although most would argue the need to base exhibitions more on specimens than concepts.

The new Earth Galleries

Nearly a quarter of a century on from the opening of *Story of the Earth*, the Geological Museum has undergone a major redevelopment of its galleries costing in excess of £12 million. The first phase of these new Earth Galleries was opened in 1996 and the second in 1998. Do they continue the Geological Museum's tradition of ground-breaking displays?

From the Exhibition Road entrance, the central hall of the old Geological Museum has been transformed into a tall atrium, (named the RTZ Atrium after its sponsor, Rio Tinto plc) which is dominated by one of the tallest escalators in Europe, rising through a huge revolving globe. The sound of this squeaking, creaking, clanking, groaning globe (when it is working) fills the atrium. At the press preview of the second phase of the

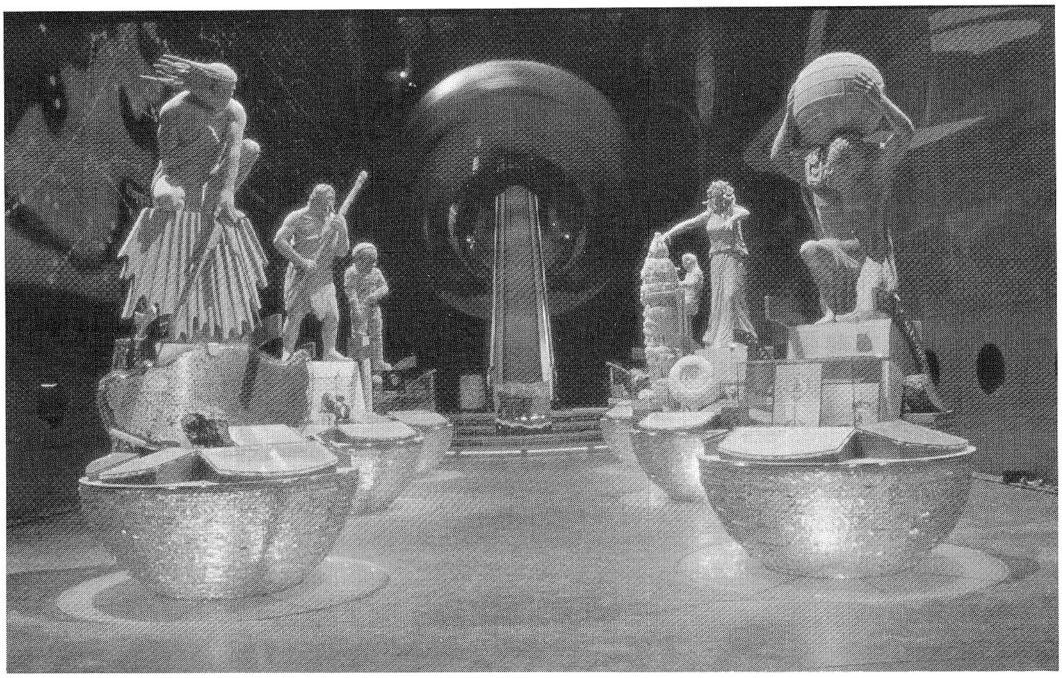

Figure 1. *Visions of Earth* in the RTZ Atrium. [© The Natural History Museum]

redevelopment, the escalator and globe were set in motion as lightning flashed and Prokofiev's The Montagues and the Capulets from *Romeo and Juliet* boomed out. Although greeted with some amusement, the music, although hackneyed, did lend a certain drama to the experience of being processed through the globe - perhaps it should be a permanent feature?

The exhibition in this area, *Visions of Earth*, is an introduction to earth science designed by Neal Potter Design Associates. The 15m high walls of the atrium are clad from floor to ceiling with large, grey (fake) slate slabs, on which are printed the Solar System on the north wall and a stylised representation of the constellations on the south. It is certainly an impressive view (more so from the first floor balcony on the stairs above the entrance), although overall the effect can be disturbing. Ghostly images, and the dark, sombre walls evoke an almost sinister and oppressive atmosphere while the sight of visitors disappearing up the escalator into the surreal globe is reminiscent of ore being carried by conveyor into a crusher. Is this structure inspired by the operations of the main sponsor? Visitors coming into the Earth Galleries from the main part of the Natural History Museum have a much less impressive view as they pass directly beneath the revolving globe. This very much feels like entering via the tradesman's entrance. With the Geological Museum now forming an integral part of the NHM, it is surprising that the spectacular vista of the atrium was not oriented towards this entrance.

The route to the escalator from the Exhibition Road entrance passes between two ranks each of three statues or 'icons' representing various 'visions of Earth' (Figure 1). These are made of resin coloured or painted pale green, presumably to imitate verdigrised bronze, and resembling ornaments found in a garden centre. The icons include, for example, William Blake's vision of God creating the Universe here used to represent 'Visions of Earth's beginnings'; Medusa, Atlas and a Cyclops representing Earth processes, Earth's shape, and Earth's past; and an astronaut and a geologist for Earth's order and Earth's future. Each icon is about 2m tall, and is mounted on a glass hemisphere around which some spectacular specimens are displayed. Medusa has her hand on a stalagmite boss, and a *Titanites* at her feet, while God's dividers are spread over a large cut section of meteorite. One has to ask how this rather obscure use of cultural icons contributes to visitor understanding of geology.

Within each slate wall is a row of 22 small portholes through which a wide range of spectacular minerals, fossils and rocks are displayed. They seem to be in no particular order or grouping, but each illustrates a theme. The specimens, mounted against a dark background, are illuminated by spotlights inside the cases and are, on the whole, well-displayed, giving the impression that they are almost suspended in space. However, the effect is spoiled in some portholes, as in the case of the lunar rock, where the interior structure of the case is lit. It also seems strange that the museum has not made more of such an important specimen.

The escalator rises through the revolving globe which spins slowly (at 0.2 mph, apparently!) anticlockwise (as viewed from below), contrary to the clockwise

Figure 2. *The power within.* [© The Natural History Museum]

rotation of the Earth when viewed from the South Pole. The 11m diameter globe is covered inside and out, with beaten copper, iron and zinc sheets, irregular in outline and not, as one might expect, resembling the continents. On the inside, some have ammonite motifs beaten into them, while text is projected, propaganda-like onto the moving interior. The globe has had considerable teething problems, with some of the sheets working loose or the globe failing to revolve. When it does work, it judders around, giving the impression that breakdown is imminent; it also engenders a sensation of imbalance in some people, who find themselves hanging onto the handrail with the feeling that they are being tilted to the right as they pass through it. This structure was probably a major cost item in the gallery; was it money well spent?

Reaching the top of the escalator, on the second floor, a spectacular vista might be expected to unfold. Instead, the visitor is disgorged from the globe and faced with a dark wall with the gallery title leading to the right into *The power within* (Figure 2). Designed by Event Communications Ltd, the exhibition begins with some magnificent large rocks to illustrate dynamic processes, here called 'forcing, squeezing, shattering, melting' and so on, using, for example, a basalt column from the Giants Causeway, flow-banded rhyolite, Shap granite, and schist. Opposite, a curved wall has a collage of images of erupting volcanoes into which are set monitors with film of earthquakes and volcanic eruptions. Interestingly, one displays a (?)live internet link showing recent earthquake activity around the world. Adjacent is a world map, and when appropriate buttons are pressed, sites of recent earthquakes and volcanic eruptions are illuminated. Curiously, this wall and its monitors are all behind glass, making it effectively a large glass case, in front of which is a further barrier of a metal railing at knee height: this degree of security seems somewhat unnecessary. Volcanoes are the main feature of the next section, with a reconstruction of an electronics store in a Philippines street being inundated by ash from the eruption of nearby Mount Pinatubo in 1991. Televisions in the store show news reports of the eruption read, somewhat incongruously, by Trevor MacDonald (is *News at Ten* broadcast in the Philippines?) with film footage and eye-witness accounts where, it appears, actors play the parts of TV reporters and scientists.

In the following section, on plate tectonics and the deep structure of the Earth, some of the graphics panels feature two geologists and the panel texts comprise conversations between them. This technique is well known and was put to good use in the Ulster Museum's dinosaur exhibition. This works well, but it does mean that much of each panel is given over to pictures of the two people.

The final section of *The power within* deals with earthquakes, and uses as an example the 1995 Kobe earthquake. Footage from a Japanese supermarket security camera is shown within a recreated store as the floor and walls shake and stock falls from shelves. This takes a stage further the old earthquake platform that was a feature of *Story of the Earth*. Using particular recent events like the Kobe earthquake and the eruption of Mount Pinatubo is all very well, but they will surely, in years to come, make the gallery seem dated, especially if there are future, more dramatic events elsewhere, as was pointed out by Bassett and Owens (1996). Also, the use of a specific, rather than a generic, earthquake might upset some visitors, especially those from Japan in this case. In a recent article in *The Times Saturday Magazine*, Will Self condemned 'the high style of bad taste involved in this pseudo catastrophe'.

On the other side of the second floor, *Restless surface* designed by MET Studio Ltd, explains surface processes. The exhibition here does not seek to enclose the visitor, but makes use of natural light coming through the large metal-framed windows of the gallery. While it makes a change to see daylight in an exhibition, the sight of the bare gallery walls above the exhibit structure makes the exhibition look as though it is only temporarily occupying this space, and, worse, done 'on the cheap'. The gallery walls are also visible in *The power within*, but are less obvious. *Restless surface* has large, bold graphics, and also cleverly uses small flip charts with further information. The gallery at times is a curious mix; there are many things to do and touch, but there are also odd features like a panoramic window beyond which is a photograph of the Grand Canyon in Arizona (at least, it is labelled as such; it is actually the Goosenecks of the San Juan River in Utah). It is not at all clear what the function of this exhibit is. There are many interactive exhibits in this exhibition, but again, as they are largely mechanical, they are subject to decoration with out-of-order notices. Some of the interactives, like a sand pit where water jets are used to form various erosional features, are perhaps over-ambitious; others, though, are clever and well thought out. If the maintenance problems of mechanical interactives can be overcome, they are of value, but if they spend any time out of order, then they can greatly detract from an exhibit.

Visions of Earth, *The power within* and *Restless surface* formed the first phase of the Earth Galleries and were received with considerable enthusiasm by the press, both public and geological (Easterbrook 1996, Hawley 1996, Jury 1996, Robinson 1996, Smith 1996), although some geologists were less impressed (Wilding 1997). Viewing this first phase before seeing the second, leaves one with the impression that the NHM had learned little from criticisms of its displays in the 1980s and early 1990s - an over-reliance on design for design's sake, many unreliable mechanical interactives, and the same dearth of specimens with only 417 on display. The use of different design companies for each section contributes to a feeling of incoherence: the whole thing just does not hang together. With the first phase very much a triumph of design over content, one enters the second phase galleries with some apprehension.

The second phase of the redevelopment, located mainly on the first and ground floors of the museum, opened on 16th July 1998 (Culver and Fleet 1998, Hawkes 1998) and comprises three new exhibitions, *Earth's treasury*, *From the beginning*, and *Earth today and tomorrow* as well as *Earth Lab*, a geology resource centre. *Earth's treasury* on the first floor is a stunning and spectacular gallery of minerals. Criticism of the first phase for the lack of specimens on display has finally been addressed, and this gallery is packed with some of the most spectacular specimens in the world. Over 3,000 specimens are exhibited, from clays to gems, with well thought out cases and lighting. Along the right wall is a huge continuous case with gems and minerals in

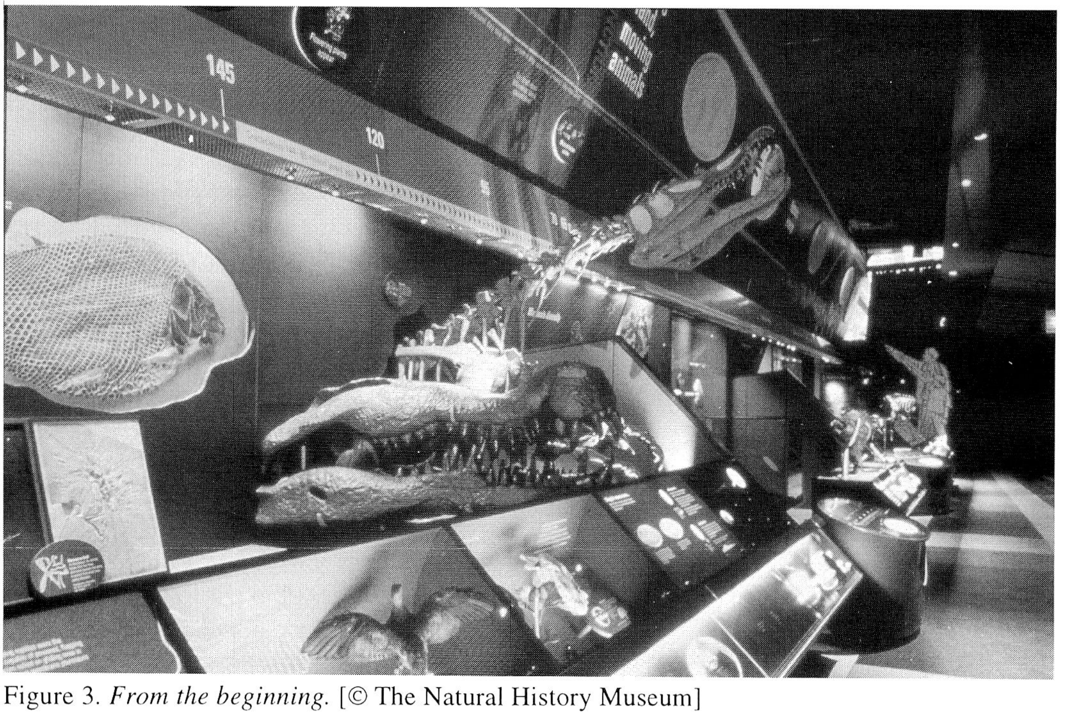

Figure 3. *From the beginning.* [© The Natural History Museum]

Figure 4. *Earth Lab.* [© The Natural History Museum]

systematic arrangement, while the left side comprises a series of small, themed alcoves. This structure can, however, make the gallery awkward to tour. A major sponsor of this gallery is De Beers who have lent diamond specimens valued at over £900,000. These make up an impressive display and include, as well as models of famous diamonds like the Hope and the Koh-i-Noor, a 3,000 carat parcel of rough diamonds from a De Beers mine, a set of polished diamonds showing the main characteristics by which value is determined, and a Liz Taylor-style pendant with a huge, 17 carat stone. The design, by David Bentheim Studios, makes use of stainless steel case claddings, giving a not inappropriate high-tech look to the gallery.

Also on the first floor is *From the beginning* (Figure 3), which starts with the origin of the Earth and follows the story of life and the Earth through time. Running through the gallery, high along one wall is a time line, scaled at 25 million years to a metre, and highlighting key points in the evolution of life and with maps of world palaeogeographies. Each section of this gallery includes touchable exhibits, often small specimens fixed firmly on plinths in front of the main displays. The gallery contains a section on British regional geology, where a wall-mounted geological map of Britain (mounted sideways for some reason) has in front of it a series of suitcases linked to geological localities shown on the map. These include the North West Highlands, Derbyshire, the Vale of York and the Dorset coast. Lifting the case lids reveals a small suite of specimens and photographs from each area. It is an interesting way of treating regional geology, but it is likely that many people would prefer more specimens and information than these suitcases can provide. With a number of large fossils on display, *From the beginning* appears to contain lots of specimens, but in fact it displays only 234. Although designed by a different company (Exhibition Plus), the style of *From the beginning* fits well with that of *Earth's treasury*.

Earth Lab, designed by Rawls & Co, on a mezzanine floor between the ground and first floors, is packed with over 2,000 specimens, with fossils arranged stratigraphically and rocks systematically (Figures 4 & 5). A computer database allows visitors to search for particular specimens or to use a simple key to identify their own material and directs them to a particular case to see comparable specimens. Alan Timms, who produced this database, is to be congratulated on designing such an accessible research tool. The lab is also staffed by museum geologists who can give demonstrations or help to identify specimens. It is equipped with microscopes and cameras linked to screens around the room and it is planned to have BGS maps and memoirs available for consultation. It therefore goes some way towards addressing the worries of the Geologists' Association about the provision of an area for interested amateurs. However, it seems likely that there could be difficulties handling large numbers of people in this limited space, especially if they require the assistance of the few members of staff who would be available at any one time.

The last gallery, *Earth today and tomorrow* (Figure 6) by Land Design Studios, is located on the ground floor in the area formerly occupied by *Story of the Earth*. Concentrating on the Earth's natural resources, it has

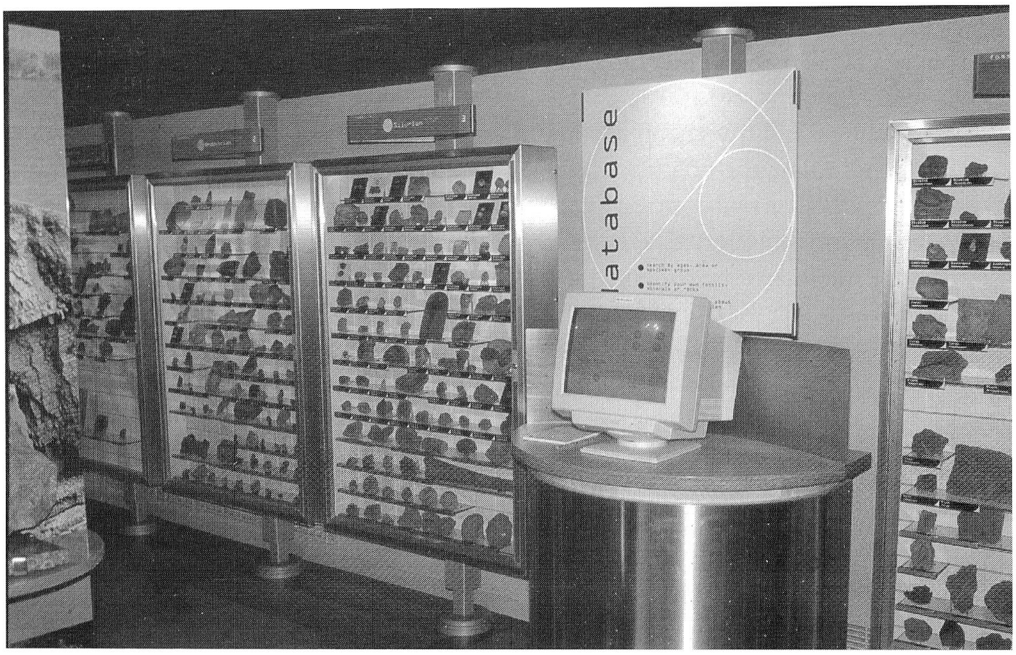

Figure 5. *Earth Lab.* [© Tom Sharpe]

quite a different design from the others, a bright style with modular display units and large backlit images suspended in front of the gallery windows. Unfortunately, this does make it look rather like a trade show. Not only does the gallery deal with the origins of raw materials like oil and gas, but it takes an environmental slant to illustrate how much of the Earth's resources a typical family consumes in a year. This is represented by upturned pallets of bricks, drinks cans, and loaves of bread hanging from the ceiling. This is probably the least successful of the galleries, lacking spectacular specimens or impressive phenomena.

The Earth Galleries shop is located on the ground floor to the right of the Exhibition Road entrance, and is a disappointment. It occupies a rather awkward space, and little thought seems to have gone into its design and layout. The stock, too, is disappointing, with an over-reliance on small mineral specimens, and a poor selection of books. Having attempted to stimulate an interest in geology through the exhibitions, it is important that a museum shop contain the best books and materials available for visitors who wish to take their study further.

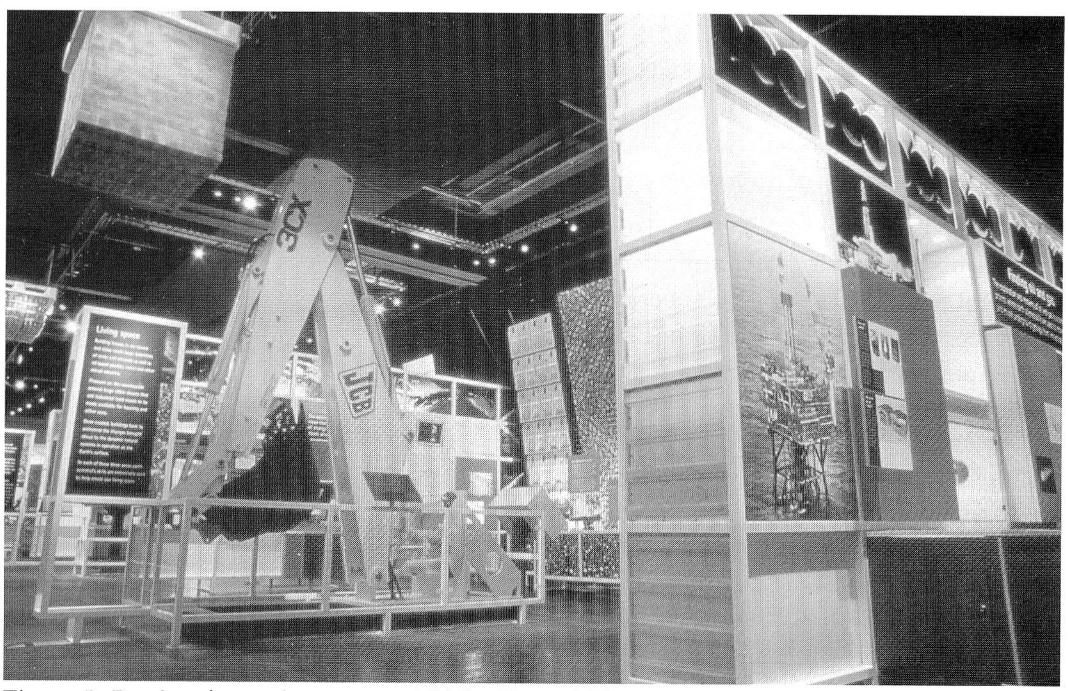

Figure 5. *Earth today and tomorrow.* [© The Natural History Museum]

The redevelopment of the Geological Museum took five years and cost over £12 million, although, as Bob Bloomfield pointed out at a GCG meeting in 1996, and in a letter to *Geology Today* (Bloomfield 1997), about £7 million of this was spent on improvements to the fabric of the building, including air-conditioning, heating, fire escapes, and toilets. The museum received a grant of just over £6 million from the Heritage Lottery Fund, and £1 million in sponsorship from Rio Tinto plc. The Earth Galleries have an area of 5,400 square metres and about £5.4 million was spent on the exhibitions, an average of £900,000 per gallery, or about £1000 per square metre. This is a remarkably low design cost, as exhibition costs today are generally around £1400 per square metre. However, the average cost per square metre for the Earth Galleries may not have much meaning as each gallery is so different in design, content, structure, and, presumably, cost.

It is difficult to get an overall feel for the Earth Galleries, because they do not have any consistency of design or structure and seem more like a series of unrelated exhibitions. Some work better than others, and in this respect, *Earth's treasury* and *From the beginning* stand out. They look good, with superb specimens, well-displayed. It is surely no coincidence that these are the galleries which have the most specimens and the fewest interactives. While some of the other galleries have equally good material, they are overwhelmed by the design. Are the new galleries an improvement over what they replaced? One could take the view that much is merely an expanded and updated version of *The Story of the Earth*, as some elements, such as the earthquake experience, will be familiar to those who knew the old displays. However, in the 25 years since *The Story of the Earth* opened, exhibition techniques and philosophy have moved on and these new galleries do reflect this. It is clear, though, that the museum has learned to some extent from the criticism of its exhibition policy over the last twenty years and, with the inclusion of *Earth Lab*, has shown that it is willing to listen to the views of interested parties.

Despite the criticisms geologists and museum professionals might have about the new galleries and the way in which the NHM approaches exhibitions, the galleries will be popular with the public. They are bright and colourful, there is a great deal going on, and there is much to attract the visitor's attention. Following the opening of the first phase of the Earth Galleries in 1996, the NHM reported that in 1997-98, the visitor numbers broke all previous records (presumably since the introduction of charging) with 1.824 million people visiting the museum. Overall, then, the Earth Galleries do succeed in presenting geology as a dynamic subject of importance to all of us.

Where do geological exhibitions go from here? Well, attention now moves to Scotland where the new Museum of Scotland and *Dynamic Earth* in Edinburgh should raise the standard further.

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LOST & FOUND

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

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

Abbreviations:

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

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

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

249. Maps and papers relating to the Lake District.

David Oldroyd, School of Science and Technology Studies, The University of New South Wales, Sydney, NSW 2052, Australia (D.Oldroyd@unsw.edu.au), is writing a book on the history of geological research in The Lake District. He would be most pleased to hear from anyone who knows of the existence of any archival material relating to the topic, and in particular the locations of manuscript maps. He has been through the archives of the Geological Survey, Birmingham University, Cambridge University (Sedgwick Museum and University Library), and to some extent at the Geological Society and Oxford University, as well as local museums in Cumbria. He has been informed that some original maps of J.F.N. Green were at Liverpool University about 10 years ago, but it does not seem to be possible to locate them now. If anyone knows their whereabouts, this would be particularly helpful. Papers or maps by such geologists as R.H. Rastall, E.J. Garwood, A.R. Dwerryhouse, E.E. Walker, J.J. Hartley (ESPECIALLY him), S.E. Hollingworth, Gertude Elles, G.S. Hadfield, W.C.C. Rose, etc., as well as Green, would all be extremely useful.

Also, it would be greatly appreciated if any geologists who have worked, or are working, in the Lake District, would contact Professor Oldroyd, if they have not already been interviewed by him. He expects to visit Britain again in the second half of next year and would like to make more contacts.

BOOK REVIEWS

Evolution. BBC Learning Support 1998. 32pp. ISBN 1-86000-114-9. Paperback. Price: £4.95. Available from BBC Education, Evolution, PO Box 7, London W12 8UD, U.K.

In March 1998, BBC2 broadcast a series of programmes over a weekend on the theme of Evolution. To accompany this *Evolution Weekend*, BBC Learning Support published this 32 page A4 booklet with contributions from a variety of authors.

It is an attractive publication, well laid out and nicely designed. It begins with a page on creation myths and evolution, with examples of creation stories from the Aztecs and from South Africa on this page and others, from China, North America, and Madagascar in boxes elsewhere in the booklet. Next comes *What is evolution?* which neatly summaries the four basic premises of Darwinism and explains how organisms adapt to their environment. This section is itself an adaptation from an Open University Workbook. How fossils form, the geological timescale and an explanation of species and speciation follows.

A section called the *Extinction Files* takes up the central 10 pages of the booklet. This takes the form of five double page spreads each dealing with an animal which became extinct and explaining the reasons why they did. The animals dealt with are the Bearsden shark, *Stenacanthus*; *Lystrosaurus*; *Lycaenops*, another mammal-like reptile; mosasaurs; and the South American 'terror birds' like *Andalgalornis*. Each double page is taken up with a large reconstruction of each animal and an enlargement of a particular feature, but the images are clearly computer-generated and both the main picture and the further enlargement are just too big, losing a lot of definition and sharpness. Smaller clearer images would have been better, and allowed more space for text or even other topics as each double page spread could have been reduced to a single page.

The subject of extinction is continued in the next section, which includes a chart of mass extinctions through geological time. Perhaps the extent of some of these would have been better illustrated by some sort of graphic, rather than a dull chart with mere percentages of species killed. A page on Hunting for fossils, adapted from BBC Education's Postcards from the past, introduces a fossil key prepared by Alan Timms of the Natural History Museum. This is a rather clever circular diagram using illustrations from the NHM's three British fossil handbooks and with very little text, but which would easily allow an identification of the major fossil invertebrate groups. The diversity of life and an explanation of evolutionary trees are covered in the last part of the booklet.

For further information, I was pleased to see that readers are directed first of all to their local museum and to GCG's *Thumbs up* leaflet, as well as to the Geologists' Association, Rockwatch, the Dinosaur Society and *Down to Earth*.

Apart from a few minor criticisms, this is a cheap, cheerful, attractive booklet to have on sale in your museum shop. It deserves a wider circulation.

Tom Sharpe, Department of Geology, National Museum of Wales, Cardiff CF1 3NP, Wales. 21st August 1998.

Wilkinson, I. 1997. _Fossil focus: Foraminifera._ Earthwise, British Geological Survey. ISBN 0-85272-298-2. Pamphlet. Price: £1-95.

This is a wonderful introduction to an important fossil group which many geologists know little about. The pamphlet is printed on A3 laminated card folded twice to produce three panels on the front and back. The glossy, colourful presentation is naturally attractive and entices the reader to look more closely at the contents within. The format is essentially soundbites of information accompanied by copious linedrawings, figures and photographs. After a brief introduction, the pamphlet leads the reader through a description of the basic physical characteristics, the micro-structure and shape of the test, and onto their use as a palaeoecological and biostratigraphical tool, before ending with a number of anecdotal facts. My one criticism concerns the target audience. Though the overall format is aimed at a layperson, the actual subject matter and inevitably some of the text (though this is largely well written in simple language) seems beyond the scope of a general readership.

In summary, this is an attractive, well illustrated introduction to Foraminifera which would be a useful addition to any geology curator's book shelf who had even a vague interest in this fossil group.

Alistair Bowden, Clitheroe Castle Museum, Castle Hill, Clitheroe, Lancashire BB7 1BA, U.K. 24th August 1998.

Stanier, Peter. 1998. _Mines of Cornwall and Devon an historic photographic record._ Twelveheads Press, 108pp + 115 photographs, maps and line illustrations. Hardback. ISBN 0 906294 401. Price: £15.00.

This attractive publication is a companion to the author's *Quarries of England and Wales* published in 1995. Like that volume, the present title includes many unpublished photographs taken by photographers of the Geological Survey during the period 1903-45.

The closure of South Crofty mine in March 1998 marked a sad day in the long history of Cornish tin mining. This book is therefore, a timely reminder of the techniques used in mineral extraction in South West England during the first half of the twentieth century. The historic photographs range in location from the wild Atlantic cliffs of Botallack, with its photogenic engine houses perched on the cliff, to the softer landscapes on the eastern flanks of Dartmoor where minerals were also worked.

In 12 chapters we are given a fascinating insight into the once great industries of the South West based largely on good quality pictures from the photographic collections of the British Geological Survey. Surface and underground mines, mining landscapes, tin mines, small mines, trial surface workings as well as stream workings and tin salvage works are covered. The mines of the Teign Valley, Devon, are also featured.

The techniques, machinery and processes are illustrated and discussed as is the decline of these extractive industries. There are super shots of the industrial landscapes, of groups of miners some carrying spare candles hung from their jackets, whilst other pictures show men (and women in some of the 1945 shots) at work. The occasional view of a cleaner, better dressed operative is thought to represent the photographer or his assistant. I am sure we have all asked friends and colleagues to feature in our own photographs to act as a scale too!

The roofless engine houses we have all photographed on trips to the area are but ghosts of a rich industrial past and this book brings it to life. In addition, these views are records of great interest to local historians and industrial archaeologists. Most concern tin mining and streaming in Cornwall, although wolfram and iron are also included. Devon is less prominent in the BGS photographic collections but this book features the extraction of barytes, micaceous haematite as well as the Oligocene ball clays in the Bovey Basin.

There is a selected bibliography of books and articles related to the area as well as an index.

Geological excursions to look at the mineralisation in the South West will be greatly enhanced by a reading of this book. It will also provide an appreciation of the importance of the mining industry in the past.

I shall eagerly await the next offering by this author to see if the quality of his output is maintained!

Tony Cross, The Curtis Museum, Alton, Hampshire, U.K. October 1998.

Lord, B. Dexter Lord, G. and Nicks, J. 1989. *The Cost of Collecting.* Collection Management in UK Museums. HMSO, xxvi + 157pp. Paperback. ISBN 0 11 290476 9.

This report attempts to quantify the cost of collecting, to assist museums and those who fund them to allocate resources, to an activity which is at the core of museum identity. The study was undertaken by consultants in 1988-89 and funded by the Office of Arts and Libraries. It was achieved through a questionnaire survey and case study visits to 20 of the 61 respondents, backed up with data from the Museums Association Database of UK Museums. A literature review and preliminary consultation shaped the questionnaire design. The museum sample was chosen to represent the range of UK museums.

The aim of the survey and the results in this report identify cost categories for projection of new acquisition costs and also managing existing collections. The report documents some of the variations in costs related both to type of collection and museum. The profile of costs of collecting in British museums is intended as a management tool for museums of all types in addressing a key factor in decision making and future planning.

The scope of the study is extensive and examines all the variables relating to defining the total costs of collecting. It looks at both direct costs of collecting, curation, conservation, documentation, security etc. and indirect costs as a proportion of general maintenance and administration. It also appraises the 'opportunity cost', useful in deciding on acquisitions or collecting choices in the context of limited resources. The real costs of acquisitions, both initial and future, when known from the outset, allow better informed management decisions. In a report of this type one might expect a wealth of numbers, but despite the apparent lack of actual figures throughout, those given are useful and significant. Actual costs will of course change with time, so the relative values indicated for different categories may be most useful.

There is a degree of repetition of information throughout the structure of the report, but this is actually a strength, since the information required will be easily located, whatever one's approach into the report. Half of the total pages are appendices including considerable details of questionnaire results. Appendix E is an extensive bibliography and literature review with a useful précis of each article.

The scope of the report is museum wide and geological collections are not specifically considered, but despite the fact that this was first published nearly ten years ago, it is an informative and useful study likely to be of relevance to museum directors or managers in providing a factual analysis of the cost of collecting, to balance against the much less quantifiable benefits.

Matthew A. Parkes, Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4, Ireland. 16th November 1998.

Newman, A., McLean, S.G. and Hudson, D. 1996. *A catalogue of the type, figured and cited fossil vertebrates in the Hancock Museum, Newcastle upon Tyne.* The Hancock Museum, Newcastle upon Tyne, 161 pp. ISBN 0-9509680-8-0. Paperback. Price: £10-00 (from the Hancock Museum, Barras Bridge, Newcastle upon Tyne NE2 4PT, U.K.; Tel: 0191 222 7418; fax: 0191 222 6753; e-mail: hancock.museum@newcastle.ac.uk).

This excellent catalogue of material in the Hancock Museum was reviewed in the last issue of the journal and my only criticism was with the large font size used throughout. I have since been notified by Alec Coles (Senior Curator, Hancock Museum) that the use of a large font size follows the access policy and associated print guidelines for Tyne and Wear Museums, which seeks to produce material that can be read by the visually impaired. It is good to know that such a group is catered for.

Patrick N. Wyse Jackson, Department of Geology, Trinity College, Dublin 2, Ireland. 16th October 1998.

The Geological Curator

Index to Volume 6 (1994-1998)

AUTHOR INDEX

PERSONAL NAMES INDEX

INSTITUTIONS AND ORGANISATIONS INDEX

PLACE NAMES INDEX

GEOLOGICAL AND SYSTEMATIC INDEX

MUSEOLOGICAL INDEX

MISCELLANEOUS INDEX

Index compiled by Patrick N. Wyse Jackson

Pagination and Dates of publication:

Volume 6, Number 1: pp 1-45 [22.4.1994]
Volume 6, Number 2: pp 46-113 [8.11.1994]
Volume 6, Number 3: pp 114-146 [27.3.1995]
Volume 6, Number 4: pp 147-184 [15.9.1995]
Volume 6, Number 5: pp 185-218 [30.5.1996]
Volume 6, Number 6: pp 218-244 [3.11.1996]
Volume 6, Number 7: pp 245-290 [25.4.1997]
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THE GEOLOGICAL CURATOR

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