ICOM-CC
18th Triennial Conference
2017 Copenhagen

NATURAL HISTORY COLLECTIONS

Conservation in a Barcode Age: A cross-discipline re-storage project for pyritic specimens

LU ALLINGTON-JONES*
The Natural History Museum
London, United Kingdom
l.allington-jones@nhm.ac.uk

AMY TRAFFORD
The Natural History Museum
London, United Kingdom
a.trafford@nhm.ac.uk

*Author for correspondence

KEYWORDS: preventive conservation, oxidation, microenvironment, barcode, digitisation, pyrite, fossil

ABSTRACT

The dichotomy of conservation and access has long been recognised within the museum profession. The recent push for digitisation has added a new dimension to this argument: digital records can both increase potential access, due to increased awareness of the existence of objects, and decrease potential handling, since a more thorough awareness of an object creates a more informed decision regarding whether access is actually necessary. The use of barcodes and the creation of digital resources have therefore been incorporated into a re-storage project at the Natural History Museum, London to reduce duplication of work (and handling) by staff and to combat the reduction in access caused by the enclosure of objects within microenvironments, which in turn helps preserve specimens for future access. This project demonstrates how conservation and digitisation can successfully synthesise through the use of barcodes, when working with a cross-discipline team.

PYRITE OXIDATION AND THE RATIONALE BEHIND MICROENVIRONMENT USE

Pyrite and marcasite are iron disulfide minerals commonly found within natural history collections as constituents of ores, mineral suites and fossils. Marcasite is rarer and more unstable than pyrite, but oxidises in a similar manner. Pyrite can occur in two forms: compact, crystalline and relatively stable, or framboidal, microcrystalline and unstable. Many factors influence the sensitivity of pyrite, such as crystal form, size and porosity, temperature, carbon content, pH, light and trace element composition (Smith and Shumate 1970, Fellowes and Hagan 2003). Pyrite oxidation manifests rapidly when relative humidity (RH) of the atmospheric oxygen in the surrounding environment exceeds 60% and reacts with the unstable mineral (Newman 1998). The resulting by-products of this oxidation (such as sulfuric acid and hydrated ferrous sulfates) can be very harmful to specimens, labels and storage media. Once pyrite has begun to oxidise, mineral hydrates will form at far lower levels of RH (Newman 1998). The resulting deterioration is evident as expansion cracks, white/yellowish acicular crystal formations and a sulfurous odour, and will lead to complete disintegration of specimens if no action is taken. The production of sulfuric acid from iron disulfides may cause further issues within collections when associated minerals are destroyed and secondary minerals form (Howie 1992). At the Natural History Museum (NHM) in London, pyrite oxidation is a significant issue. Stabilisation of decay products can be undertaken using methods such as ethanolamine thioglycolate paste (Cornish and Doyle 1983), or exposure to ammonia vapour, which renders the oxidation products non-hygroscopic between 0–80% RH (Waller 1987). Further oxidisation can only be inhibited by completely removing either water or oxygen from the system (Morth and Smith 1966), which can be achieved through preventive methods: the use of humidity- or oxygen-controlled environments.

At low RH a monolayer of water will form on inert sorbents but somewhere between 30% and 60% RH water will be adsorbed as a multilayer (Howie 1992). This may explain why some authors have assumed that storage below 30% RH will eliminate pyrite oxidation, but oxidation still occurs between 0% and 30% RH (Morth and Smith 1966, Walker 2001). At over 60% RH the dominant oxidation mechanism is electrochemical and at lower levels the main mechanism is molecular, which is accompanied by a significant drop in oxidation rate (Fellowes and Hagan 2003, Rimstidt and Vaughan 2003). Dry, low-oxygen microenvironments can be achieved through RP System A-type oxygen scavengers and are advisable for mineral suites containing species which can be damaged by ammonia (Irving 2001) and, therefore, cannot be chemically pre-stabilised. Levels below 30% RH can cause irreversible dehydration damage to clays within fossil matrices (Collins 1995) and will also cause precipitation of ferrous sulfate salts in cracks or voids, accelerating specimen disaggregation (Jerz and Rimstidt 2004). An anoxic enclosure sealed at an ambient 40%–50% RH with RP system K-type oxygen scavengers is therefore more suitable for fossils. This is supported by Lodha et al. (1983), who trialled nitrogen enclosures at 50% RH. An RH similar to ambient museum conditions will furthermore prevent shocks and alterations in mineral hydrates, both when specimens are placed inside the enclosure, and when the enclosure is opened for research.

Figure 1. A pyritic fossil ammonite undergoing oxidation

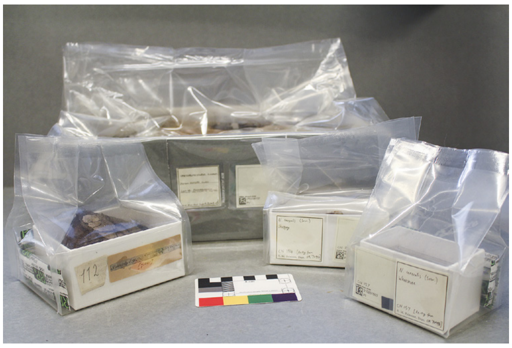

Figure 2. A selection of specimens stored in bespoke oxygen-free microenvironments

PROJECT DEVELOPMENT

The project was conceived as a large-scale preventive conservation undertaking to stabilise pyritic rocks and fossils deteriorating due to oxidation (Figure 1). Volunteer re-storage projects had been run for several years, but it became clear that the extent of the deterioration was a more urgent and widespread issue than previously anticipated. In August 2015, three members of staff assigned to the project began to survey the collections within the Earth Sciences department, and identify the specimens at highest risk from deterioration. These were joined by a fourth in June 2016. The second phase of the project involves stabilisation of the most severely affected specimens using remedial methods, followed by re-housing them in individually made microenvironments comprising archival-grade card or epoxy resin, foam, barrier film and oxygen scavengers to prevent future deterioration (Figure 2).

Howie (1977) and Borek (1994) established that many forms of pyrite are stable at over 75% RH, but that oxidation will occur rapidly at 60% RH for unstable forms. Since the fossil collections at the NHM were subjected to 65% RH in 1967 due to a faulty HVAC system (Howie 1977), it is reasonable to assume that all unstable material acquired before 1967 has already begun to show signs of deterioration, which can be extrapolated to newer acquisitions collected from the same sites and horizons. It is therefore possible to identify material containing stable pyrite and determine when re-storage is unnecessary.

It was recognised that placing specimens in anoxic enclosures, although preserving them for future access, reduces the desirability of physical access, since an enclosure must be opened for viewing and then re-sealed with fresh scavenger, increasing costs. The bags themselves, although transparent, reduce visibility and potentially several could be opened unnecessarily before the desired specimen is found. In addition, concurrent projects are being undertaken within the museum to barcode specimens and create digital resources on the collections management system (CMS). If the bagged specimens become part of a future digitisation project, every single enclosure would have to be opened, wasting time and materials. The plan to incorporate digitisation within the preventive conservation project workflow was therefore devised.

DIGITISATION

Many specimens are currently on the museum's digital CMS, but many thousand more await incorporation. To enable mass digitisation of the specimens treated during the project, holding or 'stub' records of the catalogue numbers were created by data management staff and curators. Unique data matrix barcodes can then be assigned to each specimen in the form of an acid-free label which can be placed inside the anoxic enclosure and scanned using a barcode reader (iDigBio 2015). The specimen barcode and barcode for the storage location (drawer or shelf) are then used to name images of the specimen and any associated labels. The storage location barcodes are added to the CMS by curatorial staff. A web-based application, developed by the museum's data managers, is then used to automatically create barcode stub records on the CMS. Conservation technicians then associate the barcode stub with the catalogue stub using a second web-based application. This enables enrichment of the digital catalogue record with location data and images.

WORKFLOW

The high risk specimens, identified through collection surveys, are transferred to the laboratory where each specimen is assigned a barcode. Digital images are taken of the specimen with this barcode and existing labels (Figure 3). The image is named (using Syrup software) by scanning the new unique specimen barcode and the location barcode of the storage drawer or shelf with an underscore (_) to separate the two number strings. These images are batch imported into the CMS by a data manager to create stub barcode records comprising the image, the specimen barcode and the location barcode (which links to the location record in a separate module on the CMS). Meanwhile, the conservation team assess the specimens according to condition, recording data in a spreadsheet for subsequent import in batches to the CMS. The images already taken for the catalogue module are also associated with the condition records. Remedial treatments are undertaken only where necessary. These include dry cleaning to remove oxidation products, ammonia vapour treatment, and consolidation and repair with Paraloid B-72 in acetone. The specimens are re-housed in hand-cut polyethylene nitrogen-expanded foam cushions, acid-free trays, or foam-lined epoxy mounts and polyester pockets for loose specimen labels. Small trays are ready-made from acid-free archival boxboard covered with acid-free paper and adhered using neutral pH EVA, whilst large trays are individually constructed from acid-free fluted boxboard and either sewn with binder's thread or secured with nickel-plated rivets. Tray walls exceed specimen height to prevent barrier film contact. The specimen, labels and new barcode are then placed inside a handmade reduced-oxygen enclosure (Trafford and Allington-Jones 2017).

Figure 3. A typical specimen image with scale, colour balance card and existing labels, plus a new barcode label

The microenvironment enclosure is created using ESCAL Neo, a transparent oxygen barrier film consisting of seven layers, including a gas-barrier layer of ceramic-deposited polyethylene terephthalate, a protective outer layer of polypropylene and an inner layer of polyester that can be heat-sealed (McPhail et al. 2003). Previous tests of barrier film bags using oxygen indicators over the last eight years have found that the sides of a successful enclosure will draw inwards (due to a 20% volume reduction). A failed enclosure can therefore be easily detected without the need to measure oxygen levels. For bespoke trays, bags are cut individually, but for standard (generally smaller) tray sizes, cross-shaped Perspex templates are used to accelerate production rates. The oxygen barrier film, once cut to size, is heat sealed at the edges to construct a gift bag style enclosure with a rectangular base and a pinched top. A pillow-style bag is created for larger specimens. The specimen labels and new barcode (placed in individual polyester sleeves) are attached to the outside of the storage trays using 3M 415 double-sided tape, to ensure that the data is visible from the exterior. Care is taken when handling the barrier film to prevent creases and scratches, which could compromise its integrity. The specimen, within its storage tray, is then placed inside the bag with sufficient oxygen scavenging sachets. The bag is then double heat sealed at the top, leaving enough additional material so that it can be cut open and re-sealed (with replacement scavengers) if access is required for research or exhibition.

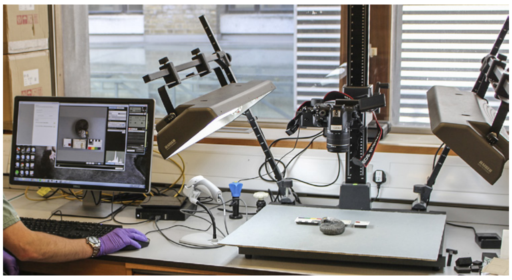

Figure 4. The digitisation workspace with barcode scanner and copy stand

Storage methods and remedial treatments are also recorded via barcode onto spreadsheets and imported in batches to the CMS. The final stage for the conservation team is to digitally associate the barcode stub records with existing catalogue records using the second web-based application (Figure 4). This operates through manual input of the specimen number (utilising the previously created digital image of the specimen and its label(s)). The application searches the CMS for the digital catalogue record bearing the registration number. The operator then has a choice to merge the record, add a suffix, create a new stub or flag the record to the curator (for example, if there is no registration number or if multiple specimens share a single number).

Some issues were generated by the original numbering system used by the Palaeontology Department: in the late 1800s the catalogue system moved from straight sequential numbering of acquisitions to a system which used sub-department prefixes based on taxonomic group, e.g. ‘R’ for reptiles and ‘C’ for cephalopods. When the museum adopted its current CMS, the use of additional prefixes was adopted to represent higher taxon, e.g. ‘PV’ for vertebrates, ‘PI’ for invertebrates, ‘PB’ for palaeobotany, etc. The original numbering sequence (which lacked any prefixes) was assigned ‘OR’ for ‘old register’ plus the higher taxon prefix. So an ammonite with number ‘2361’ would then become ‘PI OR 2361’. To facilitate digitisation of specimens all gaps existing on the CMS have been assigned stub records by curatorial staff. Old register records where higher taxon was unknown were prefixed ‘MIX OR’. To enable the conservation team to assign the correct higher taxon prefix during operation of the second web-based application, they required a guide to the prefix system (82 variables) and also a certain level of recognition of types of fossil. By the time this stage of the project was reached, the conservators had made condition reports for, photographed and re-stored sufficient fossils from the relevant group to allow confident recognition. This aspect of the project was enabled by the approach of tackling the collections by taxonomic group, rather than in a piecemeal fashion.

LESSONS LEARNED

Spreadsheet imports into the CMS worked extremely well and saved a significant amount of time for simple specimen condition reports and for treatment data. They proved too restrictive for more complex condition reports, for which it was found more appropriate to enter individuals directly into the CMS. The use of scanners and barcodes significantly speeded up specimen and conservation data association on the CMS and eliminated risks from typing errors. Other advantages of the barcoding system included easy tracking of specimen movements and the creation of unique specimen numbers, which had not previously been achieved with the traditional cataloguing system at the NHM. The use of a web-based application meant that record association could be stockpiled and processed off site, which was advantageous for staff who needed to occasionally work away from the museum.

Figure 5. A handmade tray with lift-out platform

The project required substantial input from curatorial staff for which sufficient lead time was necessary. Although the conservation team barcoded the specimens themselves, the location barcoding was undertaken by curatorial staff and it was recommended that this was completed before each collection was processed. Consideration and planning was required to accommodate specimen movements and access for loans, exhibition and storage area refurbishments occurring within the three-year period. Curatorial input was also necessary following the digital association stage to resolve inherited issues from over 100 years of cataloguing discrepancies, such as multiple specimens with one specimen number, which required re-registering. There were additional issues with large multipart specimens which required a unique specimen barcode per bag, partly to avoid dissociation of barcode and specimen part, which could be accidentally relocated independently from other morphological components, and partly to allow exhibition, loan or deliberate storage in a separate area, according to the logic of the collection. This situation was resolved through the addition of suffixes (a, b, c, etc.) to the existing catalogue number and individual records constructed on the CMS utilising partial record duplication. Finally, some specimens were not registered at all. All these issues were flagged through the association app, but curatorial staff are able to find resolutions at their leisure, since the barcode stub and associated conservation data remain as digital records perpetually associated with the unique specimen barcode and can therefore always be retrieved, regardless of whether registration issues have been resolved.

Curatorial input was also required during the project to accommodate movement within the storage cabinets. The anoxic microenvironments were specifically designed to minimise increase in specimen footprint, and two-tiered trays were constructed where appropriate (Figure 5). However, where specimens had previously been piled on top of each other, the use of inert foam surrounds unavoidably caused a size increase. To adjust the location barcodes for specimens that had to be moved due to footprint expansion, a simple spreadsheet was used for importing the new location barcode. This was rapidly filled out by scanning the specimen barcode into the first column, and the new location into the second column. The barcoding system in fact formed a resolution to its own problem. Another advantage afforded to conservation staff by the barcoding system was that records of condition, treatment and re-storage could be digitally associated to a unique number on the CMS, even if specimens had no (or problematic) catalogue numbers.

FURTHER WORK

Following completion of the project, the next step is to transcribe the data from specimen labels into the catalogue module of the CMS. Since high-quality images have been taken, this could be achieved through handwriting recognition software, contracted digitisers or through a public crowdsourcing project. This would require input from data managers to develop a third web-based application (or modify an existing one), and also require further preparation by curatorial staff, to ensure that master lists of taxonomy, location, donors and stratigraphy were available.

According to current knowledge, reduced-oxygen environments offer significant benefits to pyrite- and marcasite-bearing specimens, but further research is still necessary. This should include an investigation into the effect of the brief temperature rise caused by reaction (with oxygen) of the scavenging agents when the enclosure is initially sealed, and the long-term behaviour of existing decay products (whilst within the microenvironment) which have not undergone prior stabilisation by ammonia treatment.

CONCLUSION

Apart from the obvious benefits of preserving thousands of specimens and creating digital resources, the project also prevents duplication of effort by using the same photographs for condition reports and for the catalogue module on the CMS. There are cost savings and a reduction in risk, by minimising access to specimens when compared to digitisation by a separate team. The use of scanned barcodes prevents mistakes associated with typing errors and allows rapid specimen tracking and import of conservation data. An estimated 10,000 specimens will have been processed by the end of the three-year project.

By working in a cross-department team consisting of conservators, data managers, curators, project management and finance staff, this project has managed to successfully bring a modern resolution to the problem of conservation and access, and combine digitisation for the future with the preventive conservation of specimens from 100 million years in the past.

ACKNOWLEDGEMENTS

The authors would like to thank the organisers and reviewers of ICOM-CC for this opportunity, Lorraine Cornish (head of conservation, NHM), Chris Jones (head of department, Core Research Laboratories, NHM) and the other members of the Airless project team: Kieran Miles, Matthew Porter, Nicola Crompton, Zoë Hughes, David Smith, Lil Stevens, Martin Munt, Julie Gray, Conseulo Sendino, Richard Devany, Gill Comerford, and Lorna Steel plus many other NHM staff whose contributions have helped make this project a success.

MATERIALS LIST

3M #415 tape
Preservation Equipment Ltd
www.preservationequipment.com

Barcode scanner
CR1400 (with glare reduction)
Barcode Technologies
www.barcode-uk.com/

ESCAL™ Neo
m.art preserving GmbH
Bergneustadt, Germany

RP System®
m.art preserving GmbH
Bergneustadt, Germany

REFERENCES

BOREK, S.L. 1994. Effect of humidity on pyrite oxidation. In *Environmental geochemistry of sulfide oxidation,* ed. C.N. Alpers and D.W. Blowes, 31–44. ACS Symposium Series 550. Washington DC: American Chemical Society.

COLLINS, C. 1995. Stability of shale and other mudrocks. In *The care and conservation of palaeontological material*, ed. C. Collins, 53–8. Oxford: Butterworth-Heinemann.

CORNISH, L. and A.M. DOYLE. 1983. Ethanolamine thioglycollate as a chemical agent for the neutralization and removal of oxidised pyrite. *The Geological Curator* 3(8): 512–13.

HOWIE, F.M.P. 1977. Pyrite and conservation: Part 2. *Newsletter of the Geological Curator's Group* 10(1): 497–512.

HOWIE, F.M.P. 1992. Pyrite and marcasite. In *The care and conservation of geological materials: Minerals, rocks, meteorites, and lunar finds,* ed. F.M. Howie, 70–84. London: Butterworth-Heinemann.

FELLOWES, D. and P. HAGAN. 2003. Pyrite oxidation: The conservation of historic shipwrecks and geological and palaeontological specimens. *Reviews in Conservation* 4(1): 26–38.

IDIGBIO. 2015. Specimen barcode and labeling guide. https://www.idigbio.org/wiki/index.php/Specimen_Barcode_and_Labeling_Guide (accessed 10 January 2016).

JERZ, J.K. and J.D. RIMSTIDT. 2004. Pyrite oxidation in moist air. *Geochimica et Cosmochimica Acta* 68(4): 701–14.

LODHA, T.R., N.K. SINTIA, and A.C. SRIVASRAVA. 1983. Storage problems of Amjhore pyrites. *Fertilizer Technology* 20: 76–7.

MCPHAIL, D., E. LAM, and A. DOYLE. 2003. The heat sealing of Escal® barrier films. *The Conservator* 27(1): 107–16.

MORTH, A.H. and E.E. SMITH. 1966. Kinetics of the sulfide to sulfate reaction. In *American Chemical Society, Division of Fuel Chemistry, Proceedings of the 151st ACS National Meeting, Pittsburgh, Pennsylvania,* vol. 10, 83–92. American Chemical Society (ACS) Division of Petroleum Chemistry, Inc.

NEWMAN, A. 1998. Pyrite oxidation and museum collections: A review of theory and conservation treatments. *The Geological Curator* 6(10): 363–71.

RIMSTIDT, J.D. and D.J. VAUGHAN. 2003. Pyrite oxidation: A state-of-the-art assessment of the reaction mechanism. *Geochimica et Cosmochimica Acta* 67(5): 873–80.

SMITH, E.E. and K.S. SHUMATE. 1970. *Sulfide to sulfate reaction mechanisms*. Water pollution control series. Federal Water Pollution Control Administration Department of the Interior. Washington DC: US Government Printing Office.

TRAFFORD, A. and L. ALLINGTON-JONES. 2017. Construction of anoxic microenvironments: Project Airless. http://stashc.com/the-publication/environment/construction-of-anoxic-microenvironments-project-airless/ (accessed 20 April 2017).

WALKER, R. 2001. Instability of iron sulfides on recently excavated artifacts. *Studies in Conservation* 46(2): 141–52.

WALLER, R. 1987. An experimental ammonia gas treatment method for oxidized pyritic mineral specimens. In *ICOM-CC 8th Triennial Meeting Preprints, Sydney, 6–11 September 1987*, ed. K. Grimstad, 623–30. Paris: International Council of Museums.

How to cite this article:

Allington-Jones, L. and A. Trafford. 2017. Conservation in a Barcode Age: A cross-discipline re-storage project for pyritic specimens. In *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4–8 September 2017,* ed. J. Bridgland, art. 1101. Paris: International Council of Museums.